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An Input-Output Analysis of the Economic Role and Effects of the Mining Industry in South Korea

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Abstract: The mining industry (MI) has played a role in proving a stable supply of minerals for industrial production and human survival. The South Korean government is implementing various policies to promote the MI and needs quantitative information on the economic role and effects of the MI. Thus, this article aims to derive the information through an input-output (IO) analysis using the recently published 2015 IO table, subdividing the MI into four sectors, namely coal, crude petroleum and natural gas, metal ores, and non-metallic mineral mining, and treating the MI as exogenous rather than endogenous. To this end, three models are employed. First, the production-inducing effects, value-added creation effects, and wage-inducing effects of 1 dollar of production in the MI sector are analyzed using a demand-driven model. One dollar of production or investment in the sector causes 1.81 of production, 0.85 dollar of value-added, and 0.33 dollar of wage, respectively. Second, by applying a supply-driven model, it is found that one dollar of supply shortage in the MI causes 2.24 dollars of production failure throughout the national economy. Third, by utilizing a price-side model, it is discovered that a 10% increase in the price of output of the MI raises the overall price level by 0.025%.

Keywords: mining industry; economic effect; input-output analysis; demand-driven model; supply-driven model; price-side model

1. Introduction

The mining industry (MI) is the industrial activity of mining, extracting, and collecting basic non-metallic minerals, metal materials, and energy resources such as coal and natural gas [1–3]. The MI has played a role in supplying minerals that are indispensable for human survival as well as industrial production [4–6]. In addition, the development of micro and nano-analysis technologies has led to further in-depth research of minerals [7]. This is the case for South Korea. The steel industry, for instance, plays an important role as an essential input factor in the automobile, shipbuilding, and machinery industries, where South Korea has strengths. Moreover, the steel industry's exports account for about 5% of the country's total exports. The total price of output of the MI has grown at an average annual rate of 3.3% from 22.51 trillion dollars in 2000 to 35.66 trillion dollars in 2015 [8,9].

However, the MI output as a proportion of total output decreased from 0.190% in 2000 to 0.113% in 2015. Moreover, the MI's share of value-added in the total value-added shrank from 0.280% in 2000 to 0.145% in 2015. Mining is an industry in which exploration, development, and production cost a lot of money, with a long payback period and high risks [10,11]. Thus, it is difficult to start with private investment alone. Most domestic minerals are small and of low-quality and have low value-added, so it is impossible to meet domestic demand well. In addition, existing mines are also facing a deterioration in profitability due to the aging of manpower, the cost of environmental restoration, the increase of safety costs, and the deepening of mine development. Seventy-eight percent of the mines operating remain small, accounting for less than 850 million dollars of production [12]. The lack of mineral resources in the country has led to a significant decline in the MI [13].

In order to overcome the current difficulties facing the domestic MI and to promote the sustainable development and efficient utilization of mineral resources, the South Korean government has set major strategic goals in the Second Mining Basic Plan (2015–2024) [13]. The consumption of six major strategic minerals in South Korea—bituminous coal, uranium, iron, copper, zinc, and nickel—was ranked fourth to seventh in the world during the period 2013–2017 [14]. As the minerals as intermediates account for a large portion of the domestic industry, active efforts must be made to secure the self-development capacity of industrial raw materials and minerals [13]. Mining activities also contribute to revitalizing the local economy, including creating new jobs and value-added within the local community [3]. In summary, the government is implementing various policies to promote the MI and thus needs quantitative information on the economic role and effects of the MI.

In this context, this article strives to analyze the economic role and effects of the South Korean MI using an input-output (IO) analysis. IO analysis has been widely used for calculating the demand and supply chain impacts of producing goods and services in economic terms [15]. More specifically, for the purpose of performing the IO analysis, this study applies three models: a demand-driven model, a supply-driven model, and a price-side model.

First, by using a demand-driven model, the production-inducing effects, value-added creation effects, and wage-inducing effects of 1 dollar of production or investment in the MI on other sectors' production, value-added, and wages, respectively, can be derived. Second, by employing a supply-driven model, the effects of supply shortages in the MI on other sectors' production can be assessed. These are important in that minerals are an indispensable input to industrial production. Third, by adopting a price-side model, the effects of an increase in the price of MI output on other sectors' output prices can be evaluated. Since the price of minerals fluctuates widely according to international market conditions and is affected by changes in domestic taxation, it is necessary to predict the effect of price changes in the output of the MI in advance.

This article derives the information through an IO analysis using the recently published 2015 IO table, subdividing the MI into four sectors, namely coal, crude petroleum and natural gas, metal ores, and non-metallic mineral mining, and handling the MI as exogenous rather than endogenous. The rest of the article is structured as follows. Section 2 describes the outline and models of IO analysis methodology. Section 3 explains the data, presents and discusses the results, and reports the policy implications. The final section concludes the article.

2. Methodology

2.1. Method: IO Analysis

IO analysis, also called inter-industry analysis, is useful for uncovering the economic impacts of a particular sector within an economy. This is because the IO model is useful for analyzing and forecasting the overall economic impacts of a change in production or investment of a sector because it is characterized by a general equilibrium model that emphasizes the link between sales and purchase of inputs [16]. More specifically, the model could be utilized to identify the impacts of changes in final demand or output of a particular sector on the production, value-added, employment, wages, income, etc. of the economy as a whole, as well as in each sector. In particular, IO table, which is used as an input to the IO model, contains details of the flow of goods and services between industries, which can effectively reveal the processes of production, the use of goods and services, and the income generated from production in each sector [1].

IO analysis has been often applied to analyze the MI in the literature. San Cristóbal and Biezma [2] summarized the inter-industry linkages of mining in the 10 European Union countries through IO analysis. Sabiroglu and Bashirli [4] provided empirical research to identify the linkages between final demand and total output, final demand and total supply, and value-added ratios and prices in mining and quarrying of energy-producing materials using an IO framework for 25 sectors in the case of Azerbaijan. Lei et al. [5] derived the economic effects, inter-industry chain effects, and income distribution effects through an IO approach to socially and economically analyze the mineral development industry in China. Ivanova [17] identified the effects of backward and forward linkages and key sectors of mining in Queensland, Australia using IO analysis. Beylot and Villeneuve [6] assessed the national economic importance of metals, applying an IO approach to the case of copper in France. Xing et al. [18] evaluated the effect of local supply chain on regional economic impact of mining based on IO analysis. Kan et al. [19] tracked natural gas use from primary suppliers to final consumers via the links by producers in the world economy by applying the systems multi-regional input-output analysis.

In addition, IO analysis has been widely applied to analyze the economic effects of a particular sector within an economy. Kim et al. [20] investigated the effects of the eco-industrial park project on the whole economic system of South Korea, using IO analysis. Uehara et al. [21] developed a fully dynamic ecological-economic model by integrating IO with system dynamics. Lim and Yoo [22] inspected the impact of electricity price increase on industrial prices and general price levels in South Korea through IO analysis. Ju et al. [23] analyzed marginal costs of unsupplied electricity by using IO analysis. Li et al. [24] applied a combined IO and tourism satellite account analysis approach to comprehensively measure the significance and impact of the tourism sectors on economic benefit and environmental pollution. Chen et al. [25] evaluated the indirect economic losses of haze pollution based on IO analysis.

