Industrial linkage and spillover effects of the logistics service industry: an input–output analysis

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Abstract

This study applied input–output analysis to examine the industrial linkage effects of the logistics service industry based on the data collected from input–output tables provided by the World Input–Output Database. The results showed the detailed industrial linkage effects of the logistics service industry, indicating several logistics sectors (transportation, storage, and handling) are not only interdependent but they also form a service ecosystem. The study results provide new insights on industrial linkage effects of the logistics service industry and their ripple effects throughout the economy. The results will be valuable source of knowledge for establishing service industrial policies for both the logistics industry and a country's economy as a whole.

Keywords Logistics service industry · Industrial linkage effects · Input–output analysis

1 Introduction

The COVID-19 pandemic has brought an unprecedented experience and pain to the world. For many organizations, their global supply chains were disrupted and consumption patterns of people have changed dramatically as industry and distribution structures were altered. Online orders surged since consumers practiced the shelter-in-place policy and curb side pick-up services flourished as customers

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preferred contact-free shopping (Korea Logistics News 2020; Lee and Lee 2019). New logistics service systems had to be developed to support these new type of retail services. This is not a temporary phenomenon, but the start of a paradigm shift for organizations, global supply chains, industrial structures, and eventually the national economy (ChosunBiz 2020). The pandemic crisis amplified the importance of services as the core of organizational competitiveness, both in domestic and international markets (McKee 2008). South Korea, the location of this study, has been lauded as a model country for successfully controlling the COVID-19 crisis (CLO 2020). Korea is seizing the opportunity to strengthen the competitiveness of its industries through strengthened new global supply chains enabled by advanced service technologies. Without the support of logistics service companies, the chaos caused by COVID-19 would have been much more severe. The Korean logistics service industry has contributed significantly to minimize the damage caused by the spread of COVID-19.

The logistics service industry is a strategic priority for enhancing the quality of major activities within the supply chain, such as supply, manufacturing, distribution, and consumption as well as improving the competitiveness of the entire system (Mentzer et al. 2001). Logistics strategies influence the financial performance of organizations through supply chain agility in the dynamic business environment (Hwang and Kim 2019). In addition, the logistics service industry has high value added and employment inducement effects. Thus, an efficient logistics service system has a significant impact on lean management of the entire supply chain and subsequent contributions to competitive advantage of the manufacturing and distribution industries (Min et al. 2019). In the macro perspective, the impact of logistics service and its ripple effects is enormous for industries and the national economy, especially for export-oriented economies.

The Korean logistics service industry, which has grown from the country's transportation service sector, has expanded to the various related service fields. Today, the logistics service industry includes transportation, storage, distribution, assembly, packaging, and logistics information management. The logistics service network has expanded, both in scale and scope, with the stretched global supply chains and transportation service systems (Kim et al. 2016). Moreover, the strategic importance of the logistics service industry has become significant with the increasing demands for products of diverse industries. To gain competitive advantage, logistics service firms need to form collaborative relationships with partners and their customers (Park and Kim 2020).

The primary focus of previous studies on the logistics service industry has been on the shipping or transportation service. There is a paucity of research on the macro perspective of logistics service at the industry level. Thus, this study contributes to the literature as it investigates the logistics service industry based on the input–output analysis (IOA). IOA assumes that demand for intermediate inputs is a linear function of output, expressing production increase of an output of a sector drives continuous increase in demand for products of other sectors. IOA has been recognized as a useful approach to analyze and predict the overall economic impact, as it has the feature of a general equilibrium model that emphasizes the relationship between sales and purchases of inputs (Miller and Blair 2009).

More specifically, we analyze the linkage effects of the entire logistics service industry which encompasses such functions as land transport, pipelines, water transport, air transport, courier services, warehousing, and handling. For an empirical study, we used the Korean logistics service industry data of the National Input–Output Tables of the World Input–Output Database (WIOD) released in November 2016. IOA will derive input coefficients, production inducement coefficients, backward linkage effects, and forward linkage effects of the Korean logistics service industry.

The paper is organized as follows. In Sect. 2, we review the relevant literature to provide the theoretical support for the study. Section 3 presents research methodology used in the study, detailing the procedure to derive various coefficients by IOA and the data applied. In Sect. 4, we present the results and discussion of the analysis. We conclude the paper in Sect. 5 with a summary of results, implications, limitations of the study, and future research needs.

