Economic and social effects analysis of mineral development in China and policy implications

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Abstract

Mineral development has contributed greatly to China's economic and social development. Many challenges remain, however, including environmental pollution and resource waste in practice, as well as a dearth of systematic theoretical research. The goal of this study is to analyze the economic and social effects of various mineral developments in China from diversified perspectives, so as to provide the basis for the formulation of China’s mineral development policy. The input–output effects, industrial linkage effects and income distribution effects of different mining industries are quantitatively analyzed by adopting basic hypotheses of input–output economics, industrial linkage model and income distribution antitheses based on the latest available official data from China Statistical Yearbook from 2004 to 2010 and the 2007 Input–Output Table of China. The empirical results obtained in this study indicate that all mineral development industries, especially coal mining and washing, and petroleum and natural gas extraction industries, have given a strong impetus to the increase of China's fixed asset investment and GDP. Moreover, they have provided a large number of jobs, thereby alleviating ongoing employment pressure, and they have also played a positive role in promoting China's technology investment. The analysis of industrial linkages demonstrates that mining industries are basic to the national economy and produce a significant impetus to its downstream industries, but create weak pull effects in terms of national economic development. From the perspective of income distribution, mining industries play an important role in increasing China's fiscal revenue and per capital income. Hence, China's mineral development policy should (1) encourage additional investment in technology for exploration and development to insure sufficient supply and expand the input effects; (2) attract additional talent to work in remote regions; (3) optimize the industrial structure and promote the industrial transformation in resource regions; (4) adjust the interest distribution between the central and local governments to enable the local regions to become more self-sufficient; and (5) enhance the legal environment so that companies can more readily undertake their social responsibilities voluntarily.

Introduction

Minerals are important material foundations for social and economic development. As an emerging industrial country, China is at the stage of rapid industrialization and urbanization, so the consumption of minerals is increasing significantly. According to the forecast of Ministry of Land and Resources of China (2011), China's demand for iron ore, refined copper and alumina will reach 1.3 billion tons, 7.3–7.6 million tons and 13–14 million tons respectively by 2020, which indicates rapid consumption growth of minerals in China.

In 2010, the total output value of China's mining sector amounted to 449.507 billion Yuan, accounting for 6.43% of the total industrial output value, more than that of the agro-food processing, textile, and machinery and equipment manufacturing industries; the number of employed persons in the mining sector reached 5.459 million, accounting for 4.46% of national employment, 1.78% and 3.09% higher than that of the agriculture, forestry, animal husbandry and fishery industry, and the information transmission, computer services and software industry, respectively. The annual average wage of employees in the mining sector is 44496 Yuan, 7349 Yuan higher than the annual average wage...
industry-wide (National Bureau of Statistics of China, 2011). Hence, mineral development has made a positive contribution to promoting China's economic growth, providing employment opportunities and increasing the national income. However, mineral development also brings a series of negative effects, such as the destruction of the ecological environment, especially for the mineral regions. In 2009, the industrial waste water, waste gas and solid wastes (referred to as the industry's “three wastes”) from mineral development respectively account for 7.25%, 3.08%, and 65.80% of the industrial three wastes, which brings heavy pollution to mineral regions. Moreover, over-reliance on the mineral development results in a single industry and employment structure in many mineral regions, creating problems such as mineral resource depletion and a decline in sustainable development in many mineral regions.

Many scholars have focused on the relationship between mineral development and socio-economic development, drawing disparate conclusions about the effects of mineral development on society and the economy. For example, Hajkowicz et al. (2011) found that mining activity had a positive impact on incomes, housing affordability, communication access, education and employment across regional and remote Australia. However, Auty (1993) supported the concept of a “resource curse” through empirical research, and Sachs and Warner (1995, 1997, 1999, 2001) confirmed this view by studying the impact of mining on economic growth in developing countries. Many studies have also been conducted in China, but few published works exist from the perspective of labor input and technical input, and the methods of industrial association analysis and income distribution are rarely used in existing research. In addition, previous research tends to focus on certain categories of minerals in individual provinces, with little work addressing the national effects of multi-mineral development. So it is difficult to comprehend the complete effects of mineral development and to compare them across industries since the indicators adopted to measure the effects of mineral development and data sources used thereby are different in previous research.

This study utilizes official data from the China Statistical Yearbook from 2004 to 2010, and the 2007 Input–Output Table of China. The economic and social effects of disparate mineral developments in China are comprehensively and quantitatively analyzed from the view of input–output effect, industrial linkage effect and income distribution effect by choosing relevant indicators as production factors, forward and backward linkages, response and influence coefficients, and the national, regional and residents incomes, to provide a more complete overview of China's mineral development effects.

A literature review

Economic and social effects analysis of mineral development

Due to the assessment of different dimensions, scholars using different indicators and data have reached diverse conclusions about economic and social effects of mineral development.