Thus, the method employed in this study, IO analysis, is consistent with previous case studies found in the literature. Furthermore, this study differs in three respects from the previous studies. First, the study not only analyzes various economic effects of the MI but also presents the results of examining four mining sub-sectors. Second, various economic effects focusing on the MI are analyzed through exogenous specification of the MI, which deals with the MI as an exogenous sector rather than as one of the endogenous sectors. Third, in the absence of a case study from South Korea, the policy implications for the MI are updated by conducting a case study of South Korea using the most recently published IO table. These points are thought to be interesting parts of this article.

The application of the hypothetical extraction method (HEM), which is described in Cella [26], Song et al. [27], and Dietzenbacher et al. [28], can be considered as an alternative to the exogenous specification method adopted in this research. The HEM considers the hypothetical situation in which a certain sector under investigation is no longer in operation. That is, the application of HEM enables us to calculate the outputs of the economy to meet the original final demands when the sector is extracted. The difference between these HEM outputs and the original outputs means a measure of the importance or the linkages of the extracted sector. Naturally, the former will be smaller than the latter. If the HEM is repeatedly applied for each sector, which of all sectors is more important can be detected. Therefore, the exogenous specification method used in this study analyzes the impact of a sector on other sectors by treating the sector exogenously, while the HEM analyzes the impact of a sector on other sectors by hypothetically extracting the sector. The two methods have one similarity in terms of looking into the impact on other sectors focusing on a particular sector, but they differ in the way they deal with the sector by adopting exogenous specification versus hypothetical extraction, respectively.

Although IO analysis is well established in the literature and its application procedures are substantially standardized, there are some limitations in the use of IO analysis [15,29,30]. First, IO analysis is based on the assumption that the input coefficient is fixed and constant, which is too restrictive and unrealistic because the input coefficient can change with changed conditions. Second, the Leontief production framework adopted in IO analysis ignores the possibility of substitution between production factors, and in general, substitution between production factors is possible. Third, IO analysis is based on the assumption that no joint production exists, that is, one industry should produce only one product, but in reality, one industry may produce a variety of products.

Fourth, IO analysis is based on the assumption that there is neither economies of scale nor diseconomies of scale, but in reality one of these two can exist. Fifth, since IO analysis employs a rigid model, it cannot reflect such phenomenon as increasing costs or bottlenecks.

2.2. Demand-Driven Model

Using the demand-driven model, which is the basic model of the IO analysis, this study investigates three economic effects: production-inducing effects, value-added creation effects, and wage-inducing effects. When there are n sectors in the economy, the basic equation of the demand-driven model is:

$$X = AX + Y \text{ or } X = (I - A)^{-1}Y \tag{1}$$

where X is a column vector whose element is X_i for $i = 1, \ldots, n$; A is an $\boldsymbol{N} \times \boldsymbol{N}$ input coefficient matrix whose element is a_{ij} defined as z_{ij}/X_j, where z_{ij} means intermediate demand running from the ith sector to the jth sector; Y is a column vector, final demand matrix, whose element is Y_i; and I is an $\boldsymbol{N} \times \boldsymbol{N}$ identity matrix. $(I - A)^{-1}$ is usually called a Leontief inverse matrix or input inverse matrix [31,32].

2.2.1. Production-Inducing Effects

Production-inducing effects refer to how much 1 dollar of production or investment in a particular sector increases production in other sectors. For convenience, the particular sector of interest is denoted as sector L. The process of deriving the production-inducing effects of sector L specifying sector L as exogenous is detailed on pages 326–327 of Miller and Blair's book [33]. Let X^e be an $(\boldsymbol{N} - 1) \times \boldsymbol{1}$ column vector remaining after deleting the Lth row from X, A^e be an $(\boldsymbol{N} - \boldsymbol{1}) \times (\boldsymbol{N} - \boldsymbol{1})$ matrix that remains after removing the Lth row and column from A, A_L^e be an $(\boldsymbol{N} - \boldsymbol{1}) \times \boldsymbol{1}$ column vector that is left after eliminating the Lth element from sector L-related column vector of A, Y^e be an $(\boldsymbol{N} - \boldsymbol{1}) \times \boldsymbol{1}$ column vector remaining after deleting the Lth row from Y, and I^e be an $(\boldsymbol{N} - \boldsymbol{1}) \times (\boldsymbol{N} - \boldsymbol{1})$ identity matrix. Manipulating Equation (1) to treat sector L as an exogenous sector gives us [33,34]:

$$X^e = A^e X^e + A_L^e X_L + Y^e \tag{2}$$

$$(I^e - A^e)X^e = A_L^e X_L + Y^e \tag{3}$$

$$X^e = (I^e - A^e)^{-1}\left(A_L^e X_L + Y^e\right) \tag{4}$$

For variability model, rewriting Equation (4) produces:

$$\Delta X^e = (I^e - A^e)^{-1}\left(A_L^e \Delta X_L + \Delta Y^e\right) \tag{5}$$

Assuming $\Delta Y^e = 0$, the following equation can be obtained.

$$\Delta X^e = (I^e - A^e)^{-1}\left(A_L^e \Delta X_L\right) \tag{6}$$

where ΔX^e is an $(\boldsymbol{N} - \boldsymbol{1}) \times \boldsymbol{1}$ matrix showing changes in output of other sectors except for sector L, I^e is an $(\boldsymbol{N} - \boldsymbol{1}) \times (\boldsymbol{N} - \boldsymbol{1})$ identity matrix, and A^e is an $(\boldsymbol{N} - \boldsymbol{1}) \times (\boldsymbol{N} - \boldsymbol{1})$ matrix that remains after removing sector L-related row and column from A. A_L^e is an $(\boldsymbol{N} - \boldsymbol{1}) \times \boldsymbol{1}$ column vector that is left after eliminating the Lth element from sector L-related column vector of A, and ΔX_L denotes the change in output of sector L.

2.2.2. Value-Added Creation Effects

The value-added creation effects indicate how much 1 dollar of production or investment in sector L leads to the creation of value-added in other sectors. Let $\hat{A^v}$ be a diagonal matrix of value-added coefficients, which are defined as $a_j^v = V_j/X_j$ for $j = 1, \ldots, n$, where V_j means the value-added of the jth sector. Manipulating Equation (6) and using $\hat{A^v}$ to treat the sector as exogenous produces [35]:

$$\Delta V^e = \hat{A^v}^e (I^e - A^e)^{-1} \left(A_L^e \Delta X_L \right) \tag{7}$$

where ΔV^e is an $(\boldsymbol{N-1}) \times \boldsymbol{1}$ column vector signifying changes in the value-added of other sectors except for sector L, and $\hat{A^v}^e$ represents the $(\boldsymbol{N-1}) \times (\boldsymbol{N-1})$ matrix that remains after excluding sector L-related row and column from $\hat{A^v}$.

2.2.3. Wage-Inducing Effects

Wage-inducing effects relate to how much 1 dollar of production or investment in sector L increases wages in other sectors. Let $\hat{A^w}$ be the diagonal matrix of wage coefficients, which are defined as $a_j^w = W_j/X_j$ where W_j is the wage in the jth sector. Manipulating Equation (6) and $\hat{A^w}$ to treat sector L as an exogenous sector produces:

$$\Delta W^e = \hat{A^w}^e (I^e - A^e)^{-1} \left(A_L^e \Delta X_L \right) \tag{8}$$

where ΔW^e is the $(\boldsymbol{N-1}) \times \boldsymbol{1}$ matrix, meaning changes in wages in other sectors except for sector L, and $\hat{A^w}^e$ indicates the $(\boldsymbol{N-1}) \times (\boldsymbol{N-1})$ matrix left after excluding sector L-related row and column from $\hat{A^w}$.