2 Literature review

There have been numerous studies on industry linkage effects for the various industries. Some of the most relevant studies are reviewed here to provide theoretical foundation for our study. Choi et al. (2008) applied IOA to identify the impact of the maritime freight transportation service on the Korea's national economy. The authors investigated the industrial linkage effects of the maritime freight transportation service with 20 different sectors and extracted production inducing effects, added value-inducing effects, and supply-shortage effects. Lee and Yoo (2016) analyzed the economic impacts of four transportation service modes (rail, road, water, and air) in Korea using IOA and found that the production inducing effect of the investment in transportation service was the largest in the petroleum and transportation equipment sectors, while the rail and road transportation service sectors had the greatest supply-shortage effect. There have been more studies on the logistics service industry in Korea including those by Park et al. (2009), Kang et al. (2011), and Park (2019). Most of the data used in these studies were extracted from the Korean Input–output Tables issued by the Bank of Korea. The research conducted on Korea's logistics service and related industries tended to focus on the shipping and port logistics sectors. Studies by Park (2019) and Kang et al. (2011) were the only ones that paid attention to the industrial spillover effect of the logistics service industry using WIOD or OECD's ISIC Input–output Table.

Chiu and Lin (2012a) investigated the role and influence of the transportation service sector on the national economy of Taiwan by using IOA. The results showed that the transportation service industry in Taiwan had the capability to absorb products of related industries rather than just being used as an input by other industries, indicating its strong role in supporting other industries. Road transportation service also demonstrated comparatively more strength in supporting other domestic industries than being supported by others. Zhao et al. (2007) performed a comparative analysis of the characteristics of industry relevancy and industry spread in the transportation service industry and compared five transportation service modes between China and the USA. They

concluded that China's transportation service industry has played an increasingly more important role in the national economy. The transportation service industry in China is one of the industries that have a high ratio of intermediate demand, and its drawing power on relevant industries is much greater than that in the US. Morrissey and O'Donoghue (2013) examined the linkages and production effects of the Irish marine service sector on the national economy. Disaggregating the Irish IO table for 2007 to include 10 additional marine service sectors, this paper represented the first effort to quantify the industrial spillover effects and employment multipliers of the marine service sector. This analysis found that Irish marine service sectors, notably the maritime transportation service sector, played an important role within the wider Irish economy.

Most recent studies that analyzed Korean industrial characteristics using the international input–output table took aim at the information and communication technology (ICT) and related industries. The studies of Yun et al. (2017), Lee et al. (2019), Li et al. (2019), Min et al. (2019), and Kim and Lee (2020) are typical. These studies focused on Korea's ICT industry from various perspectives through analyzing the industry linkage effects using the reliable WIOD and OECD data. These studies conducted a comparative analysis among selected countries to derive meaningful implications. Yun et al. (2017) used the OECD data to classify Korea's ICT and automotive industries into service and manufacturing sectors to identify the differences in industrial linkage effects. Lee et al. (2019) compared and analyzed the competitive advantage, catch-up and industrial linkage effects of the ICT industries between Korea and India, while Li et al. (2019) studied the competitive advantage and industrial impact of ICT industries in China. Min et al. (2019) also used the WIOD data to compare backward and forward linkage effects of ICT and mechanical equipment industries among five countries: Korea, China, the United States, Germany, and Japan. Kim and Lee (2020) used the WIOD data to compare and analyze the production inducement effects of ICT services, ICT manufacturing, chemical and medical industries as major industries in Korea and the Netherlands. A summary of the studies, mostly recent ones, on industrial linkage effects, is shown in Table 1.

While there are numerous existing studies using IOA for various industries, there has been limited research on specific logistics service sectors to examine the economic ripple effects using IOA. There exists lack of awareness of the importance of the logistics service industry in Korea's industrial structure. This study fills this gap in the literature by conducting a research on the overall logistics service industry level within Korea's industrial structure. To this end, this study analyzes the economic ripple effects of the overall logistics service industry, which encompasses various logistics functions such as land transport, sea transport, air transport, courier, storage, and handling and suggests implications for improving industrial competitiveness.

3 Methodology

3.1 Research design

The industrial linkage effect was first explored in 1936 by Leontief. Leontief integrated Wallace's General Equilibrium Theory and a theoretical model based on