From the perspective of productivity, Habakkuk (1962) analyzed economic and social effects of natural resources development. He linked high productivity in the United States to resource abundance and claimed that the extraction of mineral resources made the United States the world leader in terms of industrial production on nineteenth-century. In terms of the proportion of natural resources in manufactured elements, Wright (1990) proposed that the abundance of natural resources was an important reason why U.S. manufacturers retained technological leadership at the turn of the twentieth century. In contrast, Auty (1993), one of the frontrunners of the resource curse literature, proposed that the abundant natural resources not only failed to promote the economic growth, but actually limited growth. Investigating 95 countries Sachs and Warner (1995, 1997, 1999, 2002) conducted a series of empirical tests associated with a prospective resource curse. Their results indicated that economies with a high ratio of natural resource exports to GDP in 1971 tended to have low growth rates during the subsequent period of 1971–1989. Based on the data of national capital market published by the World Bank Ning and Field (2005) measured natural resource abundance by natural resource dependence and natural resource endowment. They found that natural resource dependence had a negative effect on economic growth rates, while natural resource endowment had a positive impact on growth.

In China, most scholars study economic and social effects of natural resources development from the aspect of economic growth. From the perspective of the aggregate economy Guan (2004) compared the output value of resource property with the gross output value of agriculture and industry between 1985 and 2001, and calculated the contribution of natural resources to China's economic aggregate to be approximately 30%. Wu (2006) proposed that the exploitation and utilization of mineral resources had a positive role on economic growth in Tibet by analyzing the effects of mineral development on the aggregate economy, economic growth, and industrial structure. However, some scholars have argued that natural resource development had a negative impact on social and economic development. Based on the statistical data of GDP and energy consumption from 31 provinces of China between 1985 and 2004 Han et al. (2007) found a positive correlation between energy consumption, and economic output and growth rate; however, as energy production increased, economic development declined.

Other scholars analyzed economic and social effects of natural resources from the perspective of industrial structure. Based on 2002 data, the China Input–Output Association (2007) analyzed the inter-industrial linkages of energy sectors by using the improved structural coefficients, suggesting that the second energy industry had a positive effect on other national industries. Based on the 2002 Input–Output Table of Shaanxi (2010) calculated the effects of input, output, industrial relevancy and revenue allocation in the Shaanxi energy industry via input–output analysis. Results demonstrate that energy exploitation industry was able to drive the investment in other industries; meanwhile, the output of the energy exploitation industry can also promote the development of other industries.

Scholars have also investigated the economic and social effects of mineral development. Due to different data and perspectives, however, they have reached different conclusions about the economic and social effects of different mineral developments across regions. From the spatial dimensions in previous research, many researchers outside of China have investigated comparisons across nations. In contrast, most Chinese scholars have examined the phenomena at the provincial level, especially western provinces in China, such as Xinjiang, Shaanxi and Tibet, with little attention to the national level.

With increased energy consumption in China, the effect of energy resources on national economic development is enhancing as well. Chinese scholars have investigated these issues, especially the relationships between oil, gas and coal development, and regional economic growth. There are relatively few studies on other minerals, such as metallic mineral resources and nonmetallic mineral resources. Many scholars have examined the economic effects of mineral development by utilizing economic aggregate and economic incensement as indicators, but few have assessed China's national economic structure and social development. Some scholars have analyzed the economic and social effects of some...
categories of mineral developments in certain regions from the perspective of the aggregate economy, economic structure and social development by utilizing input–output, industrial linkage and income distribution as indicators. However, the economic and social effects of each mineral developments category are seldom analyzed at the national level in China. Moreover, previous research has relied on pre-2005 data. Overall, previous research on the economic and social effects of mineral development in China lacks systematic, comprehensive and timely perspectives.

As China pursues rapid industrialization and urbanization, mineral development will likely retain a rapid growth rate well into the future. Mineral development not only provides important raw materials for China’s industrialization, but also engenders wide impacts on fixed assets investment, employment opportunities, economy growth, and industrial structure, as well as income. Therefore, it is necessary to comprehensively analyze the combined effects of mineral development on socio-economic development. According to the classification standards of China’s Statistical Yearbook, the sector of mineral development is divided into five industries, including (1) mining and washing of coal, (2) extraction of petroleum and natural gas, (3) mining and processing of ferrous metal ores, (4) mining and processing of non-ferrous metal ores, and (5) mining and processing of non-metal ores and other ores. Based on the latest available official data, the economic and social effects of mineral development in China are comprehensively analyzed in this paper.

Approaches employed

Various approaches have been employed to study the relationship of mineral development and social and economic development. Based on the hypothesis of the “resource curse,” some scholars have built regression models that include capital, labor, technological innovation, institution and GDP growth in order to examine the relationship between mineral development and economic growth (Xu and Wang, 2006; Hu and Xiao, 2007; Shao and Qi, 2008). “Resource curse” approaches fundamentally deny the positive role of mineral development on economic development. Further, how one measures the variable of institution depends on a scholar’s subjective understanding. Some scholars use a time series method to establish the mix matrix of energy production, consumption and economic development, and analyze the relationship between them (Han et al., 2007; Jiang et al., 2007). This method can directly reflect the relationships among energy production, consumption and economic development, but only can be used to qualitatively—not quantitatively—analyze the relationship.