2.3. Inter-Industry Linkage Effect Analysis

In general, the linkage effects are classified into backward and forward linkage effects. The backward linkage effects are represented as the power of dispersion, which is the average of N elements in column j of the Leontief invers matrix divided by the average of all N^2 elements. Similarly, the forward linkage effects are expressed as the sensitivity of dispersion, which is the average of N elements in row i of the Leontief invers matrix divided by all N^2 elements. If in some industries the values of both the power of dispersion and sensitivity of dispersion are greater than one for both forward and backward linkage effects, these industries play a significant role in national economic development by supporting (forward linkage effects) as well as boosting (backward linkage effects) other industries.

2.4. Supply-Driven Model

The supply-driven model has been developed to deal with the direct and indirect effects of natural resources supply restrictions [36]. The basic equation of the supply-driven model is:

$$X' = X'R + V \text{ or } X' = V'(I - R)^{-1} \tag{9}$$

where the prime $(')$ denotes the transpose of the given matrix, X' is a $\boldsymbol{1} \times \boldsymbol{N}$ input matrix, R is an $\boldsymbol{N} \times \boldsymbol{N}$ output coefficient matrix whose elements are q_{ij} defined as $\partial X_j / \partial V_i$, V' is a $\boldsymbol{1} \times \boldsymbol{N}$ value-added matrix, and $(I - R)^{-1}$ is usually called an output inverse matrix [37].

Using the supply-driven model, the supply shortage effects of a sector can be obtained [38]. Supply shortage effects mean how much a unit shortage of supply in a particular sector affects the output of other sectors. Manipulating Equation (9) to treat sector L as an exogenous sector gives us:

$$\Delta X^{e\prime} = R_L^e \Delta X_L (I^e - R^e)^{-1} \tag{10}$$

where $\Delta X^{e\prime}$ is an $\mathbf{1} \times (\boldsymbol{N}-\mathbf{1})$ matrix showing changes in output of other sectors except for sector L, R^e is an $(\boldsymbol{N}-\mathbf{1}) \times (\boldsymbol{N}-\mathbf{1})$ matrix that remains after removing sector L-related row and column from R. R^e_L is an $\mathbf{1} \times (\boldsymbol{N}-\mathbf{1})$ row vector that is left after eliminating the Lth element from the Lth row vector of R, and ΔX_L denotes the change in output of sector L.

Similarly, Santos and Haimes [39] developed an inoperability IO model for dealing with how terrorism-induced perturbations can propagate due to interconnectedness. Applying the inoperability IO model to interdependent infrastructure sectors such as airport and seaport can derive the economic loss of each affected sector in terms of demand reduction. For example, the economic impact of airline demand perturbations caused by terrorism on industry sectors can be analyzed. The inoperability IO model is similar to the supply-side model given in Ghosh [40] and Oosterhaven [41], but is basically the demand-side model. In other words, the inoperability IO model and the supply-side model identify the sector of interest as an output from other sectors and an input to other sectors, respectively.

2.5. Price-Side Model

The cost structure due to the production activities of each sector also can be understood from the IO table. Thus, if the price-side model or the Leontief price model is utilized, the impacts of changes in the prices of a sector on the price levels of other sectors can be assessed. To deal with the price-side model, we should use a physical unit-based IO table rather than the monetary unit-based IO table explained so far. In addition, the effect of the percentage changes rather than the amount of the change in price for a sector on the price levels of other sectors can be analyzed using a price-side model. The price-side model that focuses on the MI and specifies the MI as exogenous is expressed as [15,22]:

$$\Delta\overline{P_e} = (I - A^{e\prime})A^e_H{\prime}\Delta\overline{P_H} \tag{11}$$

where $\Delta\overline{P_e}$ denotes the $(\boldsymbol{N}-\mathbf{1}) \times \mathbf{1}$ matrix whose elements are percentage changes in the prices for other sectors, $A^{e\prime}$ is the $(\boldsymbol{N}-\mathbf{1}) \times (\boldsymbol{N}-\mathbf{1})$ transpose matrix of A^e, $A^e_H{\prime}$ is the $(\boldsymbol{N}-\mathbf{1}) \times \mathbf{1}$ column vector left after getting rid of the MI row from the MI-related column vector of $A\prime$, and $\Delta\overline{P_H}$ signifies the percentage change in price for the MI.

3. Results and Discussion

3.1. Data

This paper utilizes the most recently published IO table for 2015 [42]. The IO table used in this study is downloadable from the Bank of Korea [9] or available from the corresponding author upon request. There are about 400 sectors in the South Korean IO table. Thus, for IO analysis, sectors must be classified properly, not arbitrarily. In this regard, the Bank of Korea provides four classification methods: large-scale, medium-scale, small-scale, and basic scale classifications. This study aims to perform IO analysis using a large-scale 32-sector classification method and a 33-sector IO table that additionally includes the MI. The 33-sector IO table is basically made from a basic-scale 384-sector IO table.

In the basic-scale IO table, the MI is subdivided into four subsectors: coal, crude petroleum and natural gas, metal ores, non-metallic mineral mining. The sector classification adopted in this study including 32 large-scale sectors and four MI subsectors is shown in Table 1. Therefore, a total of five analysis results will be presented, including one for the entire MI and one for each of the four subsectors. Furthermore, as explained above, all results will be derived from analysis that specifies the MI as an exogenous sector, not an endogenous one.

Table 1. Sector classification adopted in this study.

Number	Sectors
1.	Agricultural, forest, and fishery goods
2.	Food, beverages and tobacco products
3.	Textile and leather products
4.	Wood and paper products, printing and reproduction of recorded media
5.	Petroleum and coal products
6.	Chemical products
7.	Non-metallic mineral products
8.	Basic metal products
9.	Fabricated metal products, except machinery and furniture
10.	Computing machinery, electronic equipment and optical instruments
11.	Electrical equipment
12.	Machinery and equipment
13.	Transport equipment
14.	Other manufactured products
15.	Manufacturing services and repair services of industrial equipment
16.	Electricity, gas, and steam supply
17.	Water supply, sewage and waste treatment and disposal services
18.	Construction
19.	Wholesale and retail trade and commodity brokerage services
20.	Transportation
21.	Food services and accommodation
22.	Communications and broadcasting
23.	Finance and insurance
24.	Real estate services
25.	Professional, scientific, and technical services
26.	Business support services
27.	Public administration, defense, and social security services
28.	Education services
29.	Health and social care services
30.	Art, sports, and leisure services
31.	Other services
32.	Others
33.	Coal
34.	Crude petroleum and natural gas
35.	Metal ores
36.	Non-metallic mineral mining

This research carries out an analysis dealing with each of the four types of MI as an exogenous sector. In this regard, two points need to be discussed. First, is this exogeneous specification necessary? In examining the economic effects of MI, the effect of the change in output of the MI sector cannot be analyzed, but only the effect of the change in final demand for the MI sector can be analyzed. In other words, the standard IO model can look into the effects of changes in final demand, such as changes in consumer tastes and/or government purchases easily, but the effects of changes in production or investment in the MI sector are difficult to analyze. Therefore, the reason for adopting exogeneous specification in this study is to facilitate the analysis of the effects of the MI sector on other sectors by making the MI sector, which was originally the endogenous sector, as the exogeneous sector. Whether to use a standard model or an exogenous specification model depends not on which is right or wrong, but on the purpose of the analysis [15].