Table 1 Previous studies on industrial linkage effects

Researcher	Study subject
Kim and Lee (2020)	A comparative study on production inducement effects of key industries in Korea and the Netherlands
Lee et al. (2019)	The relationships among competitive advantage, catch-up, and linkage effects: a comparative study of the ICT industry between South Korea and India
Li et al. (2019)	The industrial impact and competitive advantage of China's ICT industry
Min et al. (2019)	A comparative study on industrial spillover effects among Korea, China, the USA, Germany, and Japan
Park (2019)	A study on economic effects of the Korean water transport industry using IOA
Yun et al. (2017)	A comparative study of linkage effects between ICT and automobile industries
Lee and Yoo (2016)	The role of transportation sectors in the Korean national economy: an input–output analysis
Dietzenbacher et al. (2013)	Construction of world input–output tables in the WIOD project
Mattioli and Lamonica (2013)	The roles of ICT in the world economy: an input–output analysis
Morrissey and O Donoghue (2013)	The role of the marine sector in the Irish national economy: an input–output analysis
Rohman (2013)	The globalization and stagnation of the ICT sectors in European countries: an input–output analysis
Chiu and Lin (2012a)	Applying an input–output model to investigate the inter-industrial linkage of the transportation industry in Taiwan
Chiu and Lin (2012b)	The inter-industrial linkage of maritime sector in Taiwan: an input–output analysis
Kang et al. (2011)	A comparative analysis of the structure and spillover effects of logistics services in South Korea, China, and Japan
Richter and Streb (2011)	Catching-up and falling behind: knowledge spillover from American to German machine toolmakers
Xing et al. (2011)	Measuring convergence of China's ICT industry: an input–output analysis
Park et al. (2009)	A study on the growth factors of the Korean logistics industry by structural decomposition of input–output tables
Choi et al. (2008)	Analysis of the role of maritime freight transport industry in the Korean national economy
Farooq et al. (2008)	An economic impact/forecast model of intelligent transportation systems in Michigan: an input output analysis
Zhao et al. (2007)	Comparative analysis on the characteristics of transportation systems between China and America based on input–output theory
Wang (1990)	Analyzing the economic effects of transportation, communications, and construction industries

empirical economic data for analyzing industrial associations (Leontief 1941, 1970, 1986; Miller and Blair 2009). The industrial linkage effect, also referred to as input–output analysis or industrial spillover effect, is useful for analyzing

specific economic structures and associations among industries, a topic that is outside the realm of macro analysis.

IOA measures the ripple effect of changes in demand on production activities, assuming that the input structure of products is stable for a certain period of time. It is fundamental to analyze the impact on final demand, the exogenous variable, through the measurement of the interrelationships between sectors. Applying IOA is a useful way to assess backward and forward linkages, because it enables analysis of inter-industry relationships in the overall industry structure with a focus on the logistics service industry.

The industrial linkage effect analysis is a useful methodology for identifying and adjusting policy directions of industrial structures, because it enables an assessment of the ripple effect of each industry's contribution to the economy, such as production, employment, and income. The industrial linkage effect measures the ripple effect of changes in an industry on production activities of other industries in a certain time period. The association of production activities with added value and income creates the ripple effect in the entire national economy. In this study, backward and forward linkage effects of the logistics service industry are derived from input coefficients and production inducement coefficients calculated for the input–output analysis. The analysis procedure is shown in Fig. 1.

4 Coefficient analysis

4.1 Input coefficient

The input coefficient represents the measure of raw materials and intermediate goods used to produce a unit of output in each sector (Cartwright et al. 1981; Miernyk 1965; Richardson 1972). The total output depends on the size of the final demand. The input coefficient plays the role of mediating the size of the final demand and the level of total output. The input coefficient is expressed as where X_{ij} is the intermediate demand for product j as an input by industry i .

4.2 Production inducement coefficient

The input coefficient is the parameter used to measure the magnitude of the production inducement coefficient. When the number of industrial segments is large, however, it is difficult to measure the infinite number of direct and indirect production ripple effects generated by one unit of output using input coefficients. The production inducement coefficient is computed using an inverse matrix. The production inducement coefficient is expressed by $(I-A)^{-1}$, which is also called the Leontief inverse. A represents the input matrix and I for the unit matrix with ones on the main diagonal and zeros elsewhere.

Fig. 1 Calculation procedure

4.3 Industry linkage effects

There are two approaches to analyze the degree of industry interdependence using the production inducement coefficient. One is to investigate the industries that demand intermediate goods, while the other is to analyze the industries that supply intermediate goods. The former analyzes the backward linkage effect, and the latter is for the forward linkage effect. Several studies measured backward and forward linkage effects, including Chenery and Watanabe (1953), Rasmussen (1957), and Jones (1976), and the methodology suggested by Rasmussen (1957) has been used most widely. Table 2 presents the formulas for calculating industry linkage effects.

4.4 Derivation of production inducement coefficients

In order to analyze the forward and backward linkage effects of the logistics service industry, the time series data in WIOD's National IO tables were used to derive the input coefficient matrix A , unit matrix I , $(I-A)$ matrix, and production inducement coefficient matrix $(I-A)^{-1}$. Five matrices were prepared for each year from 2000 to 2014. The input coefficient was calculated by dividing each industry's intermediate