Some scholars have employed cointegration analysis and the Granger causality test to investigate the effects of mineral development on regional development by establishing a dynamic econometric model of mineral development, economic development, industrialization and urbanization (Li et al., 2010). Cointegration analysis and the Granger causality test assess the relationship between mineral development and regional economic development, but cannot provide insight into the impact of mineral development on regional industrial structure. Other scholars use contribution ratios of output and growth to measure the contribution of mining sector to national economic development (Guan, 2004; Wu, 2006). This method measures the contribution of mining sector to China’s economic development from economic output and growth aspects, but it reflects neither the effects of mining investment nor the impact of mining on national industrial structure nor the impact on social development. Wang and Yang (2007) utilized the Solow Model to analyze the impact of coal resource on economic growth in China. Technological progress is taken as an exogenous variable in the Solow Model, however, so it is difficult to accurately depict the economic and social effects of technical inputs in mineral development. Overall, the existing research methods focus on the output to analyze the economic impact of mineral development; the input effects and social impact are rarely analyzed.

Disparate understandings of growth factors have spawned different theories of economic growth at various economic and social development stages. Based on the production function, modern Western economics have proposed the Harrod-Domar economic growth theory, the neoclassical economic growth theory and the new growth theory. According to the Harrod-Domar theory, the fundamental driving force of economic growth is the accumulation of physical capital, but the role of labor on economic growth is ignored and the role of technological change is not analyzed (Li, 2004). To overcome these limitations, the neoclassical growth school, represented by Solow, proposes that both labor and capital are the driving factors of economic growth and technological progress is the exogenous variable of economic growth. Unlike the neoclassical economic growth theory, Romer et al. think that human capital and technological progress are endogenous variables in the new growth theory (Zhang and Wang, 2009). Overall, under the assumption of competitive equilibrium, economic growth is the result of the long-term effect of capital accumulation, labor increments and technological progress; however, the intrinsic link between industrial structure evolution and economic growth is ignored in economic growth theories based on the production function (Yang and Zhang, 2008). By using statistical methods to analyze the gross national product and its constitutes, Kuznets et al. (1941) proposed that the main factors of economic growth are the increment of knowledge stock, the improvement of labor productivity, and the change of the structure. According to Cambridge growth theory, the income distribution is an important factor to realize stable economic growth and full employment (Zhang and Wang, 2009). The above theories demonstrate that economic growth is influenced not only by the inputs of capital, labor, technology and other production factors, but also by the industrial structure, and the income distribution. The most popular theory used to quantitatively analyze the industrial structure is input–output economics put forward by Wassily W. Leontief (Yang and Zhang, 2008). Five hypotheses have been raised in the input–output model as following: (1) independence of industrial activities; (2) unity of industrial output; (3) constant returns to scale; (4) relatively stable technology; and (5) reasonable price system. To analyze the economic and social effects of mineral development comprehensively, indicators are selected from the aspects of input–output, industrial linkage and income distribution based on the hypotheses of input–output economics, industrial linkage model and income distribution antitheses in this paper.

Research methodology and data

Input–output effect analysis

Research methodology

Because mineral development is a kind of production activity of typical high input, high-yield and high-risk, it inevitably brings substantial capital investment, greatly promoting the investment in fixed assets and will generate substantial cash flow at the same time. Therefore, mineral development not only brings a huge investment, but also drives industrial output and the national economy. The input–output effect of mineral development is analyzed from two perspectives in this paper, inputs—focusing on the capital, labor and technology to analyze the input effects of mineral development—and outputs—to analyze the contribution
of mineral development to economic growth. To quantitatively analyze the input–output effects of different mineral development industries on China’s economy, the contribution ratios of the total amount and growth rate of capital input, labor input, technology input and economic output are taken as indicators.

Taking the economic output for example, the total amount contribution ratios of various mineral development industries’ output to China’s economic output are calculated according to the following equation:

\[ a = \frac{y}{Y} \times 100\% \]  

(1)

where: \( a \) is the total amount contribution ratio of a mineral development industry’s output to China’s economic output; \( y \) is the output of a mineral development industry; \( Y \) is China’s economic output. The growth rate contribution ratios of various mineral development industries’ output to China’s economic output are calculated according to the following equation:

\[ R = \frac{az}{p} \times 100\% \]  

(2)

where: \( R \) is the growth rate contribution ratio of a mineral development industry’s output to the growth rate of China’s economic output; \( a \) is the total amount contribution ratio of the mineral development industry’s output to China’s economic output; \( z \) is growth rate of the mineral development industry’s output; \( p \) is the growth rate of China’s economic output. If \( R > 0 \), there is a positive association between the mineral development industry and the growth rate of China’s economic output; if \( R < 0 \), there is a negative association between the mineral development industry and the growth rate of China’s economic output. When \( R > 0 \), if \( R > a \), the output of the mineral development industry accelerates the growth rate of China’s economic output; if \( R < a \), the output of the mineral development industry decelerates the growth rate of China’s economic output (Du et al., 2011).

