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 shrunk 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 Biehma [2] summarized the inter-industry linkages of mining in the 10 European Union countries through IO analysis. Sabiroglu and Bashiiri [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:

\[
X = AX + Y \quad \text{or} \quad X = (I - A)^{-1}Y
\]

where \( X \) is a column vector whose element is \( X_i \) for \( i = 1, \ldots, n \); \( A \) is an \( N \times N \) input coefficient matrix whose element is \( a_{ij} \) defined as \( z_{ij}/X_j \), where \( z_{ij} \) means intermediate demand running from the \( i \)th sector to the \( j \)th sector; \( Y \) is a column vector, final demand matrix, whose element is \( Y_i \); and \( I \) is an \( N \times N \) 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 \( X^c \) be an \((N - 1) \times 1\) column vector remaining after deleting the \( L \)th row from \( X \), \( A^c \) be an \((N - 1) \times (N - 1)\) matrix that remains after removing the \( L \)th row and column from \( A \), \( A^c_L \) be an \((N - 1) \times 1\) column vector that is left after eliminating the \( L \)th element from sector \( L \)-related column vector of \( A \), \( Y^c \) be an \((N - 1) \times 1\) column vector remaining after deleting the \( L \)th row from \( Y \), and \( F \) be an \((N - 1) \times (N - 1)\) identity matrix. Manipulating Equation (1) to treat sector \( L \) as an exogenous sector gives us \([33,34]\):

\[
X^c = A^cX^c + A^c_LX_L + Y^c \tag{2}
\]

\[
(F - A^c)X^c = A^c_LX_L + Y^c \tag{3}
\]

\[
X^c = (F - A^c)^{-1}(A^c_LX_L + Y^c) \tag{4}
\]

For variability model, rewriting Equation (5) produces:

\[
AX^c = (F - A^c)^{-1}(A^c_LAX_L + AY^c) \tag{5}
\]

Assuming \( AY^c = 0 \), the following equation can be obtained.

\[
AX^c = (F - A^c)^{-1}(A^c_LAX_L) \tag{6}
\]

where \( AX^c \) is an \((N - 1) \times 1\) matrix showing changes in output of other sectors except for sector \( L \), \( F \) is an \((N - 1) \times (N - 1)\) identity matrix, and \( A^c \) is an \((N - 1) \times (N - 1)\) matrix that remains after removing sector \( L \)-related row and column from \( A \). \( A^c_L \) is an \((N - 1) \times 1\) column vector that is left after eliminating the \( L \)th element from sector \( L \)-related column vector of \( A \), and \( AX_L \) 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 $a_{ji}^{v} = W_{j}/X_{j}$ for $j = 1, \ldots, n$, where $W_{j}$ means the value-added of the $j$th sector. Manipulating Equation (7) and using $\hat{A}^{v}$ to treat sector as exogenous produces [35]:

$$\Delta X^{c} = (F - A^{c})^{-1}(A^{v}_{L} \Delta X_{L})$$  \hspace{1cm} (7)

where $\Delta V^{c}$ is an $(N-1) \times 1$ column vector signifying changes in the value-added of other sectors except for sector $L$, and $\hat{A}^{v}_{L}$ represents the $(N-1) \times (N-1)$ 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 $a_{ji}^{w} = W_{j}/X_{j}$ where $W_{j}$ is the wage in the $j$th sector. Manipulating Equation (7) and $A^{w}$ to treat sector $L$ as an exogenous sector produces:

$$\Delta W^{c} = \hat{A}^{w}_{L} (F - A^{c})^{-1}(A^{w}_{L} \Delta X_{L})$$  \hspace{1cm} (8)

where $\Delta W^{c}$ is the $(N-1) \times 1$ matrix, meaning changes in wages in other sectors except for sector $L$, and $\hat{A}^{w}_{L}$ indicates the $(N-1) \times (N-1)$ 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:

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

where the prime (') denotes the transpose of the given matrix, $X'$ is a $1 \times N$ input matrix, $R$ is an $N \times N$ output coefficient matrix whose elements are $q_{ij}$ defined as $\partial X_{i}/\partial V_{j}$, $V'$ is a $1 \times N$ 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 (10) to treat sector $L$ as an exogenous sector gives us:

$$\Delta X^{c'} = R_{L}' \Delta X_{L}(I^c - R^{c})^{-1}$$  \hspace{1cm} (10)
where $\Delta X''$ is an $1 \times (N - 1)$ matrix showing changes in output of other sectors except for sector $L$. $R^c$ is an $(N - 1) \times (N - 1)$ matrix that remains after removing sector $L$-related row and column from $R$. $R^c_L$ is an $1 \times (N - 1)$ row vector that is left after eliminating the $L$th element from the $L$th row vector of $R$, and $\Delta X_L$ 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]:

$$\Delta P_e = (I - A^c)A^c_H \Delta P_H$$

(11)

where $\Delta P_e$ denotes the $(N - 1) \times 1$ matrix whose elements are percentage changes in the prices of other sectors, $A^c$ is the $(N - 1) \times (N - 1)$ transpose matrix of $A^c$, $A^c_H$ is the $(N - 1) \times 1$ column vector left after getting rid of the MI row from the MI-related column vector of $A$, and $\Delta P_H$ 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 exogeneous 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 (6) 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   |
| 1.     | Agricultural, forest, and fishery goods       | 0.01119| 21     | 0.00804| 22     | 0.00912| 23     | 0.00842| 22     |
| 2.     | Food, beverages and tobacco products         | 0.01480| 19     | 0.01631| 17     | 0.00004| 35     | 0.00003| 34     |
| 3.     | Textile and leather products                 | 0.01113| 22     | 0.00736| 23     | 0.01499| 20     | 0.01549| 15     |
| 4.     | Wood and paper products, printing and reproduction of recorded media | 0.02097| 15     | 0.01712| 16     | 0.01100| 22     | 0.00836| 23     |
| 5.     | Petroleum and coal products                  | 0.01928| 17     | 0.01499| 18     | 0.01483| 21     | 0.01083| 19     |
| 6.     | Chemical products                            | 0.06506| 4      | 0.04139| 9      | 0.04395| 7      | 0.03378| 8      |
| 7.     | Non-metallic mineral products                | 0.00319| 9      | 0.00591| 26     | 0.10662| 2      | 0.05900| 2      |
| 8.     | Basic metal products                         | 0.02919| 11     | 0.05598| 5      | 0.00358| 28     | 0.09481| 27     |
| 9.     | Fabricated metal products, except machinery and furniture | 0.04934| 7      | 0.11203| 3      | 0.03514| 12     | 0.01320| 16     |
| 10.    | Computing machinery, electronic equipment and optical instruments | 0.01594| 18     | 0.02383| 14     | 0.05907| 5      | 0.02297| 13     |
| 11.    | Electrical equipment                          | 0.02668| 12     | 0.01489| 19     | 0.01617| 17     | 0.00980| 21     |
| 12.    | Machinery and equipment                       | 0.02079| 16     | 0.12641| 2      | 0.15433| 19     | 0.01183| 18     |
| 13.    | Transport equipment                           | 0.04100| 8      | 0.01260| 20     | 0.07301| 4      | 0.03246| 9      |
| 14.    | Other manufactured products                  | 0.00259| 31     | 0.00366| 28     | 0.04090| 10     | 0.03069| 10     |
| 15.    | Manufacturing services and repair services of industrial equipment | 0.10884| 3      | 0.01924| 15     | 0.01936| 31     | 0.00204| 30     |
| 16.    | Electricity, gas, and steam supply            | 0.05229| 6      | 0.03664| 10     | 0.02802| 14     | 0.02966| 12     |
| 17.    | Water supply, sewage and waste treatment and disposal services | 0.00449| 27     | 0.00710| 24     | 0.04258| 8      | 0.04127| 6      |
| 18.    | Construction                                  | 0.00307| 30     | 0.01094| 21     | 0.00642| 25     | 0.00582| 25     |
| 19.    | Wholesale and retail trade and commodity brokerage services | 0.04066| 9      | 0.05507| 21     | 0.00688| 24     | 0.00484| 26     |
| 20.    | Transportation                                | 0.11772| 2      | 0.04848| 8      | 0.05321| 6      | 0.03567| 7      |
| 21.    | Food services and accommodation              | 0.02629| 13     | 0.03136| 11     | 0.19289| 1      | 0.15398| 1      |
| 22.    | Communications and broadcasting              | 0.03021| 10     | 0.06152| 4      | 0.03086| 13     | 0.03015| 11     |
| 23.    | Finance and insurance                        | 0.05328| 5      | 0.05227| 7      | 0.02316| 15     | 0.02059| 14     |
| 24.    | Real estate services                          | 0.01418| 20     | 0.02434| 13     | 0.09652| 3      | 0.05625| 3      |
| 25.    | Professional, scientific, and technical services | 0.14926| 1      | 0.42877| 1      | 0.01969| 16     | 0.01207| 17     |
| 26.    | Business support services                     | 0.02238| 14     | 0.02827| 12     | 0.03969| 11     | 0.04740| 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       | Value                      | Rank       |
| 27.    | Public administration, defense, and social  |        | 0.00582 | 25           | 0.00099     | 32           | 0.04157     | 9           | 0.04957     | 4           | 0.00224     | 30           |
|        | security services                            |        |         |                            |            |              |            |              |            |              |              |
| 28.    | Education services                           |        | 0.00135 | 32           | 0.01111     | 31           | 0.00351     | 29          | 0.00193     | 31          | 0.000075    | 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                                         |        | 0.00004 | 34           | 0.00009     | 34           | 0.00624     | 26          | 0.00345     | 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)                                      | 1.99035 | 1.28357 | 1.06206 | 0.78390 | 0.81289 | 1.81289 |
|        | Self-induced effect (B)                      | 1.00000 | 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       | 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        |        | 0.00627 | 15           | 0.00512     | 16           | 0.00443     | 21          | 0.00324     | 20          | 0.00353     | 19           |
|        | reproduction of recorded media               |        |         |                            |            |              |            |              |            |              |              |
| 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  |        | 0.01751 | 8            | 0.03975     | 2            | 0.02096     | 7           | 0.00815     | 13          | 0.00968     | 11           |
|        | and furniture                                |        |         |                            |            |              |            |              |            |              |              |
