Mining development, income growth and poverty alleviation: A multiplier decomposition technique applied to China

Jianping Ge*, Yalin Lei

China University of Geosciences (Beijing), and Key Laboratory of Carrying Capacity Assessment for Resource and Environment of Ministry of Land and Resources, Beijing 100083, China

**A B S T R A C T**

Mining has grown rapidly and is expected to continue to develop solidly in the future with the economic development in China. Based on this trend, how an increase in the outputs of mining sectors affects household income and poverty alleviation is an issue worthy of study. A multiplier decomposition method within a social accounting matrix (SAM) framework shows the linkages through which a mining sector's output contributes to household income growth and poverty alleviation. The decomposition applied to China reveals that mining development has more significantly positive impacts on the high and middle income household than low income household. Moreover, the decomposition incorporated with the Foster, Greer and Thorbecke (FGT) poverty measure shows that the 'coal' sector contributes most to poverty alleviation and the low income household group, which has the biggest poverty rate, is the smallest beneficiary from the mining development. Thus, the policy implication is proposed that the government should give appropriate adjustment on the distribution of income between rich and poor households and help the unskilled human capital from the household group at a low income level to handle advanced technology of mining through education and training to reduce poverty more effectively.

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**Introduction**

Poverty alleviation is a main challenge in the growing process of developing countries, especially for China. According to the poverty line of the World Bank ($1.25 a day), China had 172.9 millions of poor in 2008, that is to say, 13.1% of the total population were living below the poverty line, though the proportion of the poor in China has declined from 60.2% in 1990 to 13.1% in 2008. Certainly, economic growth has played an important role in the poverty reduction (De Janvry and Sadoulet, 2010; Fosu, 2011; Xu, 2012). Recent works further show a key finding that the importance of sectoral growth on poverty (Thorbecke and Jung, 1996; Khan, 1999; Pyatt, 2001; Okalang, 2008). Furthermore, the mining sectors are considered to contribute to economic development and poverty reduction (Neary and van Wijnbergen, 1986; Pegg, 2006). As the foundation of the national economy, the mining industry provides abundant mineral raw materials for manufacturing sectors. Simultaneously, in order to import advanced technology and equipment and then achieve industrialization, export-oriented strategy for mineral products is usually adopted in mineral-rich developing countries with a skilled labor shortage (Owens and Wood, 1997). Unsurprisingly, a large number of investments and labors are concentrated to mining sector, which finally promotes economic growth and employment expansion. In Ghana, for example, mining industry generates foreign exchange earnings by at least 40% and gross domestic product (GDP) by more than 10% (Aryee, 2001). However, people working in mining are less likely to be in poverty than those with other occupations in Tanzania (Fisher et al., 2009).

China, as the largest developing country of the world, holds abundant mineral resources reserves. It is the world's largest producer of coal, lead, zinc, tin and rare earth minerals and also ranks high on output of iron ore, gold and bauxite. The value-added amount of mining reached CNY 1672.6 billion, accounting for 10.6% of the secondary industry and 4.9% of the total in 2010 (National Bureau of Statistics of China, 2011). Moreover, the output and value-added of the metals-intensive industrial sector grew by 9.3% and 14.8%, respectively, accounting for 48.6% of GDP in 2008 (Pitfield et al., 2010). The booming mining sector also increases employment and promotes income growth, especially for the household of miner resource-based regions which are mostly located in the center and west. In 2010, 5.62 million persons were employed in the mining sector, accounting for 4.3% of the national total in urban units (National Bureau of Statistics of China, 2011). Furthermore, the average wages of labor in mining sector were...
Furthermore, to derive the total poverty alleviation effects, the income growth of high, middle and low income households. The section "Effects of mining industry development on household income" provides detailed discussion on constructing the Chinese SAM for 2007 with a disaggregated household classification and introduction of fixed multiplier decomposition technique. The section "Incorporating poverty sensitivity effects into the multiplier decomposition" incorporates poverty sensitivity effects into the multiplier decomposition process. The section "Impacts of mining development on poverty alleviation" is devoted to results on the impacts of mining industry development on poverty alleviation. Finally, the section "Conclusion" draws summary and conclusions.

Mining industry in China

China is rich in mineral resources, particularly in rare earth, coal, iron, copper, aluminum, stibium and so on. Currently, China is one of the largest producers of 37 major mineral and metals and produces more than 50% of the world's total output of 12 of these (Pitfield et al., 2010). By the end of 2010, the national proven reserves of oil amounted to 31.28 billion tons, natural gas totaled 9.3 trillion cubic meters (Huang, 2011), and coal reached 114.5 billion tons (BP, 2011). In 2010, China also identified new reserves of major mining resources, such as coal, iron ore, copper, gold, silver, rare earth, grow in varying degrees (Huang, 2011). In the past few decades, exploitation, production and consumption of mineral resources effectively promoted China's economy and its contribution reached 0.512-0.798% (Liu et al., 2010), especially for mineral-based areas. In Yunnan, mining industry takes up about 11% of the gross domestic production (Huang et al., 2011). Similarly, China's rapid economic growth has greatly boosted the mining industry that has witnessed significant increase in investment and mineral production (Huang, 2011).