Data

The role of capital for economic growth is primarily realized by the investment in fixed assets. Typically, total investment in fixed assets is taken as the indicator to measure the investment (Economic Growth Frontier Subject Team, 2005). In China, total investment in fixed assets is divided into two categories, urban investment in fixed assets and rural investment in fixed assets. Urban investment in fixed assets refers to construction projects involving a total planned investment of 500,000 Yuan and over by enterprises of various types of ownership, institutions, administrative units and individuals in urban areas, investment in real estate development. In other words, all investments that take place in county towns and urban areas, investment in construction projects under the direct leadership and management of government agencies at and above county levels and investments by enterprises and institutions at and above county levels are covered in urban investment in fixed assets (National Bureau of Statistics of China, 2011).

Rural investment in fixed assets refers to investment in fixed assets by enterprises, institutions, administrative units and households in rural areas (National Bureau of Statistics of China, 2011). China is a developing nation, so rural development lags behind. Rural investment in fixed asset is mainly channeled to the real estate sector to meet the housing needs of farmers and minimally invested to the mining sector. In 2003, rural investment in the real estate sector was 189 billion Yuan, accounting for 59% of the rural investment in fixed assets; whereas, in mining and manufacturing sectors totaled only 7.24 billion Yuan, accounting for 2% of rural investment in fixed assets (Huang, 2006). In other words, the investment of China’s mineral development industries is derived primarily from the urban investment in fixed assets. Therefore, the urban investment in fixed assets is taken as the indicator to measure the capital input in mineral development industries in China.

Labor input refers to the amount of labor used in the process of mineral development. Due to the mobility of labor, the amount of labor input is different at different periods of mineral development, so the number of annual average employed persons is taken as the indicator.

The scale and intensity of research and development (R&D) activity is usually taken as the indicator to reflect a country’s scientific and technological strength. The development of R&D activity depends on two core factors, including human resource and capital investment. Enterprise is the most important source of R&D funds in China. In 2009, 70.4% of China’s R&D funds come from enterprises, and 24.6% come from government (Development and Planning Department of the Ministry of Science and Technology, 2010). Because of the shortage of human resource and capital, small businesses have not yet formed a dynamic mechanism to pursue progress and innovation and therefore do not receive substantial R&D funds in China. R&D investment from the government macroscopically regulates and controls R&D activity, guiding the development direction and achieving the development goals of the scientific and technology nationally and regionally, implementing the national and regional technology strategy and policy, and organizing and executing the major scientific and technological projects to promote scientific and technological progress and economic and social development. Hence, R&D investment from the government for mineral development is very limited. Thus, the R&D funds from large and medium-sized enterprises are selected to measure the technology input in mineral development.

The gross output value of mineral development is taken as the indicator of the output of mineral development.

In this paper, the input–output effect is analyzed from four aspects: one is the analysis of capital input effect, which takes the total amount and growth rate contribution ratios of the urban fixed assets investment in mineral development to the total fixed assets investment in China as indicators; second is the analysis of labor input effect, which takes the total amount and growth rate contribution ratios of the annual average employed persons in mineral development to the total annual average employed persons in China as indicators; third is the analysis of scientific and technological input effect, which takes the total amount and growth rate contribution ratios of the R&D funds from large and medium-sized enterprises in mineral resources development industry to the total R&D funds from large and medium-sized enterprises in China as indicators; the fourth is the analysis of output effect, which takes the total amount and growth rate contribution ratios of the gross output value of mineral resources development industry to China’s GDP as indicators.

To analyze the input–output effect of mineral development from the national level, data include urban fixed assets investment, annual average employed persons, R&D funds from large and medium-sized enterprises, as well as the gross output value from China Statistics Yearbook from 2004 to 2010, which are published by the National Bureau of Statistics of China.

Industrial linkage effect analysis

With high correlation with other national industries, mineral development produces different effects on different national industries, so economic and social effects of mineral development should include the industrial linkage effect between mineral development and other national industries. The industrial linkage effect of mineral development is materialized by the direct or
indirect supply or demand relationship between mineral development and other national industries.

Typically, the industrial linkage analysis is realized by adopting the Leontief input–output table to calculate the degree of linkage between inter-industries, so as to analyze the effect of certain industry on other industries. In industry linkage analysis, the direct forward linkage, direct backward linkage, response coefficient and influence coefficient are usually taken as indicators to measure the linkage degree. Direct forward linkage reflects the direct inputs of other sectors for a given sector’s increasing of a unit of output. Direct backward linkage reflects the direct inputs of other sectors for a given sector’s increasing of a unit of input. The response coefficient is the corresponding changes of a given sector’s production for each national economic sector’s increasing of a unit of final use and it is an important indicator to measure the extent and depth of a sector’s forward linkages. The influence coefficient reflects the influence of a given sector on all sectors’ production, for the sector’s increasing of a unit of final use and it is an important indicator to measure the extent and depth of a sector’s backward linkages (Li et al., 2008).

In China, the Input–Output Table is published every five years, with data presently available for 1987, 1992, 1997, 2002, and 2007. In order to accurately reflect China’s development status of national economy, this paper focuses on the 2007 Input–Output Tables of China and takes the direct forward linkage, direct backward linkage, response coefficient and influence coefficient as indicators to analyze the industrial linkage effects of mineral development in China.

**Income distribution effect analysis**

Revenues from mineral development can be allocated among different stakeholders, which will have a great impact on the existing income distribution structure. The income distribution effect of mineral development is used to analyze the impact of different mineral development industries on the core interests’ income.

