The Impact of Energy Price Deregulation on Prices in China: A Structural Path Analysis

AKKEMIK K. Ali (Corresponding author)*, LI Jia**

(Abstract)

Rapid economic growth in China is accompanied by the increasing demand for energy. It is also argued that the Chinese energy use is inefficient due to distortions in the pricing system. The deregulatory reforms in the 2000s have brought about the price increases in the energy market. The impact of the changing energy prices on price levels in production sectors in the economy is important due to inter-sectoral relations. This paper evaluates the potential impacts of changes in energy prices in China from the social accounting matrix (SAM) price modeling viewpoint. To this end, we construct a SAM for China and examine the impacts of changing energy prices on prices in the economy. We conduct our analysis separately for four different types of energy, namely, coal, oil, electricity, and natural gas. We found that the impact of changes in electricity generation cost appears to affect the consumer prices the most while the impact of natural gas prices is the least significant and negligibly small.

1. Introduction

China has been growing rapidly since the economic reform started in 1978 and this rapid growth is accompanied by the increasing demand for energy. Recently, China's energy supply fell behind its total energy demand. China has become a net oil importer in 1993 as well as a net natural gas importer in 2006, and the proportion of imported energy has been growing continuously (NSD, 2014). According to the World Development Indicators database, the net energy imports accounted for 7.5 percent of China's total energy use on average between 1999 and 2014. In the meantime, air pollution has become a serious public health issue in China due to its heavy reliance on coal as the primary source of energy. Chen et al. (2013) report that coal accounts for 67% of China's total energy consumption, and between 350,000 and 500,000 people die prematurely each year as a result of outdoor air pollution. Energy supply security, energy-saving, and improving energy efficiency appear to be the most important challenges facing the Chinese government (Yuan et al., 2008).

In a market economy, price plays an essential role in resource allocation, so China made substantial efforts in introducing market mechanism in its pricing system after 1978 and achieved significant progress by the early 1990s; however, to avoid macroeconomic turbulence, price interventions in energy sector had been largely maintained (World Bank, 1992). As a

* Yamaguchi University

** University of Niigata Prefecture

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result, China's energy prices have long been set at a relatively low level, which is sometimes even below the relevant production costs, and does not reflect storage and/or transmission costs. This low price, in turn, has led to insufficient investments in energy efficiency as well as renewables. Recently, as argued by Zhang (2018), although the task of price reform is far from complete, the market mechanism has been gradually introduced to the energy market, and the pace and scope of the reform differ across energy types.

In terms of oil, China initiated a major price reform in 1998. In the year, a linkage mechanism between domestic crude oil price and the international price was introduced; while the monthly adjustment of petroleum product price with reference to the Singapore market was implemented two years later in 2000. Thus, the price of refined oil products decoupled from the crude oil prices, which caused deficits of domestic refineries and supply shortage. To address the issue, the National Development and Reform Commission (hereafter, NDRC) has launched several rounds of reform to better reflect refiners' costs and adjust to the fluctuations of international price in a timely manner since 2001. In 2001, a reform on petroleum product price was implemented in connection to the weighted average price for petroleum products in three markets including Singapore, Rotterdam, and New York. Later on, in 2009, a new pricing mechanism was adopted which allowed domestic petroleum product prices to adjust upwards if the moving average of international crude oil prices (composite Brent, Dubai, and Cinta crude oil prices) rose by more than 4 percent within 22 consecutive working days. In 2013, the NDRC further shortened the adjustment period from 22 to 10 working days and removed the 4 percent threshold. Most recently, in 2016, the NDRC introduced a ceiling price of 130 USD/barrel together with a floor price of 40 USD/barrel and specified that price adjustment on refined oil products would be made if international crude oil prices fell into this range. Confronted with the high costs of domestic production and increasing reliance on foreign oil, the floor price is considered to sustain domestic production (Zhang, 2018); while the ceiling price is considered to avoid the macroeconomic turbulence.