Second, may any information loss occur in the course of the exogeneous specification? The exogeneous specification reduces the number of sectors. This reduction causes some elements in the input coefficient matrix or the output coefficient matrix to be discarded, and could lead to the disappearance of information that could be useful. The focus of this study is to obtain information on the impacts of an increase in production of the MI sector on other sectors, but without this reduction, a contradiction that an increase in production of the MI sector would have to increase production of the MI sector again happens. In order to prevent this contradiction in advance, the exogeneous specification is inevitably required. Therefore, the disappearance of some information in the course of exogeneous specification indicates a removal of elements that may cause contradictions rather than information loss.

The IO table used in this study was made in Korean won. Nevertheless, the various economic effects derived from this study are caused by one monetary unit of production and are not affected by the unit of money. For example, if the production-inducing effect is 1.5, this means that the production or investment of KRW 1.0 (USD 1.0) in the MI sector induces the production of the entire national economy by KRW 1.5 (USD 1.5). Therefore, when the results of economic effects are explained below, the dollar, the most familiar unit of currency, will be used for convenience.

3.2. Results of Demand-Driven Model

The results of analyzing the production-inducing effects of the MI using the demand-side model are shown in Table 2. One dollar of production or investment in the coal, crude petroleum and natural gas, metal ores, and non-metallic mineral mining sectors, respectively, induces 0.990, 1.284, 1.062, and 0.784 dollars of production in other sectors. The production-inducing effect of 1 dollar of production or investment in the entire MI on other sectors is 0.813 dollars.

The results of assessing the value-added creation effects of the MI on other sectors are presented in Table 3. One dollar of production or investment in the coal, crude petroleum and natural gas, metal ores, and non-metallic mineral mining sectors, respectively, generates 0.404, 0.546, 0.413, and 0.316 dollars of value-added for other sectors. It also produces 0.437, 0.306, 0.404, and 0.541 dollars of value-added, respectively. Therefore, it creates 0.840, 0.851, 0.817, and 0.857 dollars of value-added in the national economy, respectively

The value-added creation effect of 1 dollar of production or investment in the entire MI on other sectors is 0.329 dollars. One dollar of production or investment in the entire MI induces 0.526 dollars of value-added in the MI sector. Therefore, the value-added creation effect of 1 dollar of production or investment in the entire MI on all sectors is 0.855 dollars.

The results of computing the wage-inducing effect of the MI are summarized in Table 4. One dollar of production or investment in the coal, crude petroleum and natural gas, metal ores, and non-metallic mineral mining sectors, respectively, produces 0.205, 0.294, 0.192, and 0.153 dollars of wages in other sectors. It also leads to 0.295, 0.063, 0.231, and 0.155 dollars of self-induced wages, respectively. Thus, it induces 0.500, 0.357, 0.423, and 0.308 dollars of wages in the national economy, respectively. The wage-inducing effect of 1 dollar of production or investment in the entire MI on other sectors is 0.160 dollars. One dollar of production or investment in the entire MI leads to a 0.166-dollar increase in wage in the MI sector. Therefore, the wage-inducing effect of 1 dollar of production or investment in the entire MI on all sectors is 0.326 dollars.

3.3. Results of Supply-Driven Model

The results of estimating the supply shortage effects of the MI by employing the supply-side model in Equation (10) are given in Table 5. Each value indicates how large the production loss incurred in other sectors would be in the event of 1 dollar of supply failure in the MI. The effects of supply failure in each subsector of the MI on the national economy as a whole can be obtained by simply summing up the supply shortage effects for each sector. The supply shortage effects of the coal, crude petroleum and natural gas, metal ores, non-metallic mineral mining sectors and the entire MI are calculated to be 2.035, 2.461, 1.815, 2.263, and 2.241, respectively. Interestingly, all of them are worth more than one. In other words, 1 dollar of supply failure in the MI would result in production disruptions exceeding one in the national economy. This suggests that the products of the MI have been used as an important input for the production of other sectors.

Table 2. Production-inducing effects of mining industry.

Number	Sectors	Coal		Crude Petroleum and Natural Gas		Metal Ores		Non-Metallic Mineral Mining		Entire Mining Industry	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
1.	Agricultural, forest, and fishery goods	0.01119	21	0.00804	22	0.00912	23	0.00842	22	0.00864	22
2.	Food, beverages and tobacco products	0.01480	19	0.01631	17	0.00004	35	0.00003	34	0.01544	16
3.	Textile and leather products	0.01113	22	0.00736	23	0.01499	20	0.01549	15	0.00859	23
4.	Wood and paper products, printing and reproduction of recorded media	0.02097	15	0.01712	16	0.01100	22	0.00836	23	0.01180	19
5.	Petroleum and coal products	0.01928	17	0.01499	18	0.01483	21	0.01083	19	0.03241	10
6.	Chemical products	0.06506	4	0.04139	9	0.04395	7	0.03378	8	0.05978	3
7.	Non-metallic mineral products	0.00319	29	0.00591	26	0.10662	2	0.05900	2	0.00468	27
8.	Basic metal products	0.02919	11	0.05598	5	0.00358	28	0.00481	27	0.01560	15
9.	Fabricated metal products, except machinery and furniture	0.04934	7	0.11203	3	0.03514	12	0.01320	16	0.02729	13
10.	Computing machinery, electronic equipment and optical instruments	0.01594	18	0.02383	14	0.05907	5	0.02297	13	0.01065	20
11.	Electrical equipment	0.02668	12	0.01489	19	0.01617	17	0.00980	21	0.01310	17
12.	Machinery and equipment	0.02079	16	0.12641	2	0.01543	19	0.01183	18	0.03397	9
13.	Transport equipment	0.04100	8	0.01260	20	0.07301	4	0.03246	9	0.03126	11
14.	Other manufactured products	0.00259	31	0.00366	28	0.04090	10	0.03069	10	0.00211	31
15.	Manufacturing services and repair services of industrial equipment	0.10884	3	0.01924	15	0.00196	31	0.00204	30	0.03559	8
16.	Electricity, gas, and steam supply	0.05229	6	0.03664	10	0.02802	14	0.02966	12	0.04204	6
17.	Water supply, sewage and waste treatment and disposal services	0.00449	27	0.00710	24	0.04258	8	0.04127	6	0.00574	25
18.	Construction	0.00307	30	0.01094	21	0.00642	25	0.00582	25	0.00485	26
19.	Wholesale and retail trade and commodity brokerage services	0.04066	9	0.05507	6	0.00688	24	0.00484	26	0.03668	7
20.	Transportation	0.11772	2	0.04848	8	0.05321	6	0.03567	7	0.15434	1
21.	Food services and accommodation	0.02629	13	0.03136	11	0.19289	1	0.15938	1	0.02987	12
22.	Communications and broadcasting	0.03021	10	0.06152	4	0.03086	13	0.03015	11	0.02218	14
23.	Finance and insurance	0.05328	5	0.05227	7	0.02316	15	0.02059	14	0.05648	4
24.	Real estate services	0.01418	20	0.02434	13	0.09652	3	0.05625	3	0.01258	18
25.	Professional, scientific, and technical services	0.14926	1	0.42877	1	0.01969	16	0.01207	17	0.06276	2
26.	Business support services	0.02238	14	0.02827	12	0.03969	11	0.04740	5	0.04689	5

