LOGI – Scientific Journal on Transport and Logistics
Vol. 13 No. 1 2022 DOI: 10.2478/logi-2022-0016
© 2022 N. Tromp and T-J. Kim. This is an open access article licensed under the Creative Commons Attribution-NonCommercial-NoDerivs License (http://creativecommons.org/licenses/by-nc-nd/3.0/).

The Economic Impact of the Logistics Industry in South Korea: Based on an Input-Output Approach

Tae-Jin Kim[1] and Nikolas Tromp[2*]

[1]Korea Maritime Institute, Department of Ocean Economy Research and Statistics, 26, Haeyang-ro 301 beon-gil, Yeongdo-gu, Busan, 49111, South Korea; Email: ktjseed@gmail.com
[2]Keimyung University, Department of Economics and Finance, 1095, Dalgubeol, Dalseo-gu, Daegu, 42601, South Korea; Email: nikolas.tromp@gmail.com

***Corresponding Author:** Nikolas Tromp

Received: 14 July 2022; Revised: 15 September 2022; Accepted: 3 October 2022; Published: 4 November 2022

Abstract: Using input-output analysis, this study investigates the economic impact of the logistics industry and its four sub-sectors: land freight, water freight, air freight and logistics facilities. The inter-industry linkage model shows that land freight and logistics facilities have large pull effects on the economy. Estimates from the production-inducing model indicate that investments in the logistics industry have considerable effects on both upstream and downstream industries. The employment-inducing model suggests that although employment-inducing effects have fallen over time, total induced employment has risen, particularly for permanent jobs. Lastly, estimates from the supply-shortage model indicate large effects for land freight which highlights the need for greater diversity in transportation modes. The findings and their implications may be useful to formulate effective policies in Korea.

Keywords: Logistics industry, freight transportation, input-output analysis, South Korea

1. Introduction

Although the logistics industry is a vital part of the economy, research analyzing its comprehensive role and impacts on the economy is scarce. The majority of studies that do exist focus solely on transportation or maritime sectors rather than the logistics industry and its components [1-2]. These studies tend to exclude key sectors such as storage and warehouse operations, logistics terminals, etc., and thus overlook important relationships between sectors. With this in mind, the current paper attempts to fill in the gap in literature focusing on the logistics industry in Korea.

The Ministry of Land, Infrastructure and Transport [3] established the National Logistics Master Plan for 2016-2025 to create policies and develop the logistics industry. To create effective policies,

policymakers require access to research on the impact of the logistics industry on the economy. In line with this, the current study applies input-output (I-O) analysis to the Korean logistics industry and its sub-sectors. I-O analysis is well-suited to analyzing the logistics industry because it captures interdependencies between industries in the economy. Under the assumption that the four sub-sectors of the logistics industry are exogenous, this paper uses I-O analysis to estimate inter-industry linkage effects, production-inducing effects, employment-inducing effects, and sectoral supply-shortage effects. These estimates provide insights which may act as a guide for policymakers.

The contribution of this paper is twofold. First, analysis is conducted on the entire logistics industry and sectors that comprise the industry, rather than on transportation sectors. The definition of the logistics industry is in accordance with the Framework Act on Logistics Policies [4] which includes land freight, water freight and air freight transportation as well as logistics facilities but excludes passenger transportation. Second, a wide range of economic effects are estimated to analyze the role and impact of the logistics industry. Among these are employment-inducing effects which were overlooked in a recent study on the transportation industry in Korea [2]. Unlike previous studies, this paper also decomposes employment-inducing effects into the effects on permanent, temporary and self-employment.

As mentioned above, the existing literature on the role and impact of the logistics industry on the economy is limited. The most probable reason is that the logistics industry is not classified separately in I-O tables. Several I-O studies on transportation and maritime industries, however, do exist. For Korea, Kwak et al. [1] assess the economic impact of the maritime industry, including marine transportation, during 1975-1998 and Lee and Yoo [2] assess the role of transportation industries during 2000-2010. Jun et al. [5] analyze the smart port industry and Kim et al. [6] study the spillover effects of the logistics industries. For Pakistan, Ali et al. [7] analyze the effects of the transport strike using an inoperability I-O model. For Ireland, Morrissey and O'Donoghue [8] study maritime transportation. The port sector in South Africa is analyzed by Chang et al. [9] and that in South Wales is analyzed by Bryan et al. [10]. For China, Wang and Wang [11] analyze the port industries and Zhao et al. [12] study the air transport sector. Finally, Keček et al. [13] analyze the multiplier effects of transport sectors in Croatia.

The structure of this paper is as follows. Section 2 explains the data and methods used for the analysis. Section 3 presents and interprets the results from the analysis. Finally, Section 4 lays out the policy implications and main conclusions.

2. Data and Methods

2.1 Data Sources

This study uses Korea's original benchmark domestic I–O tables for 2010, 2015, and 2018 which are compiled by the Bank of Korea [14]. On top of that, basic data such as total output, employment, value added and compensation of employees are used from the annual Transportation Survey published by Statistics Korea and the Bank of Korea.

The definition of the logistics industry is in accordance with the Framework Act on Logistics Policies [4] which includes freight transportation (land, water and air freight), logistics terminals and warehouses, but excludes passenger transportation. These sectors cannot be directly identified in the Korean I–O tables and therefore must be disaggregated as follows. First, Korea's logistics industry is defined as the sum of four sub-sectors: land freight, water freight, air freight and logistics facilities. Next, these sub-sectors are disaggregated from the original I–O tables in 2010, 2015, and 2018 using basic data such as total output, value added and compensation of employees. Finally, original tables are aggregated into 36-sector tables, including the four logistics sub-sectors (Appendix Table A1).

2.2 Basic Framework of the I–O Model

The I–O model, developed by Leontief [15], is commonly used to analyze relationships between industries in the national economy. Suppose a national economy has $\boldsymbol{n}$ sectors. The balanced equations can be expressed as follows [16]:

$$X_i = \sum_{j=1}^{N} z_{ij} + F_i = \sum_{j=1}^{N} a_{ij} X_j + F_i \quad (1)$$

$$X_j = \sum_{i=1}^{N} z_{ij} + V_j = \sum_{i=1}^{N} r_{ij} X_i + V_j \quad (2)$$

where: $\boldsymbol{X_i}$ is the total output of sector $\boldsymbol{i}$; $\boldsymbol{F_i}$ is the final demand for sector $\boldsymbol{i}$; $\boldsymbol{a_{ij}}$ is the direct input (or technical) coefficient which is measured by dividing the inter-industry flow from sector $\boldsymbol{i}$ to sector $\boldsymbol{j}$ by the total output of sector $\boldsymbol{j}$ ($\boldsymbol{z_{ij}/X_j}$); $\boldsymbol{r_{ij}}$ is the direct output coefficient which is calculated by dividing $\boldsymbol{z_{ij}}$ by $\boldsymbol{X_i}$; and $\boldsymbol{V_j}$ is the value added of sector $\boldsymbol{j}$.