According to Zhang et al. (2011), the core interests of mineral development are the central government, the local government, residents of mineral resources regions and mineral resources enterprises. Residents of mineral resources regions can be divided into two categories, including mining employees and non-mining employees. In the income distribution of mineral development, the central government and the local government obtain revenue from taxes; the mining employees obtain revenues through wages; the non-mining employees can indirectly share in the interests of mining through the improvement of social welfare; and the mineral resources enterprises obtain revenue in the form of profits. Due to the difficulty of measuring the improvement of social welfare, which is shared by non-mining employees from mineral development, the revenue of non-mining employees is not analyzed herein. The profits of mineral resources enterprises are mainly used to reinvest, reproduce and improve the welfare of employees, which produces a wide social impact that is difficult to define and measure, so the impact of mineral development on the revenue of mineral resources enterprises is not assessed either. Therefore, the income distribution effect focuses on the impacts of mineral development on the revenue of the central and local governments, as well as mining employees.

The central government and the local government obtain mineral development revenue in the form of levying taxes, so tax revenues can be used as an indicator to analyze the impact of mineral development on government receipts. Because different employees engage in different work in mineral development and receive different wages, it is meaningless to analyze the wage of every employee. Hence, this paper takes the annual average wage of employees as the indicator to measure the impact of mineral development on the revenue of residents. Data is derived from the China Statistics Yearbook from 2004 to 2010 to calculate and analyze the income distribution effect of mineral development.

**Results and discussion**

**Capital input effects**

Table 1 provides the contribution ratios of the urban fixed assets investment in various mineral developments to the total fixed assets investment in China varies with different minerals. The contribution ratio of mining and washing of coal increased during the 2003–2005 period but was relatively stable at about 1.3% during the 2006–2009 period; the contribution ratio of extraction of petroleum and natural gas remained high at 1.6% except one year (2009) due to the international financial crisis. Because of the small amount of urban fixed assets investments in mining and processing of ferrous metal ores, non-ferrous metal ores, nonmetal ores and other ores, the contribution ratios of urban fixed assets investments in the three industries are relatively less at about 0.4%.

From the aspect of the growth rate contribution ratios of the urban fixed assets investment in various mineral developments to the total fixed assets investment, the ratios declined and have remained stable since 2005. For different mineral developments, the growth rate contribution ratios of mining and washing of coal is the largest, followed by that of extraction of petroleum and natural gas. The growth rate contribution ratios of mining and processing of ferrous metal ores fluctuates in the 0.10–0.25% range, while non-ferrous metal ores fluctuate in the 0.12–0.20% range, nonmetal ores and other ores keep low and stable.
Regardless of how capital input effect is measured, mineral development has brought about positive effects on total fixed assets investment since none of the value in Table 1 is negative, of which mining and washing of coal lead the sector, followed by extraction of petroleum and natural gas. Mineral development promotes the total investment of fixed assets, especially from the contribution of mineral development to the growth rate of total fixed assets.

**Labor input effects**

As shown in Table 2, the contribution ratios of the annual average employed persons in mineral developments to the total annual average employed persons in China remained stable from 2003 to 2009, with mining and washing of coal industry in the 0.45–0.48% range, extraction of petroleum and natural gas industry in the 0.12–0.13% range, and mining and processing of ferrous metal ores, non-ferrous metal ores, as well as nonmetal ores and other ores at 0.02%, 0.04% and 0.03% respectively. The mining and washing of coal industry has made the greatest contribution to social employment, especially by absorbing rural laborers, as most employees of mining and washing of coal industry are from rural areas.

In terms of the growth rate contribution ratio, the mining sector plays a changing role mainly because the international mining market fluctuates frequently and the total employment keeps gradually increasing due to a deluge of incentive policies made by Chinese government.

The two ratios presented in Table 2 can be contrasted: for mining and washing of coal and extraction of petroleum and natural gas, the growth rate contribution ratios are higher than the total amount contribution ratios, indicating that these two industries increase employment opportunities and absorb more laborers; for mining and processing of nonmetal ores and other ores, the growth rate contribution ratio is lower than the total amount contribution ratios, indicating that the industry adversely affects employment opportunities. The industries of mining and processing of non-ferrous metal ores and ferrous metal ores play an uncertain role with not necessarily positive or negative effects.

**Technological input effects**

Mineral developments require substantial investments in technology. As shown in Table 3, R&D input in mining and washing of coal industry contributes the most by an average of about 2.5% to total R&D funds input because China pays a lot of attention to low energy consumption and carbon emissions, while R&D input in the mining and washing of coal industry is emphasized because coal is the most consumed energy in China with the heaviest pollution.

R&D input in extraction of petroleum and natural gas industry is second, followed by mining and processing of non-ferrous metal ores, and nonmetal ores and other ores with mining and processing of ferrous metal ores as the least contributor in R&D input effect.