In the natural gas market, major pricing mechanism reform was initiated in 2011. In the year, the NDRC announced a pilot scheme targeting Guangdong and Guangxi provinces, which linked the natural gas price to the market-oriented prices of alternative fuels and set the city-gate prices accommodating the fees of pipeline transmissions. In 2013, the scheme was promoted nationwide for all volumes above the 2012 gas consumption level. In the meantime, the NDRC started to price natural gas according to the user type (non-residential and residential). Currently, the price for more than 80 percent of natural gas consumption for non-residential use is determined by the market, of which about 50 percent is completely set by the market and about 30 percent is set by benchmark prices supplemented with fluctuation ranges (Zhang, 2018). In the case of the natural gas price for residential use, the Chinese government appears to be more cautious. Although the residential natural gas price has been set at the level much lower than that of non-residential users, the NDRC has started a three-tier tariff system for household use of natural gas gradually since 2014, with each province allowed to determine the consumption volume for each tier (Zhang, 2018).

Electricity price is the most important but also the most controversial issue because, due to the heavy reliance on power generation on coal, electricity, and coal prices are inextricably linked. Electricity tariffs have remained rather flat and regulated, while coal prices were largely liberalized in the early 1990s. Specifically, in 1993, the price of coal sold to non-electricity sectors was set free; however, the price of coal used for electricity generation remained under control through contract price and the government's guidance price.[1] The mismatch between fixed electricity tariffs and varying coal prices has created significant distortions. When coal prices rose, power plants could not pass along the higher prices to end-users by raising electricity tariffs and suffered huge losses. In 2004, the NDRC introduced a co-movement mechanism between coal and electricity prices through which electricity tariffs would be raised if coal price rose by 5 percent or more in no less than six months, power plants could pass along up to 70 percent of increased fuel costs to grid companies.[2] In 2012, the Chinese government announced the coal price for electricity generation would also be determined by the market, and electricity tariffs would be adjusted if fluctuations in coal prices went beyond 5 percent or more in 12 months, and power plants could pass along up to 90 percent of increased fuel costs to grid companies. The coal-electricity co-movement mechanism was further elaborated in 2015. It specified that using the 2014 average price as a reference, on-grid electricity tariffs would be adjusted if the fluctuations in coal price for electricity generation fell into the range of RMB30-150 per ton. Additionally, retail prices for industrial and commercial users of electricity would be adjusted accordingly, while those for residential and agricultural users would still be kept relatively flat. Although the electricity tariffs have been raised for several times since 2005, it is worthy to note that the implementation of the co-movement mechanism has often been postponed due to the government's concerns on maintaining price stability and profitability of downstream power users (Zhang, 2018).

Past studies on China's energy price deregulation have mostly investigated the link between energy prices and energy efficiency. For instance, Hang and Tu (2007) investigated the impacts of changes in energy prices on aggregate energy intensity and coal/oil/electricity intensity. However, those studies have not touched upon the impacts of changing energy prices on other prices in economic activities. Changes in energy prices will be reflected in production costs in other segments of the economy and subsequently, producer and consumer prices are affected. In this paper, we would evaluate the potential impacts of changes in energy prices in China from these aspects using the social accounting matrix (SAM) price modeling approach. The SAM price model is sufficient to capture the multiplier effects that underline these pass-through effects. To this end, we construct a SAM to examine the impact of a change in energy prices on prices in the economy. We conduct our analysis for the changes in coal, oil, electricity, and gas prices.

The rest of the paper is organized as follows. The second section introduces the method of analysis. Data construction method and data sources are explained in Section 3. The results of analyses and the interpretation of the findings with policy implications are presented in the fourth section. Finally, Section 5 summarizes the results and concludes.

2. Methodology

2.1. SAM Price Model

SAM is an extended input-output table in the form of a square matrix which organizes the transactions and interdependencies among all institutions (households, enterprises, government, and the rest of the world) and production activities in the economy. Each column represents payments and each row represents receipts. Since total payments must equal total receipts in the national economy, row sum and column sums are equal. A SAM model examines the consequences of a shock in one of the SAM accounts which is set as exogenous. For this purpose, some accounts are set as exogenous and the others as endogenous. In the conventional quantity-based SAM models, which have been widely used in policy analyses, a shock given to the exogenous accounts produces changes in the endogenous accounts via a multiplier process. The quantity-based SAM models measure the changes in the activities by fixing the price levels at unity so that the results reflect the changes in quantities.