2.3 Inter-industry Linkage Model

I-O analysis of inter-industry linkage effects is based on the assumption that the inputs and outputs of one industry can expand those of other industries [17]. In this model, backward linkages refer to demand-side links and forward linkages refer to supply-side links. If $\boldsymbol{I}$ is the $\boldsymbol{N \times N}$ identity matrix, $\boldsymbol{A}$ is the $\boldsymbol{N \times N}$ matrix of input coefficients and $\boldsymbol{F}$ is the $\boldsymbol{N \times 1}$ vector of final demand, Eq. (1) can be rewritten as $\boldsymbol{X = (I - A)^{-1} F}$ in matrix form. $\boldsymbol{(I - A)^{-1}}$ is the well-known Leontief inverse matrix, in which elements $\boldsymbol{\left(\alpha_{ij} = \partial X_i / \partial F_j\right)}$ represent the total requirements (direct and indirect outputs) in sector $\boldsymbol{i}$ per unit of final demand for products in sector $\boldsymbol{j}$.

The power of dispersion index, based on Rasmussen [18], can be used as a measure of the backward linkage effects,

$$U_j^b = \sum_{i=1}^{n} \alpha_{ij} \,/\, \left((1/n)\ \sum_{i=1}^{n}\sum_{j=1}^{n} \alpha_{ij}\right), \tag{3}$$

where: $\boldsymbol{U_j^b}$ is the backward linkage effect, $\boldsymbol{\sum_{i=1}^{n} \alpha_{ij}}$ is the sum of column $\boldsymbol{j}$ in the Leontief inverse matrix and $\boldsymbol{\sum_{i=1}^{n}\sum_{j=1}^{n} \alpha_{ij}}$ is the average of the Leontief inverse matrix. Similarly, the forward linkage effects are represented as the sensitivity of dispersion index,

$$U_i^f = \sum_{j=1}^{n} \alpha_{ij} \,/\, \left((1/n)\ \sum_{i=1}^{n}\sum_{j=1}^{n} \alpha_{ij}\right), \tag{4}$$

where: $\boldsymbol{U_i^f}$ is the forward linkage effect and $\boldsymbol{\sum_{j=1}^{n} \alpha_{ij}}$ is the sum of row $\boldsymbol{i}$ in the Leontief inverse matrix. If a specific sector has both backward and forward linkage effects greater than 1, the sector not only supports other industries (forward linkage effects) but also boosts other industries (backward linkage effects) in the national economy. This means that the sector plays an important role in economic development. Thus, backward and forward linkages are helpful in assessing the impact of sectors in the supply chain of the economy.

2.4 Demand-driven Model

In the demand-driven I–O model, final demand for a target sector and total output for the remaining sectors are treated as exogenous [16]. This model can evaluate the effects of new production activity in the logistics sectors on all other industries. Adding the subscript $\boldsymbol{e}$ to the remaining sectors and the subscript $\boldsymbol{w}$ to components related to the logistics sectors gives $\boldsymbol{X_e} = (\boldsymbol{I} - \boldsymbol{A_e})^{-1}(\boldsymbol{F_e} + \boldsymbol{A_w X_w})$. Assuming that output in logistics sectors changes by one unit, $\Delta \boldsymbol{F_e} = \boldsymbol{0}$, the production-inducing effects are expressed as follows:

$$\Delta X_e = (I - A_e)^{-1} A_w \Delta X_w \tag{5}$$

where: $\boldsymbol{(I - A_e)^{-1}}$ is the Leontief inverse matrix from the reduced input coefficient matrix eliminating the column and row of sector $\boldsymbol{w}$, $\boldsymbol{A_w}$ is a column vector excluding the sector $\boldsymbol{w}$, and $\Delta \boldsymbol{X_w}$ is the change in sector $\boldsymbol{w}$'s gross output. Eq. (5) can be used to analyze the production-inducing effects of the logistics industry on the output of other sectors [1, 11].

2.5 Employment-inducing Model

The employment-inducing effects of logistics sectors measure the contribution of investments in the logistics industry to employment in all other industries. Based on the employment matrix [11], logistics sectors are considered as exogenous variables and the employment-inducing effects can be measured as follows:

$$\Delta L_e = \hat{l}_e (I - A_e)^{-1} A_w \Delta X_w \tag{6}$$

where: $\Delta \boldsymbol{L_e}$ are the employment-inducing effects of logistics sectors on other sectors. $\hat{\boldsymbol{l}}_{\boldsymbol{e}}$ is the employment matrix which excludes logistics sectors. In addition, this study divides the employment matrix into three types of employment; permanent, temporary and self-employed.

2.6 Supply-driven Model

In the supply-driven I–O model [19-20], Eq. (2) can be expressed as $\boldsymbol{X'} = \boldsymbol{V'}(\boldsymbol{I} - \boldsymbol{R})^{-\mathbf{1}}$. A prime ($'$) means the transposition of a matrix, $\boldsymbol{R}$ is the direct output (or allocation) coefficients matrix and $\boldsymbol{V'}$ is a vector of the value-added expenditures. $(\boldsymbol{I} - \boldsymbol{R})^{-\mathbf{1}}$ is the output inverse matrix of which elements ($\boldsymbol{g_{ij}} = \boldsymbol{\partial X_j / \partial V_i}$) represent the direct and indirect value of production that comes about in sector $\boldsymbol{j}$ per unit of added value in sector $\boldsymbol{i}$ [16]. Treating logistics sectors as exogenous and assuming that there is no change in added value in all other sectors yields the following [2, 11, 20]:

$$\Delta X'_e = R_w \Delta X_w (I - R_e)^{-1} \quad (7)$$

where: $\Delta \boldsymbol{X'_e}$ is the supply shortage effect, $\boldsymbol{R_w}$ is a row vector which excludes sector $\boldsymbol{w}$, and $(\boldsymbol{I} - \boldsymbol{R_e})^{-\mathbf{1}}$ is the output inverse matrix which excludes the column and row of sector $\boldsymbol{w}$. Eq. (7) estimates the impact of a unit shortage in logistics sectors on the output of all other sectors.