Table 2. *Cont.*

Number	Sectors	Coal		Crude Petroleum and Natural Gas		Metal Ores		Non-Metallic Mineral Mining		Entire Mining Industry	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
27.	Public administration, defense, and social security services	0.00582	25	0.00099	32	0.04157	9	0.04957	4	0.00224	30
28.	Education services	0.00135	32	0.00111	31	0.00351	29	0.00193	31	0.00075	32
29.	Health and social care services	0.00507	26	0.00324	29	0.00074	32	0.00069	32	0.00437	28
30.	Art, sports, and leisure services	0.00438	28	0.00450	27	0.00285	30	0.00436	28	0.00642	24
31.	Other services	0.00906	24	0.00668	25	0.00506	27	0.00667	24	0.00982	21
32.	Others	0.01041	23	0.00177	30	0.01577	18	0.00987	20	0.00398	29
33.	Coal	-	-	0.00009	34	0.00624	26	0.00343	29	-	-
34.	Crude petroleum and natural gas	0.00004	34	-	-	0.00012	34	0.00057	33	-	-
35.	Metal ores	0.00001	35	0.00002	35	-	-	0.00000	35	-	-
36.	Non-metallic mineral mining	0.00040	33	0.00063	33	0.00047	33	-	-	-	-
	Sum (A)	0.99035		1.28357		1.06206		0.78390		0.81289	
	Self-induced effect (B)	1.00000		1.00000		1.00000		1.00000		1.00000	
	Total (A + B)	1.99035		2.28357		2.06206		1.78390		1.81289	

Table 3. Value-added creation effects of mining industry.

Number	Sectors	Coal		Crude Petroleum and Natural gas		Metal Ores		Non-Metallic Mineral Mining		Entire Mining Industry	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
1.	Agricultural, forest, and fishery goods	0.00606	16	0.00436	18	0.00494	19	0.00456	16	0.00468	16
2.	Food, beverages and tobacco products	0.00257	24	0.00283	21	0.00260	25	0.00269	23	0.00268	24
3.	Textile and leather products	0.00197	27	0.00130	28	0.00195	27	0.00148	28	0.00152	28
4.	Wood and paper products, printing and reproduction of recorded media	0.00627	15	0.00512	16	0.00443	21	0.00324	20	0.00353	19
5.	Petroleum and coal products	0.00280	22	0.00217	24	0.00638	17	0.00490	15	0.00470	15
6.	Chemical products	0.01838	7	0.01170	11	0.03013	3	0.01667	6	0.01689	7
7.	Non-metallic mineral products	0.00098	29	0.00180	26	0.00109	29	0.00147	29	0.00143	29
8.	Basic metal products	0.00582	18	0.01116	12	0.00701	14	0.00263	24	0.00311	22
9.	Fabricated metal products, except machinery and furniture	0.01751	8	0.03975	2	0.02096	7	0.00815	13	0.00968	11

Table 3. *Cont.*

Number	Sectors	Coal		Crude Petroleum and Natural gas		Metal Ores		Non-Metallic Mineral Mining		Entire Mining Industry	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
10.	Computing machinery, electronic equipment and optical instruments	0.00522	19	0.00781	15	0.00530	18	0.00321	21	0.00349	20
11.	Electrical equipment	0.00799	13	0.00446	17	0.00462	20	0.00354	18	0.00392	18
12.	Machinery and equipment	0.00603	17	0.03665	3	0.02117	6	0.00941	10	0.00985	10
13.	Transport equipment	0.00702	14	0.00216	25	0.00701	15	0.00526	14	0.00535	14
14.	Other manufactured products	0.00065	31	0.00092	29	0.00050	31	0.00051	30	0.00053	30
15.	Manufacturing services and repair services of industrial equipment	0.05320	2	0.00940	14	0.01369	11	0.01450	8	0.01739	6
16.	Electricity, gas, and steam supply	0.01846	6	0.01293	10	0.01503	9	0.01457	7	0.01484	8
17.	Water supply, sewage and waste treatment and disposal services	0.00240	25	0.00379	20	0.00343	22	0.00311	22	0.00307	23
18.	Construction	0.00117	28	0.00415	19	0.00261	24	0.00184	26	0.00184	26
19.	Wholesale and retail trade and commodity brokerage services	0.02152	5	0.02914	6	0.02816	5	0.01888	5	0.01941	5
20.	Transportation	0.04739	3	0.01952	8	0.07765	1	0.06416	1	0.06214	1
21.	Food services and accommodation	0.00813	12	0.00970	13	0.00955	13	0.00933	11	0.00924	13
22.	Communications and broadcasting	0.01590	9	0.03237	4	0.01219	12	0.01084	9	0.01167	9
23.	Finance and insurance	0.03045	4	0.02987	5	0.05516	2	0.03214	3	0.03228	3
24.	Real estate services	0.01048	11	0.01799	9	0.01455	10	0.00892	12	0.00929	12
25.	Professional, scientific, and technical services	0.07539	1	0.21656	1	0.02005	8	0.02394	4	0.03170	4
26.	Business support services	0.01549	10	0.01956	7	0.02877	4	0.03430	2	0.03245	2
27.	Public administration, defense, and social security services	0.00450	20	0.00077	31	0.00271	23	0.00150	27	0.00173	27
28.	Education services	0.00093	30	0.00077	30	0.00051	30	0.00047	31	0.00052	31
29.	Health and social care services	0.00267	23	0.00171	27	0.00150	28	0.00230	25	0.00230	25
30.	Art, sports, and leisure services	0.00218	26	0.00223	23	0.00251	26	0.00331	19	0.00319	21
31.	Other services	0.00381	21	0.00281	22	0.00663	16	0.00415	17	0.00413	17
32.	Others	0.00000	35	0.00000	35	0.00000	35	0.00000	35	0.00000	32
33.	Coal	-	-	0.00004	33	0.00005	33	0.00025	32	-	-
34.	Crude petroleum and natural gas	0.00001	33	-	-	0.00001	34	0.00001	33	-	-
35.	Metal ores	0.00000	34	0.00001	34	-	-	0.00000	34	-	-
36.	Non-metallic mineral mining	0.00022	32	0.00034	32	0.00026	32	-	-	-	-
	Sum (A)	0.40355		0.54587		0.41309		0.31624		0.32856	
	Self-induced effect (B)	0.43677		0.30562		0.40397		0.54098		0.52620	
	Total (A + B)	0.84033		0.85149		0.81706		0.85721		0.85476	

Table 4. Wage-inducing effects of mining industry.