We aim to examine the consequences of changing prices in the prices of economic activities by using the SAM price modeling approach which is originally introduced by Roland-Holst and Sancho (1995). Parra and Wodon (2008) and Nganou et al. (2009) present a description of the algebraic model. Recent applications of SAM price modeling include Parra and Wodon (2008), Nganou et al. (2009), Akkemik (2011), Tlhalefang and Galebotswe (2013). The SAM price model is the dual version of the quantity-based SAM model. While the quantity-based SAM model holds the prices fixed and allows activity levels to change, the SAM price model holds the activity levels fixed and measures the changes in the price levels of the activities. The price levels of activity accounts reflect producer prices and the price level of the commodity accounts represents consumer prices.

There are other techniques available in the literature that transform the quantity-based SAM or input-output models to price models by transforming the monetary units to physical units (e.g., Han et al. 2004, Nguyen 2008). The SAM price model also does this but it additionally assumes equivalence of physical and monetary measures (Parra and Wodon 2009: 73-75). Input-output tables in physical units are not available. Therefore, the first task in SAM price modeling is to transform the official input-output table figures, which are expressed in monetary terms, to physical units.

We adopt the methodology for the SAM price model from Parra and Wodon (2009). To transform the monetary input-output figures to physical input-output figures, at the outset, we assume that there are n endogenous accounts and r-n exogenous accounts. Total expenditures of account j (Y_j) are then written as follows:

$$Y_j = \sum_{i=1}^{n} T_{ij} + \sum_{m=n+1}^{r} W_{mj} \tag{1}$$

T_{ij} represents a payment from account j to account i and W_{mj} represents a payment from account j to an exogenous account m. If we denote the price of account j by P_j, physical output of account j by Q_j, and the share of the output of account i used by account j by s_{ij}, then total expenditures of account j is written as follows:

$$P_j Q_j = \sum_{i=1}^{n} P_i s_{ij} + \sum_{m=n+1}^{r} P_m s_{mj} \tag{2}$$

Then, the price of the account j is obtained as follows:

$$P_j = \sum_{i=1}^{n} \frac{P_i s_{ij}}{Q_j} + \sum_{m=n+1}^{r} \frac{P_m s_{mj}}{Q_j} \tag{3}$$

Parra and Wodon (2008) defines the physical technical coefficients for the endogenous accounts (c_{ij}) as $c_{ij} = s_{ij}/Q_j$ and define total payments to exogenous accounts per physical unit of the output of account j as b_j. Then, the price of the account j is obtained as follows:

$$P_j = \sum_{i=1}^{n} P_i c_{ij} + b_j \tag{4}$$

This equation can be written in matrix notation as follows:

$$P = C'P + B \tag{5}$$

where C' is the transpose of the $r \times r$ matrix whose elements are c_{ij} and B is the $r \times 1$ vector whose elements are b_j. P is the $r \times 1$ price vector. Then, the price model is obtained as follows:

$$P = (I - C')^{-1} B \tag{6}$$

Miller and Blair (1985) interpret the quantity-based technical coefficients as physical coefficients by assuming that monetary values of output represent physical quantities. Based on this interpretation, Parra and Wodon (2008) rewrite the price equations in terms of physical quantities. Most SAM models in the literature are quantity models and prices are fixed to unity. In the SAM price model, quantities are fixed and prices are allowed to change. Denoting the conventional technical input-output coefficients in the Leontief model as a_{ij} and their matrix as A, price equations can be rewritten in terms of physical quantities as follows:

$$P = A'P + B \tag{7}$$

Finally, the change in the price level (ΔP) of a SAM account j is obtained as follows:

$$\Delta P = (I - A')^{-1} \Delta B \tag{8}$$

2.2. Decomposition and Structural Path Analysis

To measure the impact of the changes in energy prices, we exogenously change the price levels of the relevant energy accounts in the SAM. The resulting changes in the SAM accounts work through the so-called SAM price multipliers which extend the initial impact of the exogenous shock to intersectoral transactions. To illustrate how the multiplier works, consider the multiplier in the quantity-based SAM model and assume a new investment that increases the production capacity in one of the energy sectors. The new investment leads to an increase in the activity level of, for instance, the construction sector and consequently to an increase in the employment of labor. Increased labor, then, leads to an expansion of income and to an increase in demand and consumption of food, clothing, durable goods, etc. With an increase in output in these industries; another round of employment is started and this goes on. In the SAM price model, the multiplier process works through price levels of activities, and quantities are fixed. The increase in the price of energy due to an increase in generation cost, for instance, results in changes in the price levels of other activities through SAM price multipliers. Naturally, the prices in industries that use energy more intensively are expected to be affected more.

2.2.1. Decomposition of the SAM Price Multipliers

The decomposition of SAM price multipliers, $(I-A')^{-1}$, is adopted from Nganou et al. (2009: 19-20).[3] To start with, equation (7) can be rewritten as follows:

$$P=(A'-\tilde{A})P+\tilde{A}P+B=A^{*}P+(I-\tilde{A})^{-1}B \tag{9}$$

where $\tilde{A}$ is a non-singular matrix representing the endogenous accounts of the SAM and $A^{*}=(I-\tilde{A})^{-1}(A'-\tilde{A})$。 $\tilde{A}$ is defined as follows: $\tilde{A}=\begin{bmatrix} A'_{11} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & A'_{33} \end{bmatrix}$

Here, the first row and column are partitions of activity and commodity accounts. The second row and column are factors of production accounts (capital and labor), and the third row and column are endogenous institutional accounts, i.e., households. Replacing A^{*}, we get:

$$A^{*}=(I-\tilde{A})^{-1}(A'-\tilde{A})=\begin{bmatrix} (I-A'_{11})^{-1} & 0 & 0 \\ 0 & I & 0 \\ 0 & 0 & (I-A'_{33})^{-1} \end{bmatrix}\times\begin{bmatrix} 0 & A'_{21} & 0 \\ 0 & I & A'_{32} \\ A'_{13} & 0 & 0 \end{bmatrix}$$

$$=\begin{bmatrix} 0 & A^{*}_{12} & 0 \\ 0 & I & A^{*}_{23} \\ A^{*}_{31} & 0 & 0 \end{bmatrix} \tag{10}$$

where $A^{*}_{12}=(I-A'_{11})^{-1}A'_{21}$, $A^{*}_{23}=A'_{32}$, and $A^{*}_{31}=(I-A'_{33})^{-1}A'_{13}$

Multiplying both sides of equation (9) by A^{*}, we get:

$$A^{*}P=A^{*2}P+A^{*}(I-\tilde{A})^{-1}B \tag{11}$$

After replacing the expression for A^{*} in equation (11) into equation (9), we get:

$$P=A^{*2}P+(I+A^{*})(I-\tilde{A})^{-1}B \tag{12}$$

Multiplying this equation by A^{*2} and replacing the expression $A^{*2}P$ from equation (11), i.e., $A^{*}P-A^{*}(I-\tilde{A})^{-1}B$, we get:

$$P=(I-A^{*3})^{-1}(I+A^{*}+A^{*2})(I-\tilde{A})^{-1}B \tag{13}$$

This equation is another representation of the decomposition equation (8). Following the conventional notation, we define each term as follows: $M_1 = (I-\tilde{A})^{-1}$, $M_2 = (I+A^{*}+A^{*2})$, and $M_3 = (I-A^{*3})^{-1}$. The matrices M_1, M_2, and M_3 are found as follows:

$$M_1 = \begin{bmatrix} (I-A'_{11})^{-1} & 0 & 0 \\ 0 & I & 0 \\ 0 & 0 & (I-A'_{33})^{-1} \end{bmatrix} \quad (14)$$

$$M_2 = \begin{bmatrix} I & A^{*}_{12} & A^{*}_{12}A^{*}_{23} \\ A^{*}_{23}A^{*}_{31} & I & A^{*}_{23} \\ A^{*}_{31} & A^{*}_{31}A^{*}_{12} & I \end{bmatrix} \quad (15)$$

$$M_3 = \begin{bmatrix} (I-A'_{12}A^{*}_{23}A^{*}_{31})^{-1} & 0 & 0 \\ 0 & (I-A'_{23}A^{*}_{31}A^{*}_{12})^{-1} & 0 \\ 0 & 0 & (I-A'_{31}A^{*}_{12}A^{*}_{23})^{-1} \end{bmatrix} \quad (16)$$