3. Results

3.1 Production-inducing Effects

The effects of increases in production in each of the four logistics sectors by KRW 1.0 on production in other sectors in 2010, 2015, and 2018 are summarized in Table 1. Land freight transportation has the largest production-inducing effects which increase from KRW 0.9520 to KRW 1.1034 during 2010-2018. Logistics facilities has the second largest effects ranging from KRW 0.9066 to 1.0782. The effects of air freight transportation increase from KRW 0.3511 to KRW 0.4607, while those of water freight transportation decrease from KRW 0.3678 to KRW 0.3051. Using the total output of each sector, the total production-inducing effect of the logistics industry is estimated to have increased from KRW 49.9 trillion to KRW 66.7 trillion.[1]

The production-inducing effects of the three freight transportation modes are largest on coke and refined petroleum products (S6) and transportation equipment (S14) which indicates that these sectors account for a significant proportion of the production cost of logistics freight services. Water and air freight transportation have major effects on business support services (S27) and finance and insurance (S24), while land freight transportation has major effects on chemicals and chemical products (S7) and wholesale and retail trade (S20). Meanwhile, logistics facilities have major effects on

[1] The total production-inducing effect of each logistics sector can be measured by multiplying the total output by the production-inducing effect. For instance, the production-inducing effect of land freight amounted to KRW 41.1 trillion in 2018. This was estimated by multiplying the production-inducing effect (1.1034) by the total output (KRW 37.3 trillion).

professional, scientific and technical services (S26) and business support services (S27). To sum up, the above findings suggest investments in the logistics industry would facilitate potential demand for downstream and upstream industries because of the logistics industry's large impact on major manufacturing and service sectors.

Table 1 Production-inducing effects of Korea's logistics industry. Source: author

	Land freight transportation			Water freight transportation			Air freight transportation			Logistics facilities		
Code	2010	2015	2018	2010	2015	2018	2010	2015	2108	2010	2015	2018
S1	0.0028	0.0051	0.0048	0.0013	0.0025	0.0023	0.0007	0.0026	0.0027	0.0081	0.0074	0.0073
S2	0.0009	0.0007	0.0006	0.0003	0.0002	0.0001	0.0004	0.0003	0.0003	0.0009	0.0005	0.0006
S3	0.0053	0.0109	0.0108	0.0025	0.0065	0.0061	0.0014	0.0060	0.0064	0.0162	0.0162	0.0165
S4	0.0122	0.0193	0.0184	0.0034	0.0036	0.0041	0.0014	0.0021	0.0026	0.0608	0.0429	0.0494
S5	0.0128	0.0136	0.0135	0.0036	0.0037	0.0037	0.0023	0.0030	0.0032	0.0514	0.0589	0.0581
S6	0.3075	0.2377	0.2740	0.0962	0.0464	0.0435	0.1547	0.1932	0.1994	0.0551	0.0335	0.0413
S7	0.0747	0.0629	0.0589	0.0125	0.0121	0.0110	0.0122	0.0134	0.0128	0.0800	0.0639	0.0685
S8	0.0022	0.0039	0.0037	0.0009	0.0010	0.0009	0.0008	0.0011	0.0011	0.0050	0.0040	0.0040
S9	0.0251	0.0188	0.0210	0.0104	0.0051	0.0041	0.0102	0.0066	0.0065	0.0416	0.0149	0.0169
S10	0.0178	0.0267	0.0240	0.0079	0.0071	0.0055	0.0058	0.0077	0.0065	0.0311	0.0287	0.0291
S11	0.0129	0.0171	0.0166	0.0042	0.0051	0.0046	0.0039	0.0052	0.0050	0.0342	0.0190	0.0199
S12	0.0166	0.0236	0.0395	0.0048	0.0048	0.0050	0.0043	0.0045	0.0049	0.0433	0.0274	0.0315
S13	0.0119	0.0119	0.0102	0.0056	0.0038	0.0030	0.0051	0.0042	0.0034	0.0320	0.0096	0.0091
S14	0.0783	0.1218	0.1281	0.0304	0.0312	0.0200	0.0325	0.0333	0.0288	0.0221	0.0267	0.0293
S15	0.0041	0.0030	0.0034	0.0012	0.0009	0.0011	0.0011	0.0008	0.0011	0.0084	0.0044	0.0054
S16	0.0075	0.0144	0.0142	0.0027	0.0036	0.0033	0.0023	0.0037	0.0036	0.0145	0.0164	0.0179
S17	0.0191	0.0235	0.0242	0.0069	0.0065	0.0063	0.0062	0.0101	0.0106	0.1154	0.0688	0.0753
S18	0.0055	0.0057	0.0059	0.0014	0.0010	0.0011	0.0011	0.0011	0.0012	0.0095	0.0059	0.0067
S19	0.0027	0.0033	0.0035	0.0027	0.0011	0.0012	0.0020	0.0009	0.0011	0.0057	0.0046	0.0057
S20	0.0640	0.0565	0.0596	0.0290	0.0154	0.0150	0.0124	0.0125	0.0132	0.0720	0.0539	0.0582
S21	0.0682	0.1046	0.1153	0.0207	0.0179	0.0187	0.0178	0.0163	0.0138	0.0250	0.0763	0.0744
S22	0.0120	0.0226	0.0264	0.0059	0.0090	0.0110	0.0033	0.0109	0.0144	0.0371	0.0278	0.0340
S23	0.0292	0.0294	0.0293	0.0093	0.0105	0.0100	0.0072	0.0088	0.0095	0.0560	0.0353	0.0374
S24	0.0405	0.0297	0.0317	0.0329	0.0192	0.0188	0.0298	0.0129	0.0152	0.0495	0.0364	0.0438
S25	0.0189	0.0191	0.0208	0.0465	0.0060	0.0067	0.0083	0.0061	0.0076	0.0442	0.0307	0.0373
S26	0.0123	0.0402	0.0430	0.0054	0.0144	0.0149	0.0043	0.0133	0.0148	0.0301	0.0831	0.0998
S27	0.0327	0.0351	0.0360	0.0048	0.0555	0.0643	0.0073	0.0178	0.0214	0.0930	0.0714	0.0791
S28	0.0003	0.0017	0.0019	0.0001	0.0002	0.0002	0.0010	0.0014	0.0020	0.0006	0.0006	0.0006
S29	0.0006	0.0008	0.0008	0.0003	0.0003	0.0003	0.0003	0.0004	0.0005	0.0012	0.0013	0.0014
S30	0.0025	0.0036	0.0030	0.0008	0.0010	0.0009	0.0010	0.0011	0.0010	0.0028	0.0028	0.0026
S31	0.0021	0.0029	0.0036	0.0010	0.0017	0.0022	0.0006	0.0225	0.0271	0.0065	0.0044	0.0054
S32	0.0314	0.0446	0.0433	0.0017	0.0054	0.0053	0.0010	0.0073	0.0079	0.0125	0.0145	0.0147
S33	-	-	-	0.0036	0.0030	0.0031	0.0027	0.0034	0.0034	0.0109	0.0108	0.0116
S34	0.0011	0.0012	0.0009	-	-	-	0.0004	0.0004	0.0003	0.0007	0.0018	0.0013
S35	0.0037	0.0023	0.0019	0.0002	0.0002	0.0002	-	-	-	0.0009	0.0018	0.0015
S36	0.0124	0.0175	0.0105	0.0068	0.0063	0.0068	0.0053	0.0047	0.0074	-	-	-
Sum	0.9520	1.0360	1.1034	0.3678	0.3123	0.3051	0.3511	0.4398	0.4607	1.0782	0.9066	0.9955