Mining of coal

China is by far the largest producer of coal in the world, producing 3.24 billion tons of coal in 2010, increasing by 9.0% compared to 2009, or approximately 48.3% of all coal produced in the world (BP, 2011). In the past 10 years, coal production increased from 1.47 billion tons to 3.24 billion tons, an increase of 421% (Fig. 1) and is set to increase to over 3.30 billion tons by 2015 (Pitfield et al., 2010).

China remains highly reliant on labor-intensive underground operations as the major method of coal mining, with 5% of the mines are extracted by surface technology (He and Song, 2012). Concerning mining safety, the government has drawn up policies to regulate the coal industry, particularly, the reform policies of closing mines and restricting the yield for the small coal mines. Some studies (Shen and Andrew-Speed, 2001; He and Song, 2012) have paid attentions on small coal mines since China has about 15,000 mines of which 12,000 mines produced less than 300,000 t annually (Peng, 2010). In the first nine months of 2010, China shut 1355 small coal mines with production capacity of 125 million tons (Hill, 2010). However, 20 large coal mining groups each with an annual output of 10 million to 40 million tons are planned to build by 2015 to replace outdated mines (Bai and Chen, 2010). Therefore, coal production will continue to increase to 4 billion tons in 2020 (Peng, 2010).

Mining of petroleum and natural gas

Strong economic driving and rapid growth of private vehicles have turned China into a net importer since 1993 and the second largest consumer of oil since 2003. In 2010, China produced 4.07 million barrels of oil per day (mb/d), an increase of 7.1% compared with 2009, accounting for 5.2% of the total world production (BP, 2011). During the period 2001–2010, oil production increased from 3.306 mb/d in 2001 to the current level, an average rate of 2.3% annually since 2001 (Fig. 2). Being driven by the growth in demand, China's oil production is estimated to increase to 4.1 mb/d by 2020 and furthermore 4.3 mb/d by 2030 (OPEC (Organization of the Petroleum Exporting Countries), 2010).

China's domestic natural gas production has expanded from 30.3 billion cubic meters (bcm) in 2001 to 96.8 bcm in 2010 (BP, 2011), a notable increase of 219% (Fig. 3), due to substantial investments for natural gas infrastructure, better economic benefits than coal (Higashi, 2009) and policy support. At the beginning of 2005, the full commercial supply of natural gas by the first West-East Pipeline started in order to transport inland domestic

Fig. 1. China's production of coal between 2001 and 2010. Data source: BP, 2011.
gas to the coastal cities like Shanghai. Construction of the second West-East Pipeline began in February 2008. The pipeline will run from Khorgas in northwestern Xinjiang to Guangzhou in Guangdong province, a city on the south coast of China, with a total length of 9102 km. There are plans to build the third and fourth West-East Pipelines. The former will run from the western Xinjiang to Fujian province in the southeast and the latter will extend from the Tarim Basin or Sichuan (Higashi, 2009). Because China's future demand of natural gas will continue to increase, the production will attain 160 bcm to 170 bcm by 2020, estimated by CNPC (Higashi, 2009).

The present exploration and production of oil and natural gas in China are led by PetroChina (China National Petroleum Corporation, CNPC), Sinopec (China Petroleum and Chemical) and the China National Offshore Oil (CNOOC). PetroChina has been mainly engaged in onshore oil and gas exploration and production. Sinopec focuses on downstream refining and distribution, producing around 1/4 as much oil as PetroChina. CNOOC handles offshore exploration and production.

Mining of metal and nonmetal ores

In recent years, China maintains rapid growth of metal ore production. In 2010, the production of iron ore, pig iron, and crude steel were 1.072 billion tons, 59 thousand tons, and 627 million tons, up 21.6%, 7.4% and 9.3% compared to last year, respectively (Liu et al., 2010). The 10 kinds of main nonferrous metals output reached 31.528 million tons, of which, the production of refined copper, aluminum, and tungsten were 4.793 million tons, 15.65 million tons, and 129.7 thousand tons, respectively (Liu et al., 2010). In the same year, China’s production of important nonmetal ores showed double-digit growth compared to the previous year, of which, the production of cement, potash and phosphate rock increased by 15.5%, 12.7% and 18.5%, reached 1.87 billion tons, 3.968 million tons and 68.07 million tons, respectively (Liu et al., 2010).