| 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               | 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                                                                   | -            | -                  | 0.00044      | 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       | 0.31624      | 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       |
| Number | Sectors                                                                 | Coal Value | Coal Rank | Crude Petroleum and Natural gas Value | Crude Petroleum and Natural gas Rank | Metal Ores Value | Metal Ores Rank | Non-Metallic Mineral Mining Value | Non-Metallic Mineral Mining Rank | Entire Mining Industry Value | Entire Mining Industry 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        | 0.00192                              | 20                                  | 0.00111          | 6             | 0.00045                          | 9                               | 0.00051                     | 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   | -     | -     | 0.00003 | 33   | 0.00003 | 33   | -     | -     |
| 33.    | Coal                              | -     | -     | 0.00003 | 33   | -     | -     | 0.00003 | 33   | -     | -     |
| 34.    | Crude petroleum and natural gas   | 0.00000 | 33   | -     | -     | 0.00000 | 35   | 0.00000 | 35   | -     | -     |
| 35.    | Metal ores                         | 0.00000 | 33   | -     | -     | 0.00000 | 34   | 0.00000 | 34   | -     | -     |
| 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    | 0.03190 | 17   | 0.00483 | 20   | 0.00670 | 27   | 0.04172 | 8    |
| 6.     | Chemical products                                        | 0.15992 | 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    | 0.93261 | 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    |
| Number | Sectors                                               | Coal  | Crude Petroleum and Natural gas | Metal Ores | Non-Metallic Mineral Mining | Entire Mining Industry |
|--------|-------------------------------------------------------|-------|---------------------------------|------------|------------------------------|------------------------|
| 13.    | Transport equipment                                  | 0.12900 | 0.10301                        | 0.21220   | 0.09513                     | 2.03510               |
| 14.    | Other manufactured products                          | 0.00792 | 0.00853                        | 0.01043   | 0.00813                     | 2.46127               |
| 15.    | Manufacturing services and repair services of industrial equipment | 0.02501 | 0.02193                        | 0.01579   | 0.01548                     | 1.81483               |
| 16.    | Electricity, gas, and steam supply                   | 0.03444 | 1.06440                        | 0.00390   | 0.00281                     | 2.26286               |
| 17.    | Water supply, sewage and waste treatment and disposal services | 0.11421 | 0.01360                        | 0.00191   | 0.00714                     | 2.24098               |
| 18.    | Construction                                          | 0.09738 | 0.07246                        | 0.12891   | 0.53439                     | 19.4898               |
| 19.    | Wholesale and retail trade and commodity brokerage services | 0.03540 | 0.07589                        | 0.00716   | 0.01450                     | 16.01724              |
| 20.    | Transportation                                        | 0.06909 | 0.03996                        | 0.00992   | 0.01069                     | 18.01584              |
| 21.    | Food services and accommodation                      | 0.02741 | 0.05024                        | 0.00629   | 0.02296                     | 13.00236              |
| 22.    | Communications and broadcasting                       | 0.01172 | 0.03309                        | 0.00415   | 0.00701                     | 26.000785             |
| 23.    | Finance and insurance                                | 0.00914 | 0.02595                        | 0.00266   | 0.00520                     | 31.000588             |
| 24.    | Real estate services                                 | 0.01321 | 0.02937                        | 0.00624   | 0.02225                     | 15.002144             |
| 25.    | Professional, scientific, and technical services     | 0.04079 | 0.10472                        | 0.01145   | 0.01877                     | 14.002209             |
| 26.    | Business support services                            | 0.00777 | 0.01190                        | 0.00252   | 0.00695                     | 30.000704             |
| 27.    | Public administration, defense, and social security services | 0.01273 | 0.02061                        | 0.00282   | 0.00792                     | 23.000847             |
| 28.    | Education services                                   | 0.01562 | 0.05106                        | 0.00337   | 0.00655                     | 28.000810             |
| 29.    | Health and social care services                      | 0.02561 | 0.04732                        | 0.00462   | 0.01386                     | 25.001530             |
| 30.    | Art, sports, and leisure services                   | 0.00612 | 0.01882                        | 0.00277   | 0.00696                     | 29.000707             |
| 31.    | Other services                                       | 0.01394 | 0.01963                        | 0.00788   | 0.00900                     | 22.000958             |
| 32.    | Others                                               | 0.00106 | 0.00213                        | 0.00039   | 0.00076                     | 32.000080             |
| 33.    | Coal                                                 | -      | -                              | -         | -                           | -                     |
| 34.    | Crude petroleum and natural gas                      | 0.00002 | 0.00003                        | 0.00037   | 0.00001                     | -                     |
| 35.    | Metal ores                                           | 0.00002 | 0.00003                        | 0.00037   | 0.00001                     | -                     |
| 36.    | Non-metallic mineral mining                          | 0.00651 | 0.00156                        | 0.00031   | -                            | -                     |