Table 2 Linkage effect formulas

Backward linkage effect	Forward linkage effect
$BL_j^R = \left(\frac{1}{n} \sum_{i=1}^n r_{ij} \right) / \left(\frac{1}{n^2} \sum_{i=1}^n \sum_{j=1}^n r_{ij} \right)$	$FL_i^R = \left(\frac{1}{n} \sum_{j=1}^n r_{ij} \right) / \left(\frac{1}{n^2} \sum_{i=1}^n \sum_{j=1}^n r_{ij} \right)$

input requirement for the production process by the total amount of input of each industry. The production inducement coefficient $(I-A)^{-1}$ is the inverse of the $(I-A)$ matrix, which is calculated by subtracting the technical coefficient matrix from the unit matrix. By using the input coefficient to compute production inducement coefficient, we can measure the level of change in the final demand independently to estimate the corresponding level of change in production. The production inducement coefficient represents the cumulative multiplier that conveys all direct and indirect ripple effects on the production of each sector, assuming that final demand is 1 unit. The element (i, j) of the production inducement matrix indicates the total output increase in industry i due to the increase in the final demand of industry j .

The sum of the columns in the production inducement matrix indicates the total output change in all industries due to the unit increase in the final demand of industry j . The production inducement coefficients of industries, that use domestic raw materials as inputs for manufacturing, are expected to be higher than that of the service sector.

4.5 Data analysis

In this study, we analyzed Korea's logistics service industry. In general, the logistics service industry deals with products and/or services related to transport, storage, handling, and packaging. The detailed classification standards and methods of the logistics service industry may vary depending on the data collection agency or industry classification system of the given country. The data used for our analysis were the Korean logistics service industry for the 2000–2014 period based on the National IO Tables of the World Input–Output Database (WIOD) (released in November 2016). The selected industry classifications are from H49 to H53 (see Table 3).

5 Results and discussion

5.1 Analysis of the linkage effect

The backward linkage effect indicates the extent that an industry's production of output requires intermediate inputs from other industries, and it is computed by dividing the sum of each column in the production inducement coefficient matrix $(I-A)^{-1}$ by the overall industry average. Regarding the five sectors of the logistics service industry from 2000 to 2014, backward linkage effects of H49 (Land Transport and

Table 3 Logistics service industry classifications

Logistics service industry	
Code	Description
H49	Land transport and transport via pipelines
H50	Water transport
H51	Air transport
H52	Warehousing and support activities for transportation
H53	Postal and courier activities

Transport via Pipelines) ranged from 0.969 to 0.993 with an average of 0.98; H50 (Water Transport) ranged from 0.964 to 1.046 with an average of 1.00; H51 (Air Transport) ranged from 0.992 to 1.067 with an average of 1.03; H52 (Warehousing and Support Activities for Transportation) ranged from 1.055 to 1.125 with an average of 1.09; and H53 (Postal and Courier Activities) ranged from 1.038 to 1.142 with an average of 1.08.

In general, assuming that the overall industrial mean of the backward linkage effect is 1, an industry is considered to have a high effect if its mean is greater than 1 and a low effect if the industry mean is less than 1. Among the five sectors of the Korean logistics service industry, H49 (Land Transport and Transport via Pipelines) showed the lowest mean effect at 0.98 and H52 (Warehousing and Support Activities for Transportation) showed the highest at 1.09. Overall, the backward linkage effect of the entire logistics service industry was between 0.98 and 1.09, which is close to the average of 1. Consequently, increasing the output of the logistics service industry by one unit is expected to cause a bit higher than the average level of ripple effect on the production of the upstream industries that supply intermediate goods. Warehousing and support activities for transportation (H52) and postal and courier activities (H53) sectors showed relatively high backward linkage effects than other transportation service sectors (H49, H50, H51, and H51).

The forward linkage effect refers to the change in demand for the logistics service industry's output when the production of each industry increases by one unit, and it is computed by dividing the sum of each row in the production inducement coefficient matrix $(I-A)^{-1}$ by the overall industry average. Regarding the five sectors of the logistics service industry over the study period, the forward linkage effect of H49 (Land Transport and Transport via Pipelines) ranged from 1.31 to 1.49 with an average of 1.38. The effect of H50 (Water Transport) ranged from 0.54 to 0.58 with an average of 0.56; H51 (Air Transport) ranged from 0.60 to 0.77 with an average of 0.68; H52 (Warehousing and Support Activities for Transportation) ranged from 1.26 to 1.42 with an average of 1.33; and H53 (Postal and Courier Activities) ranged from 0.66 to 0.76 with an average of 0.70.