The SAM for China and multiplier analysis

The SAM for China

As a widely used analysis framework, the SAM captures disaggregated economic activities and their interactions in an economy. A SAM can be defined as “a particular representation of the macro and meso economic accounts of a socio-economic system, which capture the transactions and transfers between all economic agents in the system” (Round, 2003). Although input–output models are often adopted to examine the role of an industry in the national economy, the SAM further captures production factors mobility and government transfers and expenditures. The rows and columns of the SAM represent receipts and outlays of the corresponding agents (Keuning and Rueter, 1988). Thus, a defining characteristic of the SAM is that the corresponding row and column sums for any agent must be equal since the SAM is a double-entry bookkeeping system (Adelman and Robinson, 1986; Xie, 2000). In brief, a SAM expresses “how sectoral value added accrues to production factors and their institutional owners; how these incomes, corrected for net current transfers, are spent; and how expenditures on commodities lead to sectoral production and value added” and also shows savings and capital finance in an economy (Keuning and Rueter, 1988).

Table 1 shows a representative SAM framework. As shown in the table, a SAM has the following accounts: productive accounts, factor accounts, institutional accounts, capital accounts and rest of the world (ROW) accounts. There are transactions and transfers in the economy which can be described by the SAM. It is required in the multiplier analysis that the SAM accounts should be divided
In order to set up the multiplier decomposition model, the first step is to decide which accounts are exogenous and which are to be endogenous. It has been customary to take the government account, capital account, and rest of the world account to be exogenous, as shown in Table 1, because these accounts are beyond domestic control and exogenously-determined. In this study, the endogenous accounts included productive activities, value-added factors and households.

As described in the table, the matrix of endogenous transaction, which is represented in summary form by matrix $T$, can be usually defined by a matrix $A$ of column shares by dividing elements in each column of $T$ by the column total

$$T = AX$$  

where $A$ is the matrix of the average exogenous expenditure propensity. Similarly, $X$ and $Y$ are the vectors of exogenous injections and account totals. Since expenditure and receipts must tally for each account, the row and column sum vectors must be the same:

$$Y = AX + X = (I-A)^{-1}X = M_{A}X$$  

where $M_{A}$ is the SAM multiplier matrix.

In this study, the matrix of expenditure propensities can be recorded by:

$$A_{T} = \begin{bmatrix} 0 & 0 & T_{13} \\ T_{21} & T_{22} & 0 \\ 0 & T_{32} & T_{33} \end{bmatrix}$$  

One limitation of the accounting multiplier matrix $M_{A}$ is that it implies unitary expenditure elasticities and these elasticities are unrealistic for the expenditure pattern of different household groups ($T_{32}$). A more realistic alternative is to specify a matrix of marginal expenditure propensities $C_{n}$ corresponding to the observed expenditure (income) elasticities of the low, middle and high income household, under the assumption of the fixed prices (Thorbecke and Jung, 1996; Khan, 1999). The $C_{n}$ matrix and the $A_{T}$ matrix are quite similar in structure and characteristic. The zero elements and the non-zero elements of the $C_{n}$ matrix are completely the same with the $A_{T}$ matrix but $C_{32}$ is different.

Under the assumption of unchanged prices, according to Pyatt and Round (1979), we can obtain the following equation to express the change in incomes $(dy_{n})$ resulting in changes in injection $dx$:

$$dy_{n} = C_{n}dx + dx = (I-C_{n})^{-1}dx = M_{c}dx$$  

where $M_{c}$ is the fixed price multiplier matrix and includes expenditure (income) elasticities. Since the ratio of the marginal expenditure propensities $(MEP_{hi})$ to the average expenditure propensities $(AEP_{hi})$ is equal to the expenditure (income) elasticity for household group $h$ and goods $i$ $(e_{hi})$, $C_{32}$ in $C_{n}$ can be obtained when the expenditure (income) elasticities and the average expenditure propensities are known i.e.

$$e_{hi} = MEP_{hi}/AEP_{hi}$$

$$MEP_{hi} = e_{hi}AEP_{hi}$$

$M_{c}$ can be shown to be decomposable into three multiplicative components as the following formula (Pyatt and Round, 1979):

$$dy = M_{c}dy = M_{2}M_{3}M_{1}dx$$  

where $M_{1}$, $M_{2}$ and $M_{3}$ are all ‘multiplier’ matrices. In this case, $M_{1}$ represents the ‘within account’ effects, that is the multiplier effects an exogenous injection into one set of accounts will have on that same set of accounts; $M_{2}$ shows the cross effects, whereby an injection of income into one set of accounts has effects on the other set of accounts, with no reverse effects; $M_{3}$ is the multiplier effects due to the full circular flow, these are the ‘between-

Fig. 4. Simplified interrelationship among endogenous accounts. Source: Thorbecke and Jung (1996).
account' effects, after extracting the 'within-account' multipliers. Because Eq. (7) is difficult to examine in practice, Stone (1985) proposed an additive variant that is more user-friendly and better explained, that is:

\[
dy = [1 + (M_1 - I)] + (M_2 - I)M_1 + (M_3 - I)M_2M_1\text{d}x
\]

where \( I \) is the identity multiplier, which indicates the impact from an input on an account. Its revenue growth is equal to the initial input. We introduce \( T, O \) and \( C \), expressed by Eqs. (9)-(11), which show the net effect of transfer, the open-loop multiplier and the closed-loop multiplier, respectively.