3.2 Employment-inducing Effects

The effects of increases in production in each of the four logistics sectors by KRW 1.0 billion on employment in other sectors in 2010, 2015, and 2018 are summarized in Table 2. The employment-inducing effects of logistics facilities are the largest, ranging from 8.3590 persons to 5.7575 persons, and those of land freight transportation are the second largest, ranging from 5.2789 persons to 5.6902 persons. The employment-inducing effects of water freight transportation range from 1.9818 persons to 2.2338 persons, while those of air freight transportation range from 1.3996 persons to 1.8635 persons. Between 2015 and 2018, the employment-inducing effects show a downward trend which reflects a shift to labor-saving or technology-intensive production in Korea. However, given total output of each logistics sector, it is estimated that the total employment-inducing effects are 305,587 persons, 340,155 persons, and 345,809 persons, showing an upward trend between 2010, 2015 and 2018.

Table 2 Employment-inducing effects of Korea's logistics industry (Unit: person/KRW billion). Source: author

	Land freight transportation			Water freight transportation			Air freight transportation			Logistics facilities		
Code	2010	2015	2108	2010	2015	2018	2010	2015	2108	2010	2015	2018
S1	0.0755	0.1017	0.0941	0.0346	0.0502	0.0453	0.0197	0.0519	0.0526	0.2225	0.1486	0.1421
S2	0.0046	0.0020	0.0024	0.0015	0.0005	0.0005	0.0021	0.0010	0.0010	0.0045	0.0016	0.0022
S3	0.0175	0.0275	0.0274	0.0082	0.0165	0.0154	0.0045	0.0153	0.0163	0.0529	0.0409	0.0420
S4	0.0758	0.0811	0.0681	0.0209	0.0151	0.0150	0.0086	0.0088	0.0095	0.3778	0.1803	0.1827
S5	0.0633	0.0588	0.0498	0.0178	0.0162	0.0134	0.0114	0.0130	0.0118	0.2541	0.2546	0.2140
S6	0.0245	0.0254	0.0205	0.0076	0.0050	0.0033	0.0123	0.0206	0.0149	0.0044	0.0036	0.0031
S7	0.1171	0.1055	0.0925	0.0197	0.0203	0.0173	0.0191	0.0225	0.0202	0.1254	0.1070	0.1077
S8	0.0059	0.0108	0.0094	0.0025	0.0027	0.0022	0.0022	0.0031	0.0027	0.0132	0.0110	0.0100
S9	0.0143	0.0223	0.0189	0.0059	0.0060	0.0036	0.0058	0.0078	0.0059	0.0236	0.0176	0.0152
S10	0.0645	0.0989	0.0828	0.0285	0.0262	0.0190	0.0210	0.0284	0.0224	0.1130	0.1064	0.1004
S11	0.0191	0.0254	0.0199	0.0062	0.0076	0.0055	0.0058	0.0077	0.0061	0.0506	0.0282	0.0238
S12	0.0443	0.0591	0.0924	0.0129	0.0119	0.0117	0.0115	0.0112	0.0115	0.1153	0.0686	0.0737
S13	0.0368	0.0372	0.0290	0.0172	0.0117	0.0085	0.0159	0.0131	0.0096	0.0987	0.0299	0.0258
S14	0.1580	0.2297	0.2589	0.0613	0.0588	0.0404	0.0655	0.0629	0.0583	0.0446	0.0503	0.0593
S15	0.0934	0.0239	0.0205	0.0272	0.0075	0.0070	0.0244	0.0068	0.0065	0.1899	0.0354	0.0330
S16	0.0267	0.1199	0.1032	0.0095	0.0301	0.0236	0.0082	0.0309	0.0262	0.0516	0.1362	0.1295
S17	0.0165	0.0183	0.0158	0.0060	0.0050	0.0041	0.0054	0.0078	0.0069	0.1000	0.0535	0.0493
S18	0.0397	0.0349	0.0352	0.0100	0.0062	0.0063	0.0076	0.0066	0.0073	0.0684	0.0363	0.0395
S19	0.0224	0.0246	0.0230	0.0221	0.0085	0.0079	0.0165	0.0068	0.0073	0.0465	0.0345	0.0375
S20	1.0225	0.8038	0.7300	0.4627	0.2191	0.1831	0.1982	0.1779	0.1615	1.1498	0.7658	0.7125
S21	0.9151	1.2403	1.1725	0.2785	0.2129	0.1897	0.2389	0.1937	0.1407	0.3360	0.9050	0.7562
S22	0.2379	0.3308	0.3135	0.1178	0.1316	0.1309	0.0652	0.1597	0.1703	0.7358	0.4063	0.4031
S23	0.1603	0.1389	0.1316	0.0512	0.0497	0.0451	0.0394	0.0416	0.0427	0.3078	0.1670	0.1678
S24	0.2244	0.1291	0.1199	0.1823	0.0835	0.0711	0.1650	0.0561	0.0575	0.2741	0.1580	0.1659
S25	0.0757	0.0493	0.0508	0.1862	0.0154	0.0164	0.0334	0.0158	0.0184	0.1770	0.0793	0.0910
S26	0.1411	0.2934	0.2830	0.0618	0.1054	0.0981	0.0490	0.0973	0.0975	0.3440	0.6065	0.6570
S27	0.8311	0.5421	0.4451	0.1216	0.8564	0.7950	0.1863	0.2752	0.2650	2.3607	1.1018	0.9774
S28	0.0030	0.0143	0.0148	0.0012	0.0018	0.0018	0.0094	0.0120	0.0156	0.0056	0.0047	0.0051
S29	0.0097	0.0107	0.0096	0.0044	0.0042	0.0036	0.0043	0.0057	0.0056	0.0199	0.0171	0.0169
S30	0.0319	0.0469	0.0341	0.0103	0.0128	0.0096	0.0130	0.0136	0.0110	0.0352	0.0359	0.0292
S31	0.0248	0.0310	0.0322	0.0119	0.0181	0.0194	0.0069	0.2410	0.2439	0.0774	0.0475	0.0483
S32	0.9793	0.9121	0.7948	0.0520	0.1112	0.0967	0.0305	0.1497	0.1455	0.3910	0.2956	0.2688
S33	-	-	-	0.0616	0.0474	0.0440	0.0465	0.0546	0.0480	0.1857	0.1734	0.1636
S34	0.0008	0.0009	0.0008	-	-	-	0.0003	0.0003	0.0003	0.0005	0.0014	0.0012
S35	0.0063	0.0036	0.0031	0.0004	0.0003	0.0002	-	-	-	0.0016	0.0027	0.0025
S36	0.1063	0.1616	0.0796	0.0583	0.0578	0.0512	0.0460	0.0434	0.0561	-	-	-
Sum	5.6902	5.8157	5.2789	1.9818	2.2338	2.0063	1.3996	1.8635	1.7767	8.3590	6.1123	5.7575