In terms of growth rate contribution ratio, a clear trend of any mineral’s contribution does not exist. The extraction of petroleum and natural gas industry contributes the most in general, although the contribution is neither stable nor shows any obvious tendency. China has been increasing R&D input in extraction of petroleum and natural gas industry primarily because more advanced technologies are urgently needed. This is due to the rapid increase of oil consumption in recent years, requiring a greater oil supply by improving oil recovery and developing more difficult reserves such as shale oil and gas. Table 3 demonstrates that the R&D input in mining and washing of coal and extraction of petroleum and natural gas industries influences the growth rate of R&D input positively while R&D input in nonmetal minerals, non-ferrous metal and ferrous metal make very little contribution, some even negative. This result may imply that R&D input is insufficient in some minerals development because the demands for almost all kinds of minerals are increasing in China, but the resources are not renewable, while most reserves of minerals are getting more and more difficult to develop.

**Output effects**

As shown in Table 4, the output of mineral development accounts for a greater part of GDP, especially the mining and washing of coal, and extraction of petroleum and natural gas industries. The contribution of the mining and washing of coal industry has been increasing with the rise in energy consumption in China, while oil’s contribution is declining because of limited reserves and insufficient assurance of technology for developing them. The importance of other mineral output in GDP has been increasing annually since 2003. Following Table 4, the contribution ratios of output growth of all kinds of mineral development has been very positive, with that of mining and washing of coal industry reaching 28.6% in 2008. All other minerals’ contribution is satisfactory compared to other sectors. There is no doubt that the mining sector in general has maintained a prominent position in the national economy.

**Industrial linkage effects**

As shown in Table 5, the direct forward linkages of industries of extraction of petroleum and natural gas, mining and processing of ferrous metal ores and non-ferrous metal ores exceed 1.5, greater than the average level of all industries; the mining and washing of

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**Table 2**
The total amount and growth rate contribution ratios of the annual average employed persons in mineral developments to the total annual average employed persons in China.

<table>
<thead>
<tr>
<th>Year</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution to total amount (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining and washing of coal</td>
<td>0.45</td>
<td>0.45</td>
<td>0.46</td>
<td>0.47</td>
<td>0.47</td>
<td>0.47</td>
<td>0.49</td>
</tr>
<tr>
<td>Extraction of petroleum and natural gas</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Mining and processing of ferrous metal ores</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Mining and processing of non-ferrous metal ores</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.05</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Mining and processing of nonmetal ores and other ores</td>
<td>0.03</td>
<td>0.03</td>
<td>0.04</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
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<tr>
<td>Contribution to growth rate (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining and washing of coal</td>
<td>0.38</td>
<td>1.32</td>
<td>0.85</td>
<td>2.60</td>
<td>-0.11</td>
<td>0.84</td>
<td>2.83</td>
</tr>
<tr>
<td>Extraction of petroleum and natural gas</td>
<td>1.31</td>
<td>0.31</td>
<td>-0.15</td>
<td>1.03</td>
<td>0.63</td>
<td>1.36</td>
<td>0.43</td>
</tr>
<tr>
<td>Mining and processing of ferrous metal ores</td>
<td>-0.06</td>
<td>0.19</td>
<td>0.08</td>
<td>0.04</td>
<td>-0.07</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>Mining and processing of non-ferrous metal ores</td>
<td>-0.40</td>
<td>-0.10</td>
<td>0.40</td>
<td>0.28</td>
<td>0.84</td>
<td>-0.87</td>
<td>-0.60</td>
</tr>
<tr>
<td>Mining and processing of nonmetal ores and other ores</td>
<td>-0.35</td>
<td>-0.05</td>
<td>0.24</td>
<td>-0.22</td>
<td>-0.26</td>
<td>-0.09</td>
<td>-0.01</td>
</tr>
</tbody>
</table>
and medium-sized enterprises in China. From the view of direct backward linkage, all the coefficients are around 1. The results indicate that the mining sector may play an important role in pushing related downstream industries such as toy manufacturing when the petroleum industry provides the input of plastics for it as its basic industry. Mineral industries reacting strongly show their high reliance on other industries, especially its upstream industries, such as materials and equipments, while any change of their price may significantly influence the mining sector.

**Income distribution effects**

Effects on fiscal revenue

As shown in Table 6, tax receipts from the mining and washing of coal industry and its ratio of state taxes during 2006–2009 have been stable but rising. The extraction of petroleum and natural gas industry led the sector during 2006–2008 but decreased sharply in 2009 when the oil price jumped from 4318 to 2614 Yuan/ton and the oil production also dropped from 190 to 189 million tons during the financial crisis in Asia. Tax revenues from the industries of mining and processing of ferrous metal ores, non-ferrous metal ores and nonmetal ores and other ores contribute a lot to state

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**Table 3**
The total amount and growth rate contribution ratios of the R&D funds from large and medium-sized enterprises in mineral developments to the total R&D funds from large and medium-sized enterprises in China.