\[
T = (M_1 - I) = (I - C_n)^{-1} - I
\]

\[
O = (M_2 - I)M_1
\]

\[
C = (M_3 - I)M_2M_1
\]

**Effects of mining industry development on household income with fixed price multiplier decomposition**

The evaluation is based on the fixed price multiplier decomposition methodology within a SAM framework, which reflects the relationships among demand, production and income. A demand of mining products, that is mineral resource, promotes mining production, and then improves labor wage and household income, and finally boosts more consumption on mineral resource and other commodities. The analytical framework developed in this section shows how the exogenous and unitary inflows to mining industry affect household income directly and indirectly. Therefore, it quantifies how much household income can be increased, especially for low income household, when there is a unit of increase in exogenous demand in mining products. Table 2 gives the decomposition of the impacts of the development of coal, oil and gas, metal ores and nonmetal ores industry on the household income.

The rows in Table 2 show the unit variation of income for different household and output for non-mining sector due to one unit increase in the demand for mineral products (coal, oil and gas, metal ores and nonmetal ores). The first column in Table 2 presents total effects, including direct and indirect effects, on the income classes. Generally, rural high income household enjoys the highest increase in income, while rural low income household receives the lowest increase in income whichever mining sector develops. Meanwhile, middle and high income household in urban areas and rural middle income household also receive greatly positive impacts from a demand increase in mineral products. The main reason for the above results is that mining industry is capital-intensive and middle and high income household are the majority owners of capitals, while returns to capitals increase is caused by the growth of capital-intensive mining sectors. Low income households receive a few increases in income because these labourers have low levels of education, lack technology, and the wage level of mining industry is lower compared to the level of return on capital. Comparatively speaking, it is worth noting that rural households obtain higher total income benefits than the total benefit received by households in urban areas. Possibly the reason is that many labourers of the mining sectors are rural-to-urban migrant workers. Regarding all non-mining sectors combined, 1 unit mining output can increase between 10.304 units and 11.023 units output for the non-mining sectors.

The total effect of mining can be decomposed into direct and indirect impacts. In this case, direct impacts are open-loop effect for household and transfer effect for all non-mining sectors combined while indirect impacts are represented by closed-loop effect. In general, both for the residents and for the non-mining sectors, the contribution of the mining industry to revenue increase and sectoral growth is mainly reflected in indirect effect rather than direct effect. In other words, a relatively higher value

<table>
<thead>
<tr>
<th>External shock</th>
<th>Terminal account</th>
<th>Total effect ([M_i])</th>
<th>Transfer effect ([T])</th>
<th>Open-loop effect ([O])</th>
<th>Closed-loop effect ([C])</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coal mining</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Urban high income household</td>
<td>0.926</td>
<td>0.000</td>
<td>0.224</td>
<td>0.702</td>
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<td>0.000</td>
<td>0.245</td>
<td>0.765</td>
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<tr>
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<td>0.000</td>
<td>0.043</td>
<td>0.135</td>
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<tr>
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<td>1.172</td>
<td>0.000</td>
<td>0.270</td>
<td>0.902</td>
<td></td>
</tr>
<tr>
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<td>0.000</td>
<td>0.203</td>
<td>0.887</td>
<td></td>
</tr>
<tr>
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<td>0.000</td>
<td>0.015</td>
<td>0.050</td>
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</tr>
<tr>
<td>All non-mining sectors combined</td>
<td>10.816</td>
<td>1.748</td>
<td>0.000</td>
<td>9.068</td>
<td></td>
</tr>
<tr>
<td><strong>Oil and gas mining</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Urban high income household</td>
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<td>0.000</td>
<td>0.186</td>
<td>0.683</td>
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<td>0.199</td>
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<td>Rural middle income household</td>
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<td>0.250</td>
<td>0.867</td>
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<td>Rural low income household</td>
<td>0.067</td>
<td>0.000</td>
<td>0.018</td>
<td>0.049</td>
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</tr>
<tr>
<td>All non-mining sectors combined</td>
<td>10.304</td>
<td>1.502</td>
<td>0.000</td>
<td>8.802</td>
<td></td>
</tr>
<tr>
<td><strong>Metal ores mining</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0.205</td>
<td>0.693</td>
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<td>1.179</td>
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<tr>
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<td>0.226</td>
<td>0.677</td>
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</tr>
<tr>
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<td>0.000</td>
<td>0.017</td>
<td>0.050</td>
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</tr>
<tr>
<td>All non-mining sectors combined</td>
<td>11.023</td>
<td>2.086</td>
<td>0.000</td>
<td>9.397</td>
<td></td>
</tr>
<tr>
<td><strong>Nonmetal ores mining</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban high income household</td>
<td>0.906</td>
<td>0.000</td>
<td>0.210</td>
<td>0.695</td>
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<tr>
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</tr>
<tr>
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<td>0.893</td>
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<td>0.220</td>
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<tr>
<td>All non-mining sectors combined</td>
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<td>1.999</td>
<td>0.000</td>
<td>8.972</td>
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</table>
Thorbecke and Jung (1996) showed that $M_{c23}$ can be decomposed multiplicatively into two different matrices, namely distributional ($D$) and interdependency ($R$) effects. The relationship between the above three can be represented with the following formula:

$$M_{c23} = R \times D$$

where $M_{c23}$ is the matrix built up by the columns of production activities and rows of household groups of the fixed price multiplier matrix ($M_f$), and dimensions of matrix $M_{c23}$, $R$ and $D$ are (household groups $\times$ production activities), (household groups $\times$ household groups) and (household groups $\times$ production activities), respectively.