As similar to the backward linkage effect, the overall industrial mean is assumed to be 1. If the industrial average has the forward effect greater than 1, we can conclude that the industry has a high effect rate. Among the five sectors of the logistics service industry, H50 (Water Transport) showed the lowest mean at 0.56, while H49 (Land Transport and Transport via Pipelines) showed the highest at 1.38. Overall,

Table 4 Backward and forward linkage effects on the logistics service industry

Section	H49		H50		H51		H52		H53	
	BL	FL	BL	FL	BL	FL	BL	FL	BL	FL
2000	0.974	1.334	0.996	0.583	1.045	0.749	1.065	1.358	1.038	0.670
2001	0.980	1.335	0.981	0.582	1.067	0.777	1.081	1.371	1.055	0.669
2002	0.976	1.313	0.964	0.578	1.060	0.772	1.070	1.352	1.049	0.661
2003	0.974	1.349	0.993	0.581	1.055	0.759	1.067	1.374	1.045	0.666
2004	0.981	1.409	1.046	0.579	1.059	0.739	1.076	1.415	1.058	0.674
2005	0.981	1.378	1.043	0.567	1.043	0.687	1.066	1.383	1.044	0.660
2006	0.969	1.348	0.998	0.560	1.017	0.642	1.055	1.315	1.044	0.659
2007	0.979	1.394	0.993	0.554	1.018	0.595	1.064	1.331	1.055	0.676
2008	0.993	1.494	0.999	0.558	1.018	0.627	1.117	1.395	1.127	0.729
2009	0.980	1.393	0.988	0.547	0.992	0.645	1.098	1.302	1.107	0.720
2010	0.990	1.459	1.003	0.547	1.022	0.644	1.112	1.341	1.131	0.756
2011	0.991	1.386	1.001	0.550	1.009	0.630	1.125	1.267	1.142	0.752
2012	0.987	1.389	0.999	0.549	1.017	0.628	1.124	1.265	1.141	0.751
2013	0.974	1.373	0.985	0.547	1.000	0.641	1.102	1.256	1.110	0.739
2014	0.984	1.400	0.986	0.541	1.009	0.644	1.098	1.279	1.105	0.736
Average	0.980	1.38	1.000	0.56	1.030	0.68	1.090	1.33	1.080	0.70

the forward linkage effect of the entire logistics service industry distributed from 0.56 to 1.38, which indicated noticeable differences among sectors of the logistics service industry. In detail, water transport (H50), air transport (H51), and postal and courier activities (H53) had low forward linkage effects, while land transport and transport via pipelines (H49) and warehousing and support activities for transportation (H52) had relatively high forward linkage effects. Table 4 and Fig. 2 present the summary of each sector's backward and forward linkage effects.

This study calculated average backward and forward linkage effects of each sector of the Korean logistics service industry over the 2000–2014 period. On the premise that the industry mean is 1, backward and forward linkage effects of H49 (Land Transport and Transport via Pipelines) were 0.98 (−0.02) and 1.38 (+0.38), H50 (Water Transport) had 1.00 (0.00) and 0.56 (−0.44), H51 (Air Transport) showed 1.03 (+0.03) and 0.68 (−0.32), H52 (Warehousing and Support Activities for Transportation) had 1.09 (+0.09) and 1.33 (+0.33), and H53 (Postal and Courier Activities) showed 1.08 (+0.08) and 0.70 (−0.30), respectively. The results revealed that H50, H51, and H53 had high backward linkage effects, whereas H49 and H52 had high forward linkage effects. Based on the results, we can state that majority of domestic demand for transport service belongs to land transport and transport via pipelines (H49), and warehousing and support activities for transportation (H52) were performed in conjunction with this effect.

Korea's land transport service industry is a representative form of transportation service that connects supply chain entities which sequentially carry out value adding activities followed by sales contracts for goods (manufacturing–manufacturing/

Fig. 2 Trend of linkage effects in the entire logistics industry

manufacturing-logistics). Storage and logistics facilities such as warehouses, logistics centers, distribution centers, and cargo terminals serve as nodes of land transport services. The high backward linkage effect of the storage and logistics service industry is possibly attributable to its strategic nature including logistics outsourcing and third-party logistics (3PL) with manufacturing and distribution industries. In contrast, domestic transportation services were not well developed in Korea because water transport and air transport have not been efficient due to the narrowness of the nation's land area.

Fig. 3 Trend of linkage effects by logistics industry sector

The domestic demand for water and air transport service had been insignificant. Korea's coastal and air transport have primarily served for trade and transshipment activities due to the country's unique geographic and environmental characteristics.

Fig. 3 (continued)

In other words, the demand for water transport and air transport services tended to be limited to import and export businesses. In addition, a fleet of ships and aircrafts, the primary means of transportation that are essential to produce water and air transport services, require enormous amounts of investment.

The postal and courier activities industry is based on the door-to-door service concept, meaning that it is basically an industry that needs to build a tight transportation service network on a nationwide scale. Accordingly, it is an industry that does not have high demand generating effects in comparison to the total investment requirement for the logistics service infrastructure. The change trends in backward

and forward linkage effects over time by sector in the logistics service industry is shown in Fig. 3.