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining and washing of coal</td>
<td>2.71</td>
<td>2.27</td>
<td>2.26</td>
<td>2.26</td>
<td>2.36</td>
<td>2.90</td>
</tr>
<tr>
<td>Extraction of petroleum and natural gas</td>
<td>2.28</td>
<td>1.77</td>
<td>1.39</td>
<td>1.29</td>
<td>1.36</td>
<td>1.94</td>
</tr>
<tr>
<td>Mining and processing of ferrous metal ores</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.06</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>Mining and processing of non-ferrous metal ores</td>
<td>0.13</td>
<td>0.09</td>
<td>0.09</td>
<td>0.19</td>
<td>0.15</td>
<td>0.24</td>
</tr>
<tr>
<td>Mining and processing of nonmetal ores and other ores</td>
<td>0.06</td>
<td>0.14</td>
<td>0.08</td>
<td>0.10</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>Contribution ratio to total amount (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 4**
The total amount and growth rate contribution ratios of the gross output value of mineral resources development industry to China’s GDP.

<table>
<thead>
<tr>
<th>Year</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining and washing of coal</td>
<td>4.38</td>
<td>16.45</td>
<td>11.15</td>
<td>6.81</td>
<td>6.75</td>
<td>28.60</td>
<td>6.43</td>
</tr>
<tr>
<td>Extraction of petroleum and natural gas</td>
<td>6.71</td>
<td>9.19</td>
<td>11.01</td>
<td>6.40</td>
<td>1.66</td>
<td>9.83</td>
<td>7.07</td>
</tr>
<tr>
<td>Mining and processing of ferrous metal ores</td>
<td>1.44</td>
<td>4.79</td>
<td>1.72</td>
<td>2.04</td>
<td>3.02</td>
<td>9.54</td>
<td>0.14</td>
</tr>
<tr>
<td>Mining and processing of non-ferrous metal ores</td>
<td>1.00</td>
<td>1.98</td>
<td>2.31</td>
<td>2.84</td>
<td>2.24</td>
<td>1.74</td>
<td>0.29</td>
</tr>
<tr>
<td>Mining and processing of nonmetal ores and other ores</td>
<td>−0.25</td>
<td>0.74</td>
<td>1.06</td>
<td>1.33</td>
<td>1.21</td>
<td>2.28</td>
<td>1.73</td>
</tr>
<tr>
<td><strong>Contribution ratio to growth rate (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 5**
Direct and indirect correlation coefficients of various mineral developments.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Direct forward linkage</th>
<th>Direct backward linkage</th>
<th>Response coefficient</th>
<th>Ranking of response coefficient</th>
<th>Influence coefficient</th>
<th>Ranking of influence coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining and washing of coal</td>
<td>0.997</td>
<td>0.541</td>
<td>2.423</td>
<td>10</td>
<td>0.859</td>
<td>106</td>
</tr>
<tr>
<td>Extraction of petroleum and natural gas</td>
<td>1.590</td>
<td>0.403</td>
<td>4.042</td>
<td>3</td>
<td>0.746</td>
<td>121</td>
</tr>
<tr>
<td>Mining and processing of ferrous metal ores</td>
<td>1.703</td>
<td>0.667</td>
<td>1.432</td>
<td>25</td>
<td>1.010</td>
<td>69</td>
</tr>
<tr>
<td>Mining and processing of non-ferrous metal ores</td>
<td>1.503</td>
<td>0.621</td>
<td>1.319</td>
<td>26</td>
<td>0.954</td>
<td>82</td>
</tr>
<tr>
<td>Mining and processing of nonmetal ores and other ores</td>
<td>1.044</td>
<td>0.608</td>
<td>1.080</td>
<td>33</td>
<td>0.939</td>
<td>87</td>
</tr>
</tbody>
</table>
taxes although the values are lower than those from the mining and washing of coal, and the extraction of petroleum and natural gas industries. Hence, taxes from the mining sector are important sources of state revenue.

Compared with other mining industries, the mining and washing of coal industry contributes the most taxes to local governments, as depicted in Table 7. The central government obtains more than 60% of the taxes from mining and washing of coal, mining and processing of ferrous metal ores and non-ferrous metal ores, compared to less than 40% for local government. The extraction of petroleum and natural gas industry is a special case in that most of the taxes are not paid locally because the firm headquarters are all located in Beijing, headquarters for the central government. It is possible that the mining and processing of nonmetal ores and other ores industry contributes more taxes to local governments because many small companies are not officially registered or are conducting business illegally in some way.

Effects on per capita income

As shown in Table 8, the annual average wages of employees in each mineral industry kept rising during 2003–2009. The extraction of petroleum and natural gas industry still leads the entire mining sector, followed by the mining and washing of coal industry due to the increasing demand for energy and the limited supply of oil. Annual average wages for those working in industries of mining and the processing of ferrous metal ores, non-ferrous metal ores and nonmetal ores and other ores have been low primarily because some industries such as banking and tobacco make high profits in a new and transitional economic era. Compared with other industries, annual average wages in all mining industries are generally satisfactory and appear to be improving.

Policy implications and future study orientations

This paper examined the impacts on national economy, industrial structure, fiscal revenues and per capita income of various mineral developments in China by utilizing the latest available official data and applying the production function model based on new growth theory, industrial linkage effect and income-distribution antitheses. The results show that the development of mineral resources has not only provided important raw materials for China’s industrialization and modernization, but has also played a significant role in capital investment, employment, technology investment, economic growth, fiscal revenues and per capita income, although negative effects appear as in other countries. The Chinese government should promote the development of mineral resources and social and economic sustainability, as the nation still has a long way to go in terms of industrialization and urbanization, and a substantial quantity of minerals are required.