The distributional effect shows the initial effect of an exogenous change in sectoral output. It can be broken down multiplicatively into three components that are the effect caused by intermediate input and output linkages ($D_1$), the effect resulted from factors, e.g., labor and capital, used in the production activities directly ($D_2$), and the effect due to the income transfer between and among different household groups ($D_3$). Therefore, the distributional effect can be derived as follows:

$$D = D_1D_2D_3$$

where the $D$ is a distributional effect, $D_2=(I-C_{33})^{-1}$ represents the transfer effect, $D_2=C_{23}C_{13}$ stands for the direct distributional effect, and $D_1=(I-C_{32})^{-1}$ denotes the intersectoral production effect.

However, the transfer effect ($D_3$) and the intersectoral production effect ($D_1$) cannot be directly obtained because these two matrices do not connect the production sector and household group and thus cannot show the impact of external changes in production on household income. Therefore, we use $D$ and $D_2$, which have the dimension relating to the production activities and households, to define the transfer effect and the intersectoral production effect by Eqs. (14) and (15).

$$d_{i,j} = d_{i,j}/d_{21i,j}$$

(14)

$$d_{i,j} = d_{21i,j}/d_{21j}$$

(15)

where $d_{3i,j}$ represents the effect of matrix $D_3$, $d_{i,j}$ is an element of $D_2$, $d_{21i,j}$ is an element of matrix $D_2D_1$, $d_{1i,j}$ is an element of matrix $D_1$ and $d_{2j}$ is an element of matrix $D_2$. Therefore,

$$d_{j} = d_{3i,j}d_{21i,j}d_{1i,j}$$

(16)

The interdependency effect reflects the spending and responding effects, in other words, the initial income gain, caused by the external shock on a production activity, are spent on other commodities, resulting in an increase in outputs of other sectors and ultimately generate an additional indirect effect on household income growth. The above process combines the effect of the initial spending and subsequent rounds of respending by the household groups.

According to Pyatt and Round (1979), the interdependency effect can be showed that:

$$R = (I-(I-C_{32})^{-1}C_{21}(I-C_{33})^{-1}C_{32})^{-1}$$

(17)

Assuming $C_{32}=E$ and substitute $E$ into Eq. (17), therefore, we can obtain the following Eq. (18) for $R$ and Eq. (19) for $M_{c23}$:

$$R = (I-DE)^{-1}$$

(18)

$$M_{c23} = (I-DE)^{-1}D$$

(19)

If $m_{ij}$ is an element of $M_{c32}$, then,

$$m_{ij} = r_{ij}d_{ij}$$

(20)

where $r_{ij}=m_{ij}/d_{ij}$. Finally, $m_{ij}$ can be decomposed as

$$m_{ij} = r_{ij}d_{3i,j}d_{2i,j}d_{1i,j}$$

(21)
In order to assess the effect of sectoral growth on poverty alleviation, the Foster et al. (1984) (FGT) $P_α$ measure is adopted. For $α=0,1,2$, the FGT $P_α$ represents the head count ratio ($α=0$), the poverty gap ($α=1$) and the distributionally sensitive measure ($α=2$), respectively.

According to Thorbecke and Jung (1996), under the assumption of distributional neutrality, the impact of change in the sectoral growth on poverty alleviation can be shown as Eq. (22) using the elasticity of the poverty with respect to the mean per capital income developed by Kakwani (1993).

$$dP_{ij}/P_{ij} = φ_{ai}(dβ_j/β_j)$$

where $φ_{ai}$ is the elasticity of $P_{ij}$ with respect to the mean per capital income of household group $i$ caused by an increase in the output of sector $j$.

Next, Eq. (23) shows the linkage between the increase in the mean income ($dβ_j$) and the fixed price multiplier ($m_i$). Similarly, $dβ_j$ is the change in the output of sector $j$ defined on a per capita basis for household group $i$.

$$dP_{ij}/P_{ij} = φ_{ai}m_i(dx_j/β_j)$$

Using the additive decomposability of $P_{ij}$, the disaggregated poverty measure $P_{ij}$ for different household groups can be written as:

$$dP_{ij}/P_{ij} = \sum_{i=1}^{n} (dP_{ij}/P_{ij})S_{ai}$$

where

$$S_{ai} = \frac{1}{n} \sum_{i=1}^{n} [S_{ai} = \frac{1}{2} \sum_{i=1}^{n} \frac{1}{2}(z-y_i) ]$$

$S_{ai}$ denotes the poverty share of household group $i$ out of total poverty ($\sum_{i=1}^{n} S_{ai} = 1$), $q_i$ is the number of poor in the $i$th group and the total number of poor $q = \sum_{i=1}^{n} q_i$, and $z$ is the poverty line.