In this study, the employment-inducing effects of each logistics sector can be decomposed into three types of jobs: permanent jobs, temporary jobs, and self-employed jobs as shown in Table 3. The results show that increasing output of each logistics sector by KRW 1.0 billion has the largest effects on permanent jobs. In fact, the share of permanent jobs to total jobs created due to employment-inducing effects is more than 50% in 2018. Between 2010 and 2018, the share of permanent jobs also

Table 3 Decomposition of employment-inducing effects of Korea's logistics industry (Unit: person/KRW billion). Source: author

		2010		2015		2018	
		Persons	Share (%)	Persons	Share (%)	Persons	Share (%)
Land freight transportation	permanent jobs	2.4978	43.9	2.8972	49.8	2.8032	53.1
	temporary jobs	1.4714	25.9	1.1915	20.5	0.9230	17.5
	self-employed jobs	1.7210	30.2	1.7270	29.7	1.5528	29.4
	sum	5.6902	100.0	5.8157	100.0	5.2789	100.0
Water freight transportation	permanent jobs	0.8579	43.3	1.2084	54.1	1.1174	55.7
	temporary jobs	0.4982	25.1	0.5382	24.1	0.4501	22.4
	self-employed jobs	0.6258	31.6	0.4872	21.8	0.4388	21.9
	sum	1.9818	100.0	2.2338	100.0	2.0063	100.0
Air freight transportation	permanent jobs	0.6989	49.9	0.9123	49.0	0.8990	50.6
	temporary jobs	0.3398	24.3	0.4249	22.8	0.3745	21.1
	self-employed jobs	0.3609	25.8	0.5263	28.2	0.5032	28.3
	sum	1.3996	100.0	1.8635	100.0	1.7767	100.0
Logistics facilities operations	permanent jobs	3.9321	47.0	3.2056	52.4	3.1919	55.4
	temporary jobs	2.3110	27.6	1.2724	20.8	1.0534	18.3
	self-employed jobs	2.1158	25.3	1.6344	26.7	1.5122	26.3
	sum	8.3590	100.0	6.1123	100.0	5.7575	100.0

increased while the share of temporary jobs decreased for all logistics sectors. In addition, permanent employment-inducing effects from land, water, and air freight transportation increased during 2010-2018. These results indicate that investment in the logistics industry could promote the creation of permanent jobs in Korea.

3.3 Inter-industry Linkage Effects

Table 4 shows the forward and backward linkage effects of the logistics sectors in 2010, 2015, and 2018. The forward linkage effects of water freight, air freight and logistics facilities are relatively low, ranging from 0.5564 to 0.6912, while the forward linkage effects of land freight are relatively higher, ranging from 0.8679 to 0.9431. This result indicates that when there is an economic upturn or downturn, land freight transportation will be more affected than other logistics sectors. The backward linkage effects of land freight and logistics facilities are greater than 1 which means investment expenditure in these two sectors are likely to have a strong economic impact on other industries and thus the national economy.