Encourage investment in mineral industries to insure sufficient supply

As shown herein, mineral development has made a great contribution to both the amounts and growth rates of GDP, total investment in fixed assets, R&D funds input, employment and per capita income. The contributions vary with minerals, with the industries of mining and washing of coal, and the extraction of petroleum and natural gas leading the entire sector in most respects. Facing the increasing demand for myriad minerals and a large population, more investment of capital, labor and technology is urgently needed in mineral exploration and development to insure the supply, as there are rich reserves of various kinds of minerals in China, especially those difficult to develop such as shale gas. Additional funds should be invested to improve technology for oil exploration and development and environmental protection in coal production by publishing guidance and providing research funds. Moreover, talented human resources should be recruited to work in black metal, nonferrous metal and nonmetal mineral industries through special policies of recruiting college students as the reserves are mainly located in remote areas where living standards are not high.

Optimize the industrial structure and promote the industrial transformation in resource districts

The resource industry as a basic support of other industries produces substantial push forces that foster development of the national economy. As the upstream of the industry chain, the mining sector has provided rich materials to the downstream industries by its direct forward linkage effect. However, the resource advantage of resource regions has not translated into economic advantage because almost all the resource regions are built around single industries. Resource regions are prone to unemployment, poverty, and sustainability challenges due to heavy reliance on a single industry. Policies such as interest redistribution to enhance diversified industrial investment and professional training are welcome in resource regions. Certainly, it is beneficial to help industrial transfer if the interest distribution can be adjusted in some way between the central and local governments. As shown in Table 6 and Table 7, the central government enjoys substantial tax revenues while local governments receive less due to the present regulatory distribution rule. Meanwhile, it is difficult for the resource regions to obtain other tax revenue because of its single industrial structure with its downstream industries and other related industries usually

Table 6
Taxes of various mineral developments paid to central government and their ratios in state taxes.


<table>
<thead>
<tr>
<th>Year</th>
<th>Mining and washing of coal</th>
<th>Extraction of petroleum and natural gas</th>
<th>Mining and processing of ferrous metal ores</th>
<th>Mining and processing of non-ferrous metal ores</th>
<th>Mining and processing of nonmetal ores and other ores</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>560.07</td>
<td>1483.42</td>
<td>162.62</td>
<td>141.02</td>
<td>70.86</td>
</tr>
<tr>
<td>2007</td>
<td>668.90</td>
<td>1504.58</td>
<td>299.44</td>
<td>146.56</td>
<td>85.08</td>
</tr>
<tr>
<td>2008</td>
<td>1060.03</td>
<td>1700.11</td>
<td>228.94</td>
<td>95.41</td>
<td>82.96</td>
</tr>
<tr>
<td>2009</td>
<td>1353.95</td>
<td>799.84</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The ratios in state taxes (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>Mining and washing of coal</th>
<th>Extraction of petroleum and natural gas</th>
<th>Mining and processing of ferrous metal ores</th>
<th>Mining and processing of non-ferrous metal ores</th>
<th>Mining and processing of nonmetal ores and other ores</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>2.20</td>
<td>5.82</td>
<td>0.21</td>
<td>0.42</td>
<td>0.21</td>
</tr>
<tr>
<td>2007</td>
<td>1.99</td>
<td>4.48</td>
<td>0.22</td>
<td>0.38</td>
<td>0.22</td>
</tr>
<tr>
<td>2008</td>
<td>2.68</td>
<td>4.30</td>
<td>0.76</td>
<td>0.28</td>
<td>0.20</td>
</tr>
<tr>
<td>2009</td>
<td>3.19</td>
<td>1.88</td>
<td>0.54</td>
<td>0.22</td>
<td>0.20</td>
</tr>
</tbody>
</table>
located in developed (i.e., high consumption) regions. Thus, policies to adjust the interest distribution between the central and local governments are needed under the present economic structure to enable each local government to adjust its industrial structure attentively.

Improve the legal environment so that firms can undertake their social responsibility voluntarily

Firms in China are not required to account for environmental costs associated with operations. Mineral companies are required to pay an environmental protection fee only in some regions. Meanwhile, the required resource compensation of most minerals in most regions is calculated according to production, making the resource compensation too low when compared with the high price of minerals. Higher resource compensation and environmental protection fees should be written into the law to encourage firms to undertake their social responsibility voluntarily.

Aimed at a more comprehensive understanding of the effects of various mineral developments and providing a sounder basis for the formulation of China’s mineral development policies, the economic and social effects from diversified perspectives have been examined in this paper. The findings presented herein are worthy of full consideration by policy makers. However, several limitations should be noted.

(1) With employment statistics for any given industry, the research faculties are not included in the data even though the number is not very large when compared to the number of mining employees overall. This may lead to lower contribution rates for all the mineral industries to social employment, especially in the mining and processing of ferrous metal ores, nonferrous metal ores and nonmetal mineral industries, as these industries have been rapidly developing in China.

(2) The policy recommendations presented herein emanate from the research results, but can benefit from additional analysis and should be the topics of future studies.

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References