Number	Sectors	Coal		Crude Petroleum and Natural gas		Metal Ores		Non-Metallic Mineral Mining		Entire Mining Industry	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
1.	Agricultural, forest, and fishery goods	0.00096	26	0.00069	27	0.00078	27	0.00072	27	0.00074	27
2.	Food, beverages and tobacco products	0.00132	21	0.00146	21	0.00134	23	0.00139	19	0.00138	19
3.	Textile and leather products	0.00106	22	0.00070	25	0.00105	26	0.00080	26	0.00082	26
4.	Wood and paper products, printing and reproduction of recorded media	0.00297	13	0.00243	14	0.00210	17	0.00154	16	0.00167	16
5.	Petroleum and coal products	0.00030	31	0.00023	31	0.00067	28	0.00052	29	0.00050	29
6.	Chemical products	0.00573	9	0.00365	12	0.00939	8	0.00520	8	0.00527	8
7.	Non-metallic mineral products	0.00038	30	0.00070	26	0.00042	30	0.00057	28	0.00055	28
8.	Basic metal products	0.00208	18	0.00399	11	0.00250	14	0.00094	22	0.00111	22
9.	Fabricated metal products, except machinery and furniture	0.00814	7	0.01847	3	0.00974	7	0.00379	11	0.00450	11
10.	Computing machinery, electronic equipment and optical instruments	0.00145	20	0.00216	15	0.00147	21	0.00089	24	0.00097	24
11.	Electrical equipment	0.00279	16	0.00156	20	0.00161	19	0.00124	21	0.00137	20
12.	Machinery and equipment	0.00317	12	0.01928	2	0.01114	6	0.00495	9	0.00518	9
13.	Transport equipment	0.00391	11	0.00120	23	0.00390	13	0.00293	12	0.00298	12
14.	Other manufactured products	0.00040	29	0.00056	29	0.00030	31	0.00031	31	0.00032	31
15.	Manufacturing services and repair services of industrial equipment	0.03364	2	0.00595	10	0.00866	9	0.00917	6	0.01100	5
16.	Electricity, gas, and steam supply	0.00291	14	0.00204	16	0.00237	15	0.00230	14	0.00234	14
17.	Water supply, sewage and waste treatment and disposal services	0.00104	23	0.00165	19	0.00149	20	0.00135	20	0.00134	21
18.	Construction	0.00096	25	0.00344	13	0.00216	16	0.00152	17	0.00152	17
19.	Wholesale and retail trade and commodity brokerage services	0.01173	5	0.01589	4	0.01536	4	0.01029	5	0.01059	6
20.	Transportation	0.02423	3	0.00998	8	0.03969	1	0.03280	1	0.03176	1
21.	Food services and accommodation	0.00527	10	0.00628	9	0.00618	10	0.00604	7	0.00598	7
22.	Communications and broadcasting	0.00614	8	0.01250	6	0.00471	11	0.00419	10	0.00451	10
23.	Finance and insurance	0.01327	4	0.01302	5	0.02404	2	0.01401	4	0.01407	4
24.	Real estate services	0.00102	24	0.00176	18	0.00142	22	0.00087	25	0.00091	25
25.	Professional, scientific, and technical services	0.05124	1	0.14720	1	0.01363	5	0.01627	3	0.02155	2
26.	Business support services	0.00935	6	0.01181	7	0.01736	3	0.02071	2	0.01959	3
27.	Public administration, defense, and social security services	0.00281	15	0.00048	30	0.00169	18	0.00093	23	0.00108	23

Table 4. *Cont.*

Number	Sectors	Coal		Crude Petroleum and Natural gas		Metal Ores		Non-Metallic Mineral Mining		Entire Mining Industry	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
28.	Education services	0.00080	28	0.00066	28	0.00044	29	0.00040	30	0.00044	30
29.	Health and social care services	0.00198	19	0.00126	22	0.00111	24	0.00170	15	0.00170	15
30.	Art, sports, and leisure services	0.00095	27	0.00098	24	0.00110	25	0.00145	18	0.00140	18
31.	Other services	0.00263	17	0.00194	17	0.00458	12	0.00287	13	0.00285	13
32.	Others	0.00000	35	0.00000	35	0.00000	35	0.00000	35	0.00000	32
33.	Coal	-	-	0.00003	33	0.00003	33	0.00017	32	-	-
34.	Crude petroleum and natural gas	0.00000	33	-	-	0.00000	34	0.00000	33	-	-
35.	Metal ores	0.00000	33	-	-	0.00000	34	0.00000	33	-	-
36.	Non-metallic mineral mining	0.00006	32	0.00010	32	0.00007	32	-	-	-	-
	Sum (A)	0.20470		0.29404		0.19254		0.15281		0.15999	
	Self-induced effect (B)	0.29459		0.06282		0.23095		0.15546		0.16560	
	Total (A + B)	0.49929		0.35686		0.42348		0.30827		0.32559	

Table 5. Supply shortage effects of mining industry.

Number	Sectors	Coal		Crude Petroleum and Natural gas		Metal Ores		Non-Metallic Mineral Mining		Entire Mining Industry	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
1.	Agricultural, forest, and fishery goods	0.01253	25	0.01758	28	0.00261	29	0.00672	26	0.00733	27
2.	Food, beverages and tobacco products	0.02262	19	0.03963	15	0.00734	15	0.03151	10	0.03062	11
3.	Textile and leather products	0.01535	21	0.02805	21	0.00509	19	0.01001	18	0.01071	21
4.	Wood and paper products, printing and reproduction of recorded media	0.01071	27	0.02795	22	0.00264	28	0.00636	29	0.00707	28
5.	Petroleum and coal products	0.44679	1	0.03390	17	0.00483	20	0.00670	27	0.04172	8
6.	Chemical products	0.15592	3	0.12415	2	0.02867	8	0.11744	5	0.11927	5
7.	Non-metallic mineral products	0.04594	10	0.03065	19	0.01327	10	0.89317	1	0.79676	1
8.	Basic metal products	0.39336	2	0.11481	3	0.93281	1	0.12125	4	0.15393	3
9.	Fabricated metal products, except machinery and furniture	0.07416	7	0.05496	9	0.14214	3	0.04168	7	0.04590	7
10.	Computing machinery, electronic equipment and optical instruments	0.04566	11	0.08837	6	0.04458	7	0.13666	3	0.12720	4
11.	Electrical equipment	0.04347	12	0.03517	16	0.07335	6	0.03845	8	0.03926	10
12.	Machinery and equipment	0.06444	9	0.04968	12	0.11172	5	0.03641	9	0.03993	9

Table 5. *Cont.*

Number	Sectors	Coal		Crude Petroleum and Natural gas		Metal Ores		Non-Metallic Mineral Mining		Entire Mining Industry	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
13.	Transport equipment	0.12900	4	0.10301	5	0.21220	2	0.09513	6	0.09956	6
14.	Other manufactured products	0.00792	29	0.00853	31	0.01043	12	0.00813	20	0.00815	24
15.	Manufacturing services and repair services of industrial equipment	0.02501	18	0.02193	24	0.01579	9	0.01548	14	0.01635	17
16.	Electricity, gas, and steam supply	0.03444	15	1.06440	1	0.00390	23	0.00281	31	0.02634	12
17.	Water supply, sewage and waste treatment and disposal services	0.11421	5	0.01360	29	0.00191	31	0.00714	22	0.01558	19
18.	Construction	0.09738	6	0.07246	8	0.12891	4	0.53439	2	0.48498	2
19.	Wholesale and retail trade and commodity brokerage services	0.03540	14	0.07589	7	0.00716	16	0.01450	15	0.01724	16
20.	Transportation	0.06909	8	0.03996	14	0.00992	13	0.01069	17	0.01584	18
21.	Food services and accommodation	0.02741	16	0.05024	11	0.00629	17	0.02296	11	0.02360	13
22.	Communications and broadcasting	0.01172	26	0.03309	18	0.00415	22	0.00701	23	0.00785	26
23.	Finance and insurance	0.00914	28	0.02595	23	0.00266	27	0.00520	30	0.00588	31
24.	Real estate services	0.01321	23	0.02937	20	0.00624	18	0.02225	12	0.02144	15
25.	Professional, scientific, and technical services	0.04079	13	0.10472	4	0.01145	11	0.01877	13	0.02209	14
26.	Business support services	0.00777	30	0.01190	30	0.00252	30	0.00695	25	0.00704	30
27.	Public administration, defense, and social security services	0.01273	24	0.02061	25	0.00282	25	0.00792	21	0.00847	23
28.	Education services	0.01562	20	0.05106	10	0.00337	24	0.00655	28	0.00810	25
29.	Health and social care services	0.02561	17	0.04732	13	0.00462	21	0.01386	16	0.01530	20
30.	Art, sports, and leisure services	0.00612	32	0.01882	27	0.00277	26	0.00696	24	0.00707	29
31.	Other services	0.01394	22	0.01963	26	0.00788	14	0.00900	19	0.00958	22
32.	Others	0.00106	33	0.00213	32	0.00039	32	0.00076	32	0.00080	32
33.	Coal	-	-	0.00017	34	0.00006	34	0.00004	33	-	-
34.	Crude petroleum and natural gas	0.00002	34	-	-	0.00003	35	0.00001	34	-	-
35.	Metal ores	0.00002	35	0.00003	35	-	-	0.00001	35	-	-
36.	Non-metallic mineral mining	0.00651	31	0.00156	33	0.00031	33	-	-	-	-
	Total	2.03510		2.46127		1.81483		2.26286		2.24098	