Table 4 Forward and backward linkage effects in Korea. Source: author

	Forward linkage effects						Backward linkage effects					
	2010		2015		2018		2010		2015		2018	
Code	value	rank	value	rank	value	rank	value	rank	value	rank	value	rank
S1	0.9750	16	1.0086	18	0.9654	20	0.9915	19	1.0038	19	1.0063	19
S2	0.5851	32	0.6219	31	0.6137	31	0.9531	23	1.0306	16	1.0695	14
S3	1.0944	10	1.2420	8	1.1855	9	1.1681	8	1.1983	2	1.2000	2
S4	0.9181	22	0.8992	23	0.9103	22	1.1047	11	1.0857	13	1.0543	15
S5	1.1077	9	1.0929	14	1.0656	15	1.1120	10	1.1202	11	1.1139	11
S6	1.6716	4	1.3876	4	1.4926	4	0.6385	36	0.6804	36	0.6721	36
S7	2.2290	2	1.9818	1	1.9305	1	1.0937	12	1.0226	17	1.0417	17
S8	0.7654	24	0.8080	24	0.7777	24	1.0796	15	1.1729	6	1.1851	4
S9	2.3395	1	1.3202	6	1.3615	6	1.2475	2	1.0110	18	1.0346	18
S10	1.1249	8	1.1847	10	1.1322	13	1.2601	1	1.1525	7	1.1557	8
S11	1.0663	11	1.0118	17	0.9746	19	1.0167	18	0.9408	25	0.8452	28
S12	1.0127	12	0.9713	20	1.0008	18	1.2036	6	1.1212	10	1.1212	10
S13	1.0110	13	0.9174	22	0.8578	23	1.2441	3	1.1786	5	1.1586	7
S14	1.0027	14	1.1056	13	1.1233	14	1.2409	4	1.3476	1	1.3318	1
S15	0.6700	26	0.6469	28	0.6538	29	1.2185	5	1.1834	4	1.1725	6
S16	0.9666	18	1.1485	12	1.1448	11	0.9909	21	1.0469	15	1.0498	16
S17	1.3132	6	1.3851	5	1.3629	5	0.7814	31	0.7810	32	0.8241	29
S18	0.7567	25	0.7102	26	0.7158	26	1.0932	13	0.9929	20	0.9810	21
S19	0.6199	29	0.6322	30	0.6349	30	1.1748	7	1.1163	12	1.0998	13
S20	1.8231	3	1.7442	2	1.7396	2	0.9502	24	0.9569	23	0.9626	23
S21	0.9469	20	1.0398	16	1.0338	16	0.8766	28	0.8968	28	0.9202	25
S22	0.9210	21	1.0603	15	1.1383	12	1.0852	14	1.1870	3	1.1864	3
S23	1.1925	7	1.1869	9	1.1566	10	0.9911	20	0.9317	26	0.9086	26
S24	1.4051	5	1.2977	7	1.3419	7	0.9048	26	0.9077	27	0.8952	27
S25	0.9881	15	0.9841	19	1.0221	17	0.7310	34	0.7642	33	0.7845	33
S26	0.9671	17	1.4843	3	1.5221	3	0.9033	27	0.9820	21	0.9963	20
S27	0.9506	19	1.1750	11	1.2134	8	0.8462	29	0.8163	30	0.8238	30
S28	0.5444	36	0.5804	33	0.5799	33	0.7502	32	0.7514	34	0.7499	34
S29	0.5529	35	0.5723	36	0.5667	34	0.7837	30	0.8399	29	0.8126	31
S30	0.5925	31	0.6191	32	0.6042	32	0.9543	22	0.9530	24	0.9513	24
S31	0.6116	30	0.6454	29	0.6587	28	0.9406	25	0.9732	22	0.9788	22
S32	0.6426	28	0.7651	25	0.7539	25	1.0336	17	1.1283	9	1.1215	9
S33	0.8679	23	0.9453	21	0.9431	21	1.0633	16	1.1434	8	1.1728	5
S34	0.5616	33	0.5779	34	0.5662	35	0.7319	33	0.7241	35	0.7146	35
S35	0.5564	34	0.5737	35	0.5648	36	0.7227	35	0.7945	31	0.7994	32
S36	0.6458	27	0.6726	27	0.6912	27	1.1183	9	1.0628	14	1.1042	12

Overall, water freight and air freight transportation have low forward and backward linkages. Thus, these sectors are classified as final primary production industries. This means that water freight

and air freight transportation have a small impact on upstream and downstream industries.[2] Land freight transportation and logistics facilities have low forward linkages but high backward linkages. Thus, these sectors are classified as intermediate primary production industries. This means that land freight transportation and logistics facilities are more likely to consume outputs of upstream sectors than provide inputs for downstream sectors.

3.4 Supply Shortage Effects

The costs of supply shortages in the four logistics sectors in 2010, 2015, and 2018 are summarized in Table 5. The total supply shortage effects are KRW 1.8107–1.8673 for land freight, KRW 0.1166–0.1549 for water freight, KRW 0.7773–1.0242 for air freight, and KRW 1.7001–1.8533 for logistics facilities. Thus, it can be concluded that supply shortages in land freight, air freight, and logistics

Table 5 Supply shortage effects of Korea's logistics industry. Source: author

	Land freight transportation			Water freight transportation			Air freight transportation			Logistics facilities		
	2010	2015	2108	2010	2015	2018	2010	2015	2108	2010	2015	2018
Code	0.0214	0.0213	0.0195	0.0016	0.0019	0.0020	0.0072	0.0073	0.0069	0.0362	0.0328	0.0314
S1	0.0109	0.0108	0.0109	0.0006	0.0006	0.0007	0.0006	0.0007	0.0007	0.0046	0.0044	0.0044
S2	0.0928	0.1042	0.1014	0.0052	0.0076	0.0085	0.0210	0.0254	0.0258	0.1125	0.1206	0.1218
S3	0.0487	0.0596	0.0453	0.0021	0.0023	0.0021	0.0161	0.0226	0.0186	0.0385	0.0416	0.0331
S4	0.0536	0.0635	0.0617	0.0027	0.0025	0.0027	0.0081	0.0076	0.0075	0.0328	0.0283	0.0275
S5	0.0325	0.0216	0.0222	0.0079	0.0054	0.0062	0.0079	0.0048	0.0055	0.0285	0.0127	0.0139
S6	0.1878	0.1665	0.1682	0.0123	0.0121	0.0136	0.0463	0.0699	0.0746	0.1306	0.1154	0.1204
S7	0.0883	0.1065	0.1096	0.0080	0.0159	0.0164	0.0096	0.0093	0.0096	0.0421	0.0405	0.0411
S8	0.1722	0.0997	0.1070	0.0132	0.0129	0.0155	0.0243	0.0161	0.0178	0.0922	0.0369	0.0387
S9	0.0736	0.0741	0.0686	0.0046	0.0056	0.0059	0.0168	0.0227	0.0213	0.0498	0.0416	0.0386
S10	0.1387	0.1038	0.0899	0.0078	0.0063	0.0057	0.0501	0.0970	0.0937	0.1118	0.0675	0.0602
S11	0.0572	0.0536	0.0525	0.0039	0.0049	0.0054	0.0212	0.0462	0.0455	0.0454	0.0341	0.0350
S12	0.0836	0.0797	0.0817	0.0053	0.0057	0.0066	0.0322	0.0554	0.0600	0.0619	0.0490	0.0519
S13	0.1523	0.1645	0.1306	0.0084	0.0144	0.0120	0.0368	0.0700	0.0555	0.1118	0.1094	0.0885
S14	0.0177	0.0169	0.0181	0.0009	0.0011	0.0014	0.0051	0.0071	0.0077	0.0137	0.0106	0.0117
S15	0.0240	0.0340	0.0311	0.0012	0.0015	0.0015	0.0045	0.0087	0.0083	0.0159	0.0226	0.0216
S16	0.0097	0.0099	0.0117	0.0007	0.0006	0.0008	0.0046	0.0076	0.0080	0.0142	0.0057	0.0069
S17	0.0256	0.0243	0.0272	0.0009	0.0013	0.0017	0.0032	0.0024	0.0026	0.0125	0.0089	0.0096
S18	0.1501	0.1471	0.1564	0.0097	0.0136	0.0151	0.0375	0.0368	0.0388	0.1011	0.0822	0.0880
S19	0.1867	0.1835	0.1894	0.0083	0.0077	0.0089	0.1738	0.1557	0.1601	0.4287	0.4300	0.4798
S20	0.0120	0.0130	0.0135	0.0008	0.0011	0.0012	0.0144	0.0159	0.0154	0.0658	0.0491	0.0303
S21	0.0377	0.0559	0.0616	0.0019	0.0035	0.0043	0.0141	0.0274	0.0305	0.0482	0.0834	0.0910
S22	0.0315	0.0313	0.0289	0.0012	0.0010	0.0011	0.0406	0.0859	0.0866	0.0404	0.0316	0.0306
S23	0.0242	0.0180	0.0180	0.0008	0.0007	0.0008	0.0411	0.0245	0.0255	0.0287	0.0155	0.0157
S24	0.0133	0.0139	0.0162	0.0006	0.0009	0.0011	0.0090	0.0103	0.0121	0.0120	0.0106	0.0121
S25	0.0276	0.0430	0.0467	0.0010	0.0020	0.0024	0.0472	0.0736	0.0750	0.0290	0.0456	0.0475
S26	0.0102	0.0188	0.0208	0.0003	0.0007	0.0008	0.0085	0.0108	0.0113	0.0092	0.0171	0.0190
S27	0.0143	0.0164	0.0180	0.0006	0.0010	0.0032	0.0144	0.0160	0.0173	0.0108	0.0128	0.0135
S28	0.0148	0.0160	0.0141	0.0007	0.0009	0.0008	0.0099	0.0110	0.0097	0.0149	0.0154	0.0137
S29	0.0252	0.0292	0.0324	0.0014	0.0017	0.0021	0.0130	0.0178	0.0199	0.0272	0.0333	0.0383
S30	0.0076	0.0099	0.0107	0.0004	0.0005	0.0006	0.0050	0.0090	0.0097	0.0083	0.0106	0.0112
S31	0.0121	0.0201	0.0193	0.0006	0.0012	0.0012	0.0096	0.0183	0.0179	0.0119	0.0213	0.0208
S32	-	-	-	0.0009	0.0014	0.0016	0.0201	0.0170	0.0176	0.0343	0.0473	0.0227
S33	0.0048	0.0025	0.0017	-	-	-	0.0017	0.0012	0.0008	0.0250	0.0144	0.0080
S34	0.0005	0.0005	0.0004	0.0001	0.0001	0.0001	-	-	-	0.0027	0.0017	0.0017
S35	0.0039	0.0040	0.0054	0.0002	0.0008	0.0011	0.0018	0.0048	0.0066	-	-	-
Sum	1.8673	1.8373	1.8107	0.1166	0.1412	0.1549	0.7773	1.0167	1.0242	1.8533	1.7046	1.7001