5.2 Linkage effects by industry sectors

The linkage effect that indicates the logistics service industry's demand for intermediate inputs from other industries when its production changes by one unit represents the backward linkage effect. And the forward linkage effect, which indicates the degree to which the products of the logistics service industry are used as intermediate goods for other industries, varies from sector to sector within the logistics service industry. This study analyzed the production inducement coefficients of the five sectors of the Korean logistics service industry to identify the sectors with the highest backward linkage and forward linkage effects. These sectors were divided into two groups: industries that were impacted the most during the entire study period (2000–2014) and industries that were impacted the most for a certain period. This study selected the 10% of the industries of each logistics industry with the highest forward/backward linkage effect according to the analysis results. The selected industries were divided into two groups. One contains the industries remained in the top 10% over the entire study period, the other contains industries with the highest forward/backward linkage effect for only a certain period of time. The industries with high forward/backward linkage effects over the entire study period could be considered as the significant forward/backward industries. On the other hand, among the industries which are with high linkage effect for only a certain period of time, if an industry's linkage effects have been increasing to a greater extent recently, it can be regarded as a relatively more important forward/backward industry. By using this, the changes in the industries that affect the upstream and downstream of the logistics industry can be estimated.

According to the results, transport had a high production inducement effect on several manufacturing sectors over the entire period. More specifically, each transport service sector was closely related to the manufacturing sector that produces the equipment/machines that are used by the corresponding mode of transportation service. As a result, land transport and transport via pipelines (H49), exerted a significant production inducement effect on petroleum products manufacturing (C19) and automobile manufacturing (C29), while water transport (H50) and air transport (H51) exerted a strong production inducement effect on petroleum products manufacturing (C19) and other transport equipment manufacturing including ship and aircraft (C30). Moreover, the three transportation sectors had a common production inducement effect for warehousing and support activities for transportation (H52) within the logistics sector. In addition, water transport (H50), air transport (H51), warehousing and support activities for transportation (H52) related to international logistics have a common production inducement effect in the financial industry (K64). This is because overseas payment, remittance, currency exchange, receipt of bill of exchange, issuance of L/C, and purchase of marine cargo insurance. These service sectors showed large production inducement effects on the financial service activities sector (K64).

Table 5 Backward linkage industries in the logistics service industry

Category	Entire period (2000–2014)	Certain period	
H49	C19, C29, H52 O84 (2000–2005)	K64 (2000–2008)	C20 (2009–2014) D35 (2013–2014)
H50	C19, C30, H52, K64, N		
H51	C19, C30, H52, K64, N		
H52	D35, K64, N	I (2000–2010) L68 (2000–2009)	C18 (2011–2014) C20 (2010–2014)
H53	N	C26 (2000–2009) G46 (2000–2008) G47 (2000–2009)	C18 (2010–2014) C19 (2010–2014) H49 (2009–2014) H51 (2014–2014) H52 (2010–2014)

Because the focus of warehousing and support activities for transportation (H52) is on selecting strategic locations to construct and operate logistics service facilities, it had a production inducement effect on real estate activities (L68) and electricity, gas, steam and air conditioning supply sectors (D35). In addition, accommodation and food service activities (I) showed a production inducement effect due to the needs for transportation equipment and personnel by logistics service facilities. The transportation service industry also induced production in the wholesale and retail industries (G46, G47) and several transportation service sectors (H49, H50, H51). It also showed a production inducement effect on the manufacture of computers, electronics, and optical products sector (C26), which produces equipment with high added value. Industries that have production inducement effects due to the backward linkage effect of the logistics service industry, in which products from other industries are inputted as intermediate goods for the production activities, are organized in Table 5.

While logistics services, such as transport and storage and handling, are final products of land transport and transport via pipelines (H49), air transport (H51), warehousing and support activities for transportation (H52), and postal and courier activities (H53), they are commonly used as intermediate inputs by distributors like wholesalers and/or retailers (G45, G46, G47). However, among the transportation service sectors, only water transportation (H50) had a relatively low forward linkage effect, because water transportation mainly served import/export activities for the manufacturing industry, rather than wholesale and retail trade.

Therefore, water transport services are used for mass transportation of bulk products, such as forestry and logging (A02), mining and quarrying (B), manufacture of wood and products of wood and cork, except furniture (C16). Also, in general, the shipbuilding industry is an upstream industry, while the port industry is a downstream industry of water transport (H50).