3.4. Results of the Price-Side Model

Based on the price-side model, the effects of a 10% increase in the price of the products of the MI on the price levels of other sectors are analyzed. The results are shown in Table 6. The price-pervasive effects are expressed in percentage units. For example, the price-pervasive effect of the entire MI for the agricultural, forest, and fishery goods sector is reported as 0.0005 in Table 5. This implies that a 10% increase (decrease) in the price of the products of the MI raises (lowers) the price level of the agricultural, forest, and fishery goods sector by 0.0005%.

In order to find the impact of price changes in the MI on the national economy as a whole, the impact on each sector should not be simply summed up or averaged. When the percentage values are simply summed up, the total effect is overvalued. Simple averaging of the percentage values does not reflect the effect of differences in the output of the individual sectors. Therefore, the price-pervasive effect on the economy as a whole should be calculated by weighted averaging of the price-pervasive effect of each sector on the output of each sector. The weighted averages of the price-pervasive effects of a 10% increase in the price level of the coal, crude petroleum and natural gas, metal ores, and non-mineral mining sectors and the entire MI sector on the national economy are estimated to be 0.0018, 0.0006, 0.0003, 0.0227, and 0.025%, respectively. The price effect seems to be quite small. When looking at the cost structure of each industrial sector, expenditure on the MI sector accounts for a low percentage of total cost. Therefore, even if the price of minerals rises or falls, the effect of this on overall price level will be small.

3.5. The Sectoral Linkage Effects

Table 7 shows two linkage effects indices of mining industry sectors including the entire mining industry sector. Two important and interesting observations can be found. The first is that the sensitivity of dispersion of the mining industry is all less than 1, which means that the forward linkage effect of the mining industry is smaller than that of the entire industry. In other words, the mining industry is not influenced much by business fluctuations and is a vital input to national existence. The second is that the power of the dispersion of the mining industry is greater than or closer to 1. This implies that the mining industry has bigger impacts in terms of investment expenditures on the national economy than other business. That is, the mining industry has a relatively strong capacity for pulling in other industries. It therefore has a low forward linkage effect, a high backward linkage effect and can be classified into final manufacture.

Table 6. Price-pervasive effects of 10% increase in the price for the output of mining industry.

Number	Sectors	Coal		Crude Petroleum and Natural Gas		Metal Ores		Non-Metallic Mineral Mining		Entire Mining Industry	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
1.	Agricultural, forest, and fishery goods	0.00007	25	0.00002	29	0.00000	27	0.00041	24	0.00050	24
2.	Food, beverages and tobacco products	0.00007	24	0.00003	25	0.00000	20	0.00106	12	0.00116	14
3.	Textile and leather products	0.00006	26	0.00003	23	0.00000	21	0.00048	21	0.00058	21
4.	Wood and paper products, printing and reproduction of recorded media	0.00008	20	0.00006	5	0.00000	22	0.00056	19	0.00070	20
5.	Petroleum and coal products	0.00165	2	0.00003	20	0.00000	24	0.00028	28	0.00196	6
6.	Chemical products	0.00021	7	0.00004	11	0.00001	14	0.00180	5	0.00206	5
7.	Non-metallic mineral products	0.00039	5	0.00007	3	0.00002	9	0.08485	1	0.08527	1
8.	Basic metal products	0.00104	3	0.00008	2	0.00045	1	0.00362	3	0.00518	3
9.	Fabricated metal products, except machinery and furniture	0.00024	6	0.00005	8	0.00008	2	0.00156	7	0.00193	7
10.	Computing machinery, electronic equipment and optical instruments	0.00005	28	0.00003	28	0.00001	12	0.00182	4	0.00191	8
11.	Electrical equipment	0.00015	12	0.00003	22	0.00005	5	0.00151	8	0.00173	10
12.	Machinery and equipment	0.00017	8	0.00003	18	0.00005	3	0.00109	11	0.00135	12
13.	Transport equipment	0.00017	9	0.00003	16	0.00005	4	0.00141	9	0.00166	11
14.	Other manufactured products	0.00013	14	0.00004	12	0.00003	7	0.00156	6	0.00176	9
15.	Manufacturing services and repair services of industrial equipment	0.00014	13	0.00003	24	0.00002	10	0.00095	13	0.00113	15
16.	Electricity, gas, and steam supply	0.00012	15	0.00098	1	0.00000	26	0.00012	35	0.00122	13
17.	Water supply, sewage and waste treatment and disposal services	0.00195	1	0.00006	4	0.00001	16	0.00138	10	0.00340	4
18.	Construction	0.00015	11	0.00003	26	0.00004	6	0.00949	2	0.00970	2
19.	Wholesale and retail trade and commodity brokerage services	0.00005	29	0.00003	27	0.00000	32	0.00023	31	0.00030	28
20.	Transportation	0.00016	10	0.00002	30	0.00000	19	0.00028	29	0.00046	26
21.	Food services and accommodation	0.00007	22	0.00003	17	0.00000	25	0.00068	16	0.00079	18
22.	Communications and broadcasting	0.00003	33	0.00002	31	0.00000	31	0.00020	33	0.00025	31
23.	Finance and insurance	0.00002	35	0.00001	32	0.00000	35	0.00013	34	0.00016	32
24.	Real estate services	0.00003	34	0.00001	33	0.00000	29	0.00048	20	0.00052	23

Table 6. *Cont.*

Number	Sectors	Coal		Crude Petroleum and Natural Gas		Metal Ores		Non-Metallic Mineral Mining		Entire Mining Industry	
		Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
25.	Professional, scientific, and technical services	0.00007	21	0.00005	6	0.00000	23	0.00038	26	0.00050	25
26.	Business support services	0.00003	31	0.00001	35	0.00000	30	0.00035	27	0.00039	27
27.	Public administration, defense, and social security services	0.00003	32	0.00001	34	0.00000	34	0.00024	30	0.00029	30
28.	Education services	0.00004	30	0.00004	13	0.00000	33	0.00021	32	0.00029	29
29.	Health and social care services	0.00004	30	0.00004	13	0.00000	33	0.00021	32	0.00029	29
30.	Art, sports, and leisure services	0.00006	27	0.00004	10	0.00000	18	0.00072	15	0.00083	17
31.	Other services	0.00009	19	0.00003	21	0.00001	13	0.00064	17	0.00077	19
32.	Others	0.00009	18	0.00005	7	0.00001	15	0.00074	14	0.00088	16
33.	Coal	-	-	0.00004	9	0.00001	11	0.00040	25	-	-
34.	Crude petroleum and natural gas	0.00009	17	-	-	0.00002	8	0.00063	18	-	-
35.	Metal ores	0.00012	16	0.00004	14	-	-	0.00047	22	-	-
36.	Non-metallic mineral mining	0.00012	16	0.00004	14	-	-	0.00047	22	-	-
	Weighted average	0.00180		0.00055		0.00029		0.02269		0.02532	

Table 7. Linkage effects of mining industry.