facilities would have significant effects on the economy. Assuming that all logistics activities completely disappeared in 2010, 2015, and 2018, the total costs in all other sectors would be KRW

[2] If the forward and backward linkage effects of an industry are respectively low and low, low and high, high and low, and high and high, the industry can be classified into final primary production, final manufacture production, intermediate primary production, and intermediate manufacture production [1].

74.5 trillion, KRW 90.5 trillion, and KRW 104.5 trillion, respectively.[3] It is clear that the effects of logistics supply shortages are greatest on industries that consume logistics services intensively such as wholesale and retail trade (S20), chemicals and chemical products (S7), transportation equipment (S14) and construction (S19).

4. Policy Implications and Conclusions

4.1 Policy Implications

In this section, we outline the policy implications of the findings from each model: the inter-industry linkage model, demand-driven model, employment-inducing model, and supply-driven model.

The inter-industry linkage model demonstrated that the logistics sectors are more influential in consuming products from their upstream industries than producing products for their downstream industries. The land freight transportation and logistics facilities sectors have significant pull effects on the economy since the backward linkage effects of these two logistics sectors are greater than the national average. Thus, we conclude that the development of the logistics industry in Korea plays an important role in driving the growth of not only itself but also other Korean industries.

Production-inducing effects are used to evaluate the economic benefits of logistics investment projects such as freight transport infrastructure, logistics complexes and port hinterland development projects. The main production-inducing effects of the three freight transportation sectors are on coke and refined petroleum products (S6) and transportation equipment (S14), while those of logistics facilities are on professional, scientific and technical services (S26) and business support services (S27). The findings suggest that large-scale logistics investment projects with a rational allocation of logistics production costs may contribute to the development of the above sectors.

The employment-inducing effects show that overall industrial production in the Korean economy has progressed in a labor-saving manner. Nonetheless, it is worth noting that total employment effects induced by the logistics industry show an upward trend. Additionally, there is an increasing trend in the creation of permanent jobs induced by the logistics industry. Thus, when managing logistics investment projects and designing policies, policymakers should take into account the benefit of creating additional job opportunities, especially permanent jobs, from the logistics industry.

Finally, the supply-driven model offers useful information on the impacts of a complete disappearance of the logistics industry. The supply shortage effects of land freight and logistics facilities sectors on the economy are severe, while those of water freight and air freight are relatively minor. In particular, the supply constraints of land freight transportation could lead to serious losses

[3] The supply shortage costs of each logistics industry can be derived by multiplying the total output value by the sum of supply shortage effects. For example, the supply shortage costs of land freight added up to KRW 67.5 trillion in 2018. This is estimated by multiplying the total output value (KRW 37.3 trillion) by the sum of supply shortage effects (1.8107).

in the economy because more than 92% of domestic freight traffic is handled by land freight transportation. Thus, policies that promote a modal shift from land freight to water freight transportation could help to diminish the effects of a severe supply shortage.

4.2. Conclusions

For an in-depth understanding of the role of the logistics industry in the Korean economy, this study examined the economic impact of four logistics sectors using I–O analysis. This analysis included several models such as the inter-industry linkage model, demand-driven model, employment-inducing model, and supply-driven model. In addition, the employment-inducing model decomposed employment into three types: permanent, temporary and self-employed. The implications of the findings may be used by policymakers to formulate effective logistics policies in Korea.