The analysis also showed that water transport (H50) had a high forward linkage effect on warehousing and support activities for transportation (H52) over the entire study period. On the other hand, land transport and transport via pipelines (H49) continued to be widely used by mining and quarrying (B) and manufacture of other

Table 6 Forward linkage industries in the logistics service industry

Category	Entire period (2000–2014)	Certain period	
H49	B, C23	G45 (2000–2005)	C17 (2006–2014) E37–E39 (2006–2014)
		G46 (2000–2005)	
		G47 (2000–2005)	
H50	E37–E39 H52	A02 (2000–2005)	H53 (2006–2014)
		B (2000–2005)	J61 (2006–2014)
		C16 (2000–2005)	K65 (2010–2014)
H51	G45, G46, G47, H53	–	J58 (2008–2014)
H52	A03, B, G45, G46, G47, H49, H50, H51,	C23 (2000–2003)	H53 (2010–2014)
H53	–	G45 (2000–2009)	E37–E39 (2010–2014)
		G46 (2000–2009)	K64 (2008–2014)
		G47 (2000–2009)	K65 (2008–2014)
		M74–M75 (2000–2006)	K66 (2008–2014)
		N (2000–2008)	O84 (2010–2014)

non-metallic mineral products (C23). Since 2006, it also started to be widely used for manufacture of paper and paper products (C17) and sewerage, waste collection, treatment, and disposal activities (E37–E39).

Warehousing and support activities for transportation (H52) had been used in all transport service industries (H49, H50, H51, H53), implying that transport, storage and handling service of logistics are not independent but instead a structure in which services are linked together. Since 2008, H53 had been widely used in financial sectors (K64, K65, K66).

Due to the advances in IT technology, offline face-to-face financial services have diminished considerably while internet and mobile financial services increased. Accordingly, the use of courier services in financial services, such as card issuance and document delivery, have seen a dramatic up trend. Table 6 shows industries that had production inducement effects due to forward linkage effects of the logistics service industry that provided its products as intermediate goods.

6 Conclusions

This study conducted an input–output analysis on Korea’s logistics service industry using the WIOD data for the 2000–2014 period. Five logistics service industry sectors (H49, H50, H51, H52, H53) were analyzed based on the WIOD industry classification criteria. This study identified the forward and backward industries of the logistics industry, and calculated the production inducement coefficients of the logistics service industry on other industries to check the existence and degree of the forward and backward linkage effects.

Through an input–output analysis, this study classified the upstream and downstream industries that are impacted by the production inducement effect of the logistics service industry. Therefore, this study makes significant contribution to the existing body of knowledge about the linkage and spillover effects the logistics service industry to other industries. Our findings also disclose that the transport, storage, and handling fields of logistics service are not independent of each other, but instead they constitute a services ecosystem. In addition, our study found that in the transportation service sector, the transport equipment and petroleum manufacturing are an upstream industry while wholesale and retail industries are downstream industries.

The results of this study also recognized that the logistics service industry was playing a role in connecting supply, manufacturing, and distribution activities in the supply chain. Specifically, ocean transportation service was shown to be the most common mode of water transportation service in Korea which supports import and export activities of products of the manufacturing industry. This study also confirmed the fact that shipbuilding industry is an upstream industry while port industry is a downstream industry. Moreover, due to the recent development of IT technology, the financial service industry showed an extensive use of courier services.

The study results showed the evidence of high forward linkage effects of land transport and transport via pipelines (H49) and warehousing and support activities for transportation (H52), which may be a consequence of Korea's successful quarantine efforts related to COVID-19. In Korea, most domestic logistics service needs are handled by land transport and transport via pipelines (H49), and warehousing and support activities for transportation (H52) are intimately linked to supporting the land transport service. Besides, their services are widely used as intermediate inputs in wholesale and retail service business (G45, G46, G47). Logistics infrastructure related to the industry H49 and H52, which have been shown in the results to have high forward linkage effect, is difficult to be established in the short term. Besides, it cannot be systemized easily as needed in a timely manner. In the COVID-19 pandemic, the effective quarantine in Korea and the stable national life due to the various distribution and logistics services can be seen as the continued growth of the logistics industry. The recent surge in a variety of delivery services in Korea can be considered as the evidence. In this context, it can be expected that industry H49 and H52, which have been shown in a result of this study's 15-year (2000–2014) data analysis, have been developed steadily to date and are contributing to the COVID-19 pandemic.

Without the expansion of land transport service networks and storage and handling service facilities in Korea, the recent chaos caused by COVID-19 would have been much greater in scale and scope. Without properly equipped logistics services, there would have been many disruptive problems with the purchase of daily necessities as well as the distribution of essential medical supplies such as personal protective equipment (PPE), testing supplies, and medicine. Online purchases have skyrocketed in Korea due to COVID-19. Additionally, being supported by Korea's land transport and transport via pipelines (H49) and warehousing and support activities for transportation (H52), distribution companies have created various delivery services such as one-day delivery service, overnight delivery service, and early morning delivery service.

It should be noted that Korean logistics service companies have been contributing effectively to delivering the necessary products/services to consumers who rely on online

purchases, and they have played an important role in managing the spread of COVID-19. The Korean logistics services have been operating to their maximum capacity in the current national emergency. The results of this study, linkage and ripple effects among industries, can shed important new insights that can contribute to establishing efficient and effective policies for pandemic management through the logistics service industry.