Combining Eqs. (24) and (25),

$$dP_{ij}/P_{ij} = \sum_{i=1}^{n} S_{ai} φ_{ai}m_i(dx_j/β_j)$$

Now let us define as $m'_{aij} = S_{aij}m_i$ and $q'_{aij} = φ_{aij}(dx_j/β_j)$. Then the modified multiplier $m'_{aij}$ now is a part of multiplier $m_i$ which contributes to the income effect of the poor in a household group $i$. The term $q'_{aij}$ means the poverty sensitivity of $P_{ij}$ to the change in income. Based on Eq. (21), defining $m'_{aij} = S_{aij}m_i$ and $dP_{ij}/P_{ij} = \sum_{i=1}^{n} (r_{aij})dS_{aij}/dγ_j$, we get:

$$dP_{ij}/P_{ij} = \sum_{i=1}^{n} m'_{aij}q'_{aij} = \sum_{i=1}^{n} (r_{aij})dS_{aij}/dγ_j = \sum_{i=1}^{n} (r_{aij})S_{aij}dγ_j$$

(28)

The term $S_{aij}dγ_j$ represents the part of the total distributional effect received by the poor in the household group $i$, and the term $r_{aij}$ denotes the related interdependency effects. The poverty sensitivity effects are positively related to poverty elasticity ($φ_{ai}$) and negatively related to mean income $γ_j$. If we define the modified direct distributional effects ($dS_{aij}$) as $dS_{aij} = S_{aij}dγ_j$ and we obtain $dP_{ij}/P_{ij} = S_{aij}dγ_j$ as $dS_{aij} = dγ_j(S_{aij}dγ_j)dγ_j = dγ_jdγ_jdγ_j$. Then Eq. (28) becomes

$$dP_{ij}/P_{ij} = \sum_{i=1}^{n} r_{aij}dγ_jdγ_jdγ_j$$

(29)

Eq. (29) shows that the overall income change accruing to the poor across household groups is composed of two parts, the total multiplier effect ($m'_{aij} = \sum_{i=1}^{n} m'_{aij} = \sum_{i=1}^{n} S_{aij}m_i$) and poverty effect ($q'_{aij} = -(dP_{ij}/P_{ij})m_i$).

**Impacts of mining development on poverty alleviation**

The multiplier decomposition incorporated by poverty sensitivity effects is adopted to analyze the impacts of mining development on poverty alleviation in China. In order to carry out the poverty decomposition, Table 3 is constructed to give the poverty profiles along the disaggregated six household groups (including both rural and urban households). Table 3 shows the estimates of elasticities of $P_{ij}$ with respect to mean income ($φ_{ai}$) and the poverty share out of total poverty ($S_{ai}$) using from 2008 China Urban Life and Price Yearbook and 2008 China Yearbook of Rural Household Survey. In Table 3, the poverty shares of rural low and middle are significantly higher than the other groups and the elasticities of poverty measure to mean income of rural high and urban high are greatly conspicuous.

**Table 3**

China’s poverty profile.

<table>
<thead>
<tr>
<th>Household</th>
<th>Mean income CNY</th>
<th>Population share</th>
<th>Elasticity of poverty measure to mean incomes</th>
<th>Group poverty share out of total poverty</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean CNY</td>
<td></td>
<td>Head count index</td>
<td>Poverty gap index</td>
</tr>
<tr>
<td>Rural-low</td>
<td>1802</td>
<td>0.140</td>
<td>-0.903</td>
<td>-1.647</td>
</tr>
<tr>
<td>Rural-middle</td>
<td>4867</td>
<td>0.229</td>
<td>-2.420</td>
<td>-3.950</td>
</tr>
<tr>
<td>Rural-high</td>
<td>5727</td>
<td>0.212</td>
<td>-12.656</td>
<td>-25.078</td>
</tr>
<tr>
<td>Urban-low</td>
<td>5630</td>
<td>0.068</td>
<td>-3.450</td>
<td>-4.260</td>
</tr>
<tr>
<td>Urban-middle</td>
<td>7560</td>
<td>0.171</td>
<td>-6.048</td>
<td>-9.279</td>
</tr>
<tr>
<td>Urban-high</td>
<td>9650</td>
<td>0.180</td>
<td>-13.672</td>
<td>-26.685</td>
</tr>
</tbody>
</table>

*Mean income is set for 80% of the upper limit in the low income group, 130% of the lower limit in the high income group and weighted average in the middle group, according to Chen and Ravallion (1998).