Sectors	Sensitivity of Dispersion		Power of Dispersion		Overall Effects	
	Value	Rank	Value	Rank	Value	Rank
Coal	0.533	4	1.214	1	1.747	1
Crude petroleum and natural gas	0.532	5	1.097	2	1.629	2
Metal ores	0.597	1	0.949	4	1.546	4
Non-metallic mineral mining	0.536	3	1.059	3	1.595	3
Entire mining industry	0.590	2	0.946	5	1.536	5

3.6. Discussion of the Results

The IO models employed in this study are quite intuitive and relatively easy to apply because they do not require complicated statistical analysis. Nevertheless, since the IO model makes use of an IO table that summarizes inputs and outputs among sectors within a country's whole economy in a single table, the quantitative findings from IO analysis are suitable for various uses in policy planning and evaluation related to the MI. Furthermore, this study aimed to update the implications of the results by using the most recently published 2015 IO table. The economic effects derived by IO analysis have three important implications.

First, we inspected the economic effects of the MI using the demand-side model. The production -inducing effects, value-added creation effects, and wage-inducing effects of 1 dollar of production or investment in the MI on the national economy were estimated to be 1.813, 0.855, and 0.326 dollars, respectively. This quantitative information indicates how much production or investment in the MI causes increased production, value-added creation, and wage inducement for the national economy. Thus, the results of this study can be useful in predicting in advance the economic effects from the perspective of increased production, value-added, and wages when a new MI project or company starts up or enters the economy.

Since the study also estimated the economic effects for each sector, it is possible to examine the impacts of increased production or investment in the MI on each sector. In particular, the transportation sector is the most affected by production or investment in the MI. This means that if the MI is activated, the transportation sector will be activated the most. That is, the MI demands output from the transportation sector more than it does from other sectors. On the other hand, production or investment in the MI has the smallest impact on the education service sector.

Second, we examined the supply shortage effects of the MI using the supply-side model. Although the supply-side model has not been dealt with much in traditional IO analysis, it can be very useful for proactively diagnosing the negative effects of supply failure of essential input factors, such as natural resources and energy, on the industry as a whole. Disaster situations, such as wars and earthquakes, can cause disruptions in the supply of output from the MI. The production-retarding effects of supply shortages in the coal, crude petroleum and natural gas, metal ores, non-metallic mineral mining sectors and the entire MI on the national economy were calculated to be 2.035, 2.461, 1.815, 2.263, and 2.241 dollars, respectively.

These values are all clearly greater than 1.0, which implies that production failure in the MI has had a considerable negative impact on the national economy. This is because the output of the MI is being used as an indispensable input for the production of other industries. Therefore, the government should take all possible measures to ensure that the supply of the MI is kept stable. Otherwise, a supply shortage in the MI could have a very bad effect on the economy. Particularly, the supply shortage effects of crude petroleum and natural gas sector are the greatest of the four MI subsectors.

Third, we looked into the impacts of an increase in the price of the output of the MI and sub-MI sectors on other sectors using the price-side model. To this end, an exogenous specification of the MI instead of the value-added sector, which is usually made exogenous in conventional price-side models, was attempted in the price-side model adopted here. The price-pervasive effects of a 10% price increase in the MI sectors on the national economy were 0.0018, 0.0006, 0.0003, 0.0227, and 0.0253% for the coal, crude petroleum and natural gas, metal ores, non-metallic mineral mining sectors and the entire MI, respectively. Overall, the price effects are small.

For several reasons, there may be changes in the price of the output of the MI. A rise in raw material prices or labor costs for the MI, stricter government regulations related to safety and the environment for the MI, or a decrease in yield due to a reduction in mineral deposits may cause an increase in the price of output in the MI. The results of the analysis in this study can be useful in predicting the impacts of the increase in advance. In particular, since the price effects of the MI are presented separately for each industry sector, it is possible to identify which sectors are affected significantly or less. For example, the price effect of the MI is the largest for non-metallic mineral products sector.

4. Conclusions

The MI of South Korea has been playing the role of supplying minerals stably for industrial production and human survival. Thus, the government is implementing various policies to promote the MI and needs quantitative information on the economic role and effects of the MI. In particular, questions are being asked about how much production or investment in the MI causes the production, value-added, and wages of other sectors; how much supply failure of the MI reduces the production of other sectors; and how much a price increase in the MI affect prices in other sectors. In order to answer these questions, this article applied an IO analysis using the recently published 2015 IO table, subdividing the MI into four sectors, namely coal, crude petroleum and natural gas, metal ores, and non-metallic mineral mining, and making the MI exogenous instead of endogenous.

This study has several findings in terms of research as well as policy. There are three important findings that can be utilized in policy analysis and evaluation. First, the three economic effects of the MI on the backward side were quantitatively revealed using the demand-side model. One dollar of production or investment in the MI induced about 1.81, 0.85, and 0.33 dollars of production, value-added, and wages, respectively. Second, the effects of supply disruptions in the MI on the production of each sector and the national economy were identified by employing the supply-side model. One dollar of supply shortage in the MI caused 2.24 dollars of production throughout the national economy. Third, the impacts of a change in the price of the MI on the price of each sector and the national economy were analyzed by adopting the price-side model. A 10% increase in the price of output of the MI raised the overall price level by 0.025%.

The study also has three implications in terms of research. First, it was found that the IO analysis was useful in estimating the economic effects of the South Korean MI. This finding is consistent with the findings of previous case studies for the MI. Although IO has the fundamental limitation of assuming fixed input requirements, it is a useful tool for analyzing various policy issues related to the MI. Second, when applying IO analysis, three models, namely a demand-side model, a supply-side model, and a price-side model, were systematically combined to perform an analysis of the economic effects of the MI. The implications of the results of analysis of each model were discussed along with how to use them in the real world. In particular, the implications of this paper will be even more valuable given that both the supply-side model and the price-side model do not have many application cases compared to the demand-side model. Third, by treating the MI as an exogenous sector rather than as an endogenous one, the economic effects of the change in production or investment in the MI, rather than the change in the final demand or value-added for the MI, could be analyzed. The conventional IO analysis that deals with the MI as an endogenous sector creates contradictions such that an exogenous shock such as production or investment in the MI affects the production, value-added, and wages of the MI again, and makes it difficult to obtain the supply shortage effects and the price effects of the MI.

As a follow-up to this study, future related studies may be carried out in three directions. First, because the study performed a static IO analysis using the 2015 IO table, it is necessary to collect IO tables for a number of years and perform multi-period IO analysis using them. For example, a dynamic IO model may be considered. Second, although the article used the national IO table, multi-regional IO analysis can be carried out by employing a multi-regional IO table. This allows quantitative analysis of inter-regional effects as well as intra-regional effects. Third, various further implications can be obtained if comparative IO analysis is performed using IO tables for other countries with MI structures similar to the MI structures of South Korea, considering that the article utilized the IO table only for South Korea. The advantages and disadvantages of the country's MI in terms of the economic effects can be clarified through a comparative analysis.

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