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 Value | Coal Rank | Crude Petroleum and Natural Gas Value | Crude Petroleum and Natural Gas Rank | Metal Ores Value | Metal Ores Rank | Non-Metallic Mineral Mining Value | Non-Metallic Mineral Mining Rank | Entire Mining Industry Value | Entire Mining Industry 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        | 0.00003                               | 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                     | 0.000050             | 25                     |
| 26.    | Business support services                                    | 0.00003          | 31                              | 0.00001          | 35                          | 0.00000                | 30                     | 0.000035             | 27                     | 0.000039             | 27                     |
| 27.    | Public administration, defense, and social security services| 0.00003          | 32                              | 0.00001          | 34                          | 0.00000                | 34                     | 0.000024             | 30                     | 0.000029             | 30                     |
| 28.    | Education services                                           | 0.00004          | 30                              | 0.00004          | 13                          | 0.00000                | 33                     | 0.000021             | 32                     | 0.000029             | 29                     |
| 29.    | Health and social care services                              | 0.00004          | 30                              | 0.00004          | 13                          | 0.00000                | 33                     | 0.000021             | 32                     | 0.000029             | 29                     |
| 30.    | Art, sports, and leisure services                            | 0.00006          | 27                              | 0.00004          | 10                          | 0.00000                | 18                     | 0.000072             | 15                     | 0.000083             | 17                     |
| 31.    | Other services                                               | 0.00009          | 19                              | 0.00003          | 21                          | 0.00001                | 13                     | 0.000064             | 17                     | 0.000077             | 19                     |
| 32.    | Others                                                       | 0.00009          | 18                              | 0.00005          | 7                           | 0.00000                | 15                     | 0.000074             | 14                     | 0.000088             | 16                     |
| 33.    | Coal                                                         | -                | -                               | -                | -                           | -                      |            | -                   |            | -                   |            |
| 34.    | Crude petroleum and natural gas                              | 0.00009          | 17                              | -                | -                           | -                      |            | -                   |            | -                   |            |
| 35.    | Metal ores                                                   | 0.00012          | 16                              | 0.00004          | 14                          | -                      | -                     | 0.000047             | 22                     | -                   | -                     |
| 36.    | Non-metallic mineral mining                                  | 0.00012          | 16                              | 0.00004          | 14                          | -                      | -                     | 0.000047             | 22                     | -                   | -                     |
|        | Weighted average                                             | 0.00180          | 1                               | 0.00055          | 1                           | 0.00029                | 1                     | 0.02269              | 5                     | 0.02532              | 5                     |

### 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 affects 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.
Author Contributions: All three authors played their own significant roles in planning and writing this paper. K.-H.K. proposed ideas for the paper, laid out the basic framework for the study, and wrote half of the paper; J.-H.K. analyzed the data and wrote Sections 2 and 3; and S.-H.Y. supervised the entire course of the research, wrote part of the paper, and refined the entire paper. All authors have read and agreed to the published version of the manuscript.

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