Elasticities with respect to different poverty measures are obtained by running POVCAL which can be downloaded at http://research.Worldbank.org/povcalNet.

The poverty line is set to 2 US$ for rural households and 4 US$ for urban households which are computed by 2005 PPP for the year 2007.

FGT indexes are obtained by running POVCAL and then calculated to gain the group poverty share out of total poverty. Each of the household group was then allocated its share of poverty based on its population share.
shock of CNY 100 per capita in each mining sector. The modified multiplier \( (m'_{i,m}) \) in row 3 showing income increase is decomposed into distributional effects (row 1) and interdependency effects (row 2); and furthermore, the distributional effects are decomposed into intersectoral production linkages, direct linkages and transfer linkages. The impact of mining development is positively related to the multiplier effect but negatively related to the sensitivity effect. This implies mining growth would reduce poverty through the increase in income of the poor.

In addition, the fixed price multiplier effect is equal to the product of the corresponding distributional and interdependency effects. Taking head count measure as an example, the poverty alleviation effect from ‘metal ores’ sector is \(-0.137\) which is the product of the modified fixed price multiplier \((0.529)\) and the poverty sensitivity effect \((-0.258)\). Moreover, the modified fixed price multiplier is a product of the distributional effect \((0.129)\) and interdependency effect \((4.091)\). The above procedure can be adopted to obtain the distributional effect by multiplying the corresponding intersectoral production effect \((3.308)\), direct effect \((0.039)\) and transfer effect \((1.000)\).

From Table 4, it can be found that the impact of a particular mining sector on poverty alleviation varies in the different poverty measures. However, the ranking of the four mining sectors based on their total poverty alleviation is the same across the three poverty measures, such as ‘coal’ sector ranks first in the head count, poverty gap and distribution-sensitive measure. Therefore, the discussion of poverty alleviation effects can be based on any one of the three poverty measures. In this study, we would like to make a detailed investigation within the head count measure framework.

The first instructive observation is the detailed effects derived from the fixed price multiplier effect which is the product of the distributional effect and interdependency effect. Scrutinizing Table 4 across poverty measures, it is easy to find the total income effect from the mining sectors is more contributed by the interdependency effect than the distributional effect, shown by the ranking. The values and degree of independency effects differ more largely than the distributional effects across the mining sectors. This implies that the diversification of the different household group expenditure on the mining products has more effect on the income generation.

Moreover, the poverty sensitivity effects have a higher variation than do the modified fixed price multiplier rank and show significant effects to poverty alleviation. For instance, it can be seen that the largest poverty reduction for poverty gap measure and distribution-sensitive measure both appear in the ‘coal’ sector, which are largely explained by the poverty sensitivity effects since the fixed price multiplier ranking of the ‘coal’ is not the top in the poverty gap measure and distribution-sensitive measure. It is important to note that the poverty sensitivity effects are higher when the poverty rate in the particular mining sector is lower. This implies that the distribution of labor and capital from different income groups in the various mining sectors has effect on sectoral poverty alleviation. For instance, ‘coal’ sector has the biggest poverty sensitivity effect \((-0.143)\), which means the proportion of the labor and capital from high income household in the ‘coal’ is higher than other mining sectors. The effects in head count measure show that the poverty alleviation is contributed both by poverty sensitivity effects and modified multiplier.

At the sectoral level, Table 4 further shows that the ‘coal’ has the largest poverty reduction effects \((-0.143)\), followed by the ‘nonmetal and other ores’ \((-0.139)\), ‘metal ores’ \((-0.137)\) and ‘petroleum and natural gas’ \((-0.130)\). This is caused by the fact that the ‘coal’ has the largest poverty sensitivity effects among the sectors, which is an indication that the ‘coal’ is more intensive in the use of production factors (e.g. labor and capital) endowment of high income households than other mining sectors. Meanwhile, the poverty alleviation results are also proved by Table 2. On the one hand, we can find that the ‘coal’ has the largest positive effect on household income in Table 2, indicated by the total effects on household group at different levels. Two values of the total effects resulted from the ‘coal’ are greater than 1.000, which are for urban middle income and rural high income household because they

### Table 4

Poverty alleviation effects of income growth (per unit of income change).

<table>
<thead>
<tr>
<th>Head count measure</th>
<th>Coal</th>
<th>Petroleum and natural gas</th>
<th>Metal ores</th>
<th>Nonmetal and other ores</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Distributional effects</td>
<td>0.130</td>
<td>0.132</td>
<td>0.129</td>
<td>0.129</td>
</tr>
<tr>
<td>1a. Distributional transfer effects</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>1b. Direct distributional effects</td>
<td>0.049</td>
<td>0.073</td>
<td>0.039</td>
<td>0.043</td>
</tr>
<tr>
<td>1c. Distributional effects from production linkages</td>
<td>2.650</td>
<td>1.815</td>
<td>3.308</td>
<td>3.001</td>
</tr>
<tr>
<td>2. Interdependency effects</td>
<td>4.090</td>
<td>3.983</td>
<td>4.091</td>
<td>4.094</td>
</tr>
<tr>
<td>3. Fixed price multipliers</td>
<td>0.531</td>
<td>0.528</td>
<td>0.529</td>
<td>0.530</td>
</tr>
<tr>
<td>4. Poverty sensitivity effects</td>
<td>-0.270</td>
<td>-0.246</td>
<td>-0.258</td>
<td>-0.262</td>
</tr>
<tr>
<td>5. Poverty alleviation effects</td>
<td>-0.143</td>
<td>-0.130</td>
<td>-0.137</td>
<td>-0.139</td>
</tr>
</tbody>
</table>