This study was conducted on the logistics service industry, which belongs to the service sector, in which industrial chain effect analysis was not as active as the manufacturing sector. It also looks into both the backward and forward industrial linkage structure of the logistics service industry, which has played a supporting role in connecting relations between members within the manufacturing-oriented supply chain. In addition, unlike prior research that put the focus on one specific sector of the logistics service industry, this study investigated the entire logistics service industry that includes all logistics service functions.

In terms of corporate management, the service industry could also provide a foundation to shape supply chain management into a service entity's management strategy, as in manufacturing. In addition, managers of logistics service companies will be able to use them to make strategic decisions on the relationships among service supply chain members. In other words, depending on the strategic orientation of the relationship, this study could provide indicators of strategic decisions such as outsourcing, strategic alliances, and vertical integration.

On the other hand, from a national policy perspective, this study provides a foundation for understanding the backward and forward linkage effects of the logistics service industry. The backward and forward linkage effects can play an important role in determining the priority of investment when selecting the national policy-building sectors with limited resources. If the logistics service industry has a greater backward linkage effect than other industries, it can be more beneficial in terms of the overall economy's productive activities than investment to foster other industries. It is possible to establish efficient and effective industrial policies for the industries that impose strong ripple effects on the logistics service industry and the industrial areas whose outputs were highly utilized in the logistics service industry.

This study has several limitations which can provide opportunities for future research. First, while the study used the highly reliable WIOD data, we could not exclude the passenger sector included in the transportation service industry. Thus, it is necessary to secure subdivided industrial classifications to obtain more suitable data of the logistics service industry. The industrial structure and the associated forward and backward linkages differ significantly from country to country. Second, our study focused on the logistics service industry of South Korea. Thus, future studies should investigate the logistics service industries of different countries to establish the concept of logistics service supply chains (LSSC). Future research should also investigate the association between the GDP level and the production inducement effect of the logistics service industry and compare the degree of association across countries.

Appendix

See Table 7.

Table 7 Industrial classification of WIOD industrial classification of national IO tables

Section	Code	Description
1	A01	Crop and animal production, hunting and related service activities
2	A02	Forestry and logging
3	A03	Fishing and aquaculture
4	B	Mining and quarrying
5	C10–12	Manufacture of food products, beverages, and tobacco products
6	C13–15	Manufacture of textiles, wearing apparel, and leather products
7	C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
8	C17	Manufacture of paper and paper products
9	C18	Printing and reproduction of recorded media
10	C19	Manufacture of coke and refined petroleum products
11	C20	Manufacture of chemicals and chemical products
12	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
13	C22	Manufacture of rubber and plastic products
14	C23	Manufacture of other non-metallic mineral products
15	C24	Manufacture of basic metals
16	C25	Manufacture of fabricated metal products, except machinery and equipment
17	C26	Manufacture of computer, electronic, and optical products
18	C27	Manufacture of electrical equipment
19	C28	Manufacture of machinery and equipment n.e.c.
20	C29	Manufacture of motor vehicles, trailers, and semi-trailers
21	C30	Manufacture of other transport equipment
22	C31–32	Manufacture of furniture; other manufacturing
23	C33	Repair and installation of machinery and equipment
24	D35	Electricity, gas, steam, and air conditioning supply
25	E36	Water collection, treatment, and supply
26	E37–39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
27	F	Construction
28	G45	Wholesale and retail trade and repair of motor vehicles and motorcycles
29	G46	Wholesale trade, except of motor vehicles and motorcycles
30	G47	Retail trade, except of motor vehicles and motorcycles
31	H49	Land transport and transport via pipelines
32	H50	Water transport
33	H51	Air transport
34	H52	Warehousing and support activities for transportation
35	H53	Postal and courier activities
36	I	Accommodation and food service activities
37	J58	Publishing activities
38	J59–60	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities

Table 7 (continued)

Section	Code	Description
39	J61	Telecommunications
40	J62–63	Computer programming, consultancy and related activities; information service activities
41	K64	Financial service activities, except insurance and pension funding
42	K65	Insurance, reinsurance, and pension funding, except compulsory social security
43	K66	Activities auxiliary to financial services and insurance activities
44	L68	Real estate activities
45	M69–70	Legal and accounting activities; activities of head offices; management consultancy activities
46	M71	Architectural and engineering activities; technical testing and analysis
47	M72	Scientific research and development
48	M73	Advertising and market research
49	M74–75	Other professional, scientific and technical activities; veterinary activities
50	N	Administrative and support service activities
51	O84	Public administration and defense; compulsory social security
52	P85	Education
53	Q	Human health and social work activities
54	R-S	Other service activities
55	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
56	U	Activities of extraterritorial organizations and bodies

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