To summarize the key findings, the strong pull effects of the land freight transportation and logistics facilities sectors on the economy mean these sectors play an important role in driving economy-wide growth. Analysis of production-inducing effects shows that investments into logistics projects are likely to contribute positively to the development of S6, S14, S26, S27. The logistics industry contributes to employment, particularly in permanent jobs, which should be included in cost-benefit analyses of logistics-related investments. Finally, a modal shift from land freight to water freight transportation is recommended given the serious supply constraints of the former.

Although this study has provided important insights into the Korean logistics industry, future studies can expand on it using various other approaches. For example, future studies could use a computable general equilibrium model to consider capital accumulation in the logistics industry. Multi-regional input-output analysis could also be used to explore the impact of the logistics industry on the regional economy. Such analyses could add to the foundation laid out by this study.

Appendix A

Table A1 Sector classification Source: author

Code	Sector name	Category	Code	Sector name	Category
S1	Agriculture, forestry, and fisheries	Primary	S19	Construction	Service
S2	Mining and quarrying	Primary	S20	Wholesale and retail trade	Service
S3	Food and food products	Manufacturing	S21	Other transportation services	Service
S4	Textiles and products	Manufacturing	S22	Accommodation and food service	Service
S5	Paper, wood products, and printing	Manufacturing	S23	Information and communication	Service
S6	Coke and refined petroleum products	Manufacturing	S24	Finance and insurance	Service
S7	Chemicals and chemical products	Manufacturing	S25	Real estate	Service
S8	Non-metallic mineral products	Manufacturing	S26	Professional, scientific and technical services	Service
S9	Basic metals	Manufacturing	S27	Business support services	Service
S10	Fabricated metal products	Manufacturing	S28	Public administration and defense	Service
S11	Computer, electronic and optical products	Manufacturing	S29	Education	Service
S12	Electrical equipment	Manufacturing	S30	Human health and social services	Service
S13	Other machinery and equipment	Manufacturing	S31	Arts, sports and entertainment services	Service
S14	Transportation equipment	Manufacturing	S32	Other services	Service
S15	Furniture and other manufacturing	Manufacturing	S33	Land freight transportation	Logistics
S16	Repair of machinery and equipment	Manufacturing	S34	Water freight transportation	Logistics
S17	Electricity, gas, steam	Service	S35	Air freight transportation	Logistics
S18	Water supply, waste management services	Service	S36	Logistics facilities operations	Logistics

References

[1] Kwak, S.J., Yoo, S.H. & Chang, J.I. (2005). The role of the maritime industry in the Korean national economy: an input–output analysis. Marine Policy 29(4), 371-383. DOI: 10.1016/j.marpol.2004.06.004.

[2] Lee, M.K. & Yoo, S.H. (2016). The role of transportation sectors in the Korean national economy: an input-output analysis. Transportation. Transportation Research Part A: Policy and Practice 93, 13–22. DOI: 10.1016/j.tra.2016.08.016.

[3] Ministry of Land, Infrastructure and Transport. (2016). The National Logistics Master Plan (2016–2025). Sejong, Korea: Ministry of Land, Transport and Maritime Affairs.

[4] Framework Act on Logistics Policies. (2019). Framework Act on Logistics Policies. Retrieved June 28. 2020, from https://elaw.klri.re.kr

[5] Jun, W.K., Lee, M.K. & Choi, J.Y. (2018). Impact of the smart port industry on the Korean national economy using input-output analysis. Transportation Research Part A: Policy and Practice 118, 480-493. DOI: 10.1016/j.tra.2018.10.004.

[6] Kim, Y.J., Lee, S.G. & Trimi, S. (2021). Industrial linkage and spillover effects of the logistics service industry: an input–output analysis. Service Business 15(2), 231-252. DOI: 10.1007/s11628-021-00440-1.

[7] Ali, Y., Bilal, M. & Sabir, M. (2021). Impacts of transport strike on Pakistan economy: An inoperability Input-Output model (IIOM) approach. Research in Transportation Economics 90, 100860. DOI: 10.1016/j.retrec.2020.100860.

[8] Morrissey, K. & O'Donoghue, C. (2013). The role of the marine sector in the Irish national economy: an input–output analysis. Marine policy 37, 230-238. DOI: 10.1016/j.marpol.2012.05.004.

[9] Chang, Y.T., Shin, S.H. & Lee, P.T.W. (2014). Economic impact of port sectors on South African economy: An input–output analysis. Transport Policy 35, 333-340. DOI: 10.1016/j.tranpol.2014.04.006.

[10] Bryan, J., Munday, M., Pickernell, D. & Roberts, A. (2006). Assessing the economic significance of port activity: evidence from ABP Operations in industrial South Wales. Maritime Policy & Management 33(4), 371-386. DOI: 10.1080/03088830600895600.

[11] Wang, Y. & Wang, N. (2019). The role of the port industry in China's national economy: An input–output analysis. Transportation Policy 78, 1-7. DOI: 10.1016/j.tranpol.2019.03.007.

[12] Zhao, B., Wu, H. & Wang, N. (2022). Changing characteristics of the industrial correlation and economic contribution of air transport in China: An input–output analysis. Journal of Air Transport Management 104, 102275. DOI: 10.1016/j.jairtraman.2022.102275.

[13] Keček, D., Brlek, P. & Buntak, K. (2022). Economic effects of transport sectors on Croatian economy: an input–output approach. Economic Research-Ekonomska Istraživanja 35(1), 2023-2038. DOI: 10.1080/1331677X.2021.1931908.

[14] Bank of Korea. (2020). Economic Statistics System. Retrieved June 25. 2020, from http://ecos.bok.or.kr

[15] Leontief, W. (1936). Quantitative input-output relations in the economic system of the United States, Review of Economics and Statistics 18, 105-125. DOI:10.2307/1927837.

[16] Miller, R.E. & Blair, P.D. (2009). Input-Output Analysis: Foundations and Extension (2nd ed.). Cambridge, United Kingdom: Cambridge University Press.

[17] Hirschman, A.O. (1958). The Strategy of Economic Development. New York, USA: Yale University Press.

[18] Rasmussen, P.N. (1956). Studies in Inter-Sectoral Relations. Amsterdam, Netherlands: North-Holland.

[19] Giarratani, F. (1976). Application of an Interindustry Supply Model to Energy Issues, Environmental Planning A: Economy and Space 8(4), 447-454. DOI: 10.1068/a080447.

[20] Davis, H.C. & Salkin, E.L. (1984). Alternative approaches to the estimation of economic impacts resulting from supply constraints. The Annals of Regional Science 18(2), 25–34. DOI: 10.1007/BF01287372.