### Poverty gap measure

| 1. Distributional effects | 0.081 | 0.089 | 0.084 | 0.084 |
| 1a. Distributional transfer effects | 1.000 | 1.000 | 1.000 | 1.000 |
| 1b. Direct distributional effects | 0.030 | 0.050 | 0.026 | 0.027 |
| 1c. Distributional effects from production linkages | 2.761 | 1.780 | 3.369 | 3.080 |
| 2. Interdependency effects | 4.163 | 3.851 | 4.038 | 4.072 |
| 3. Fixed price multipliers | 0.339 | 0.342 | 0.341 | 0.340 |
| 4. Poverty sensitivity effects | -0.513 | -0.468 | -0.491 | -0.497 |
| 5. Poverty alleviation effects | -0.174 | -0.160 | -0.167 | -0.169 |

### Distribution-sensitive measure

| 1. Distributional effects | 0.051 | 0.058 | 0.054 | 0.054 |
| 1a. Distributional transfer effects | 1.000 | 1.000 | 1.000 | 1.000 |
| 1b. Direct distributional effects | 0.018 | 0.033 | 0.016 | 0.017 |
| 1c. Distributional effects from production linkages | 2.816 | 1.763 | 3.399 | 3.119 |
| 2. Interdependency effects | 4.323 | 3.776 | 4.014 | 4.071 |
| 3. Fixed price multipliers | 0.221 | 0.211 | 0.219 | 0.218 |
| 4. Poverty sensitivity effects | -0.754 | -0.688 | -0.722 | -0.731 |
| 5. Poverty alleviation effects | -0.164 | -0.152 | -0.158 | -0.159 |
input more production factors into the ‘coal’ mining activity. On the other hand, it has few positive impacts on urban and rural low income households.

The above analysis suggests that the poor can receive income and welfare growth if they are involved in the mining industry development. This may be one way to reduce poverty, especially in the resource-rich region. However, the positive effects on income and welfare of the poor are limited. This implies the government should appropriate adjustment on the distribution of income between rich and poor households, such as direct subsidy and transfer payment to the poor.

Conclusion

This study attempts to examine the mining growth effect on household income increase with fixed price multiplier decomposition and poverty alleviation by a multiplier decomposition procedure incorporated poverty sensitivity effects. The analysis of the former can be adopted to capture the direct and indirect effects of a unit change in demand of mining sectors on income increase for household groups at different income levels in detail. However, it is difficult to obtain useful information on the linkage between mining growth and poverty alleviation. Therefore, the latter SAM multiplier decomposition method developed by Thorbecke and Jung (1996) is used to analyse the impact of different mining sectors on poverty reduction which is constituted of the multiplier effect and sensitivity effect.

By using the SAM approach, the effects of mining development on poverty can be decomposed into the multiplier effect and sensitivity effect. The multiplier effect takes into account the poverty share of the different household groups and shows the income growth effects on the households. This effect can be further decomposed into the distribution effects and interdependency effects. The distribution effect in turn is decomposed into the transfer effects, direct distributional effects and distributional effects from production linkages.

The household income-effect results, evaluated by the former fixed multiplier decomposition, confirm that an increase in mining activities benefits households, especially for the income of high and middle income households. However, disappointing, rural and urban low income household receive the least increase in income. In order to measure the role of mining in poverty alleviation within a clearer analysis framework, we incorporate the FGT poverty measure into the multiplier decomposition. The results show that the ‘coal’ contributes most to poverty alleviation followed by the ‘nonmetal and other ores’, ‘metal ores’ and ‘petroleum and natural gas’. The poverty sensitivity effect largely contributes to poverty alleviation, showing the same implication that low income household group, which has the biggest poverty rate, is the smallest beneficiary from the mining industry development. Therefore, the mining growth is more conducive to high income residents while has a minor role in poverty reduction for low income households. The policymakers should pay attention to the poverty alleviation for low income households while driving local resource-dependent economy growth in resource-rich areas and provides appropriate adjustment on the distribution of income between rich and poor households. Moreover, the government should help the unskilled human capital from the low income household group to handle advanced technology of mining through education and training. When the quality of the labour force is similar to the labour from the middle or high income households, the poverty alleviation effects (especially on the low income group) aroused by the mining development would be larger in the future.

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