Therefore, the original multiplier $(I-A')^{-1}$ in equation (8) is finally decomposed into M_1, M_2, and M_3 as follows:

$$(I-A')^{-1} = M_3M_2M_1 \quad (17)$$

After algebraic manipulation, we can further decompose the multiplier into an additive form as follows:

$$(I-A')^{-1} = I+(M_1-I)+(M_2M_1-M_1)+(M_3M_2M_1-M_2M_1) \quad (18)$$

The first term on the right-hand side (the identity matrix I) represents the initial shock. The matrix M_1 shows the net effect of an account on itself via direct transfers. The matrix M_2 shows the effect of the shock among different accounts, and the matrix M_3 shows the circular effect of income multipliers across the endogenous accounts of the SAM. The term (M_1-I) is named the transfer effect (TE), the term $(M_2M_1-M_1)$ is named the open-loop effect (OLE), and the term $(M_3M_2M_1-M_2M_1)$ is named the closed-loop effect (CLE).

TE, OLE, and CLE demonstrate the formation of prices across sectors by taking into account interdependencies across various SAM accounts. Direct price effect measures the effect of a change in the price level of an activity on the production block itself (activity and commodity accounts combined).

Transfer effect (TE) is found as follows:

$$TE = \begin{bmatrix} (I-A'_{11})^{-1}-I & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & (I-A'_{33})^{-1}-I \end{bmatrix} \quad (19)$$

TE shows the effect of endogenous SAM blocks on themselves as shown by the diagonal elements. Specifically, TE accounts for the changes arising from an exogenous shock within a group of accounts (e.g., activities block, commodities block, and institutions block). In the institutions block, note that the enterprises, government and the rest of the world accounts are all exogenous and only the households account is endogenous. TE is not allowed within the factors block (capital and labor) as represented by diagonal members corresponding to the second row and second column which are zero. If the price level of an energy activity account changes, TE measures how the changing energy cost is multiplied through cost relationships across production activities.

Open-loop effect (OLE) is found as follows:

$$\text{OLE} = \begin{bmatrix} 0 & A^*_{12} & A^*_{12}A^*_{23}((I-A'_{33})^{-1}-I) \\ A^*_{23}A^*_{31}((I-A'_{11})^{-1}-I) & 0 & A^*_{23}((I-A'_{33})^{-1}-I) \\ A^*_{31}((I-A'_{11})^{-1}-I) & A^*_{31}A^*_{12} & 0 \end{bmatrix} \tag{20}$$

OLE measures the effect of an exogenous shock across different SAM blocks. OLE resulting from a change in the price level of an energy account reflects the interactions of costs across production sectors due to intersectoral cost structure in the economy. The diagonal members of this matrix are zero, implying direct effects among SAM accounts.

Finally, closed－loop effect (CLE) is found as follows:

$$\text{CLE} = \begin{bmatrix} M^*_{31}(I-A'_{11})^{-1} & M^*_{31}A^*_{12} & M^*_{31}A^*_{12}A^*_{23}(I-A'_{33})^{-1} \\ M^*_{32}A^*_{23}A^*_{31}(I-A'_{11})^{-1} & M^*_{32} & M^*_{32}A^*_{23}(I-A'_{33})^{-1} \\ M^*_{33}A^*_{31}(I-A'_{11})^{-1} & M^*_{33}A^*_{31}A^*_{12} & M^*_{33}(I-A'_{33})^{-1} \end{bmatrix} \tag{21}$$

where $M^*_{31} = (I - A^*_{12}A^*_{23}A^*_{31})^{-1} - \text{I}$, $M^*_{32} = (I - A^*_{23}A^*_{31}A^*_{12})^{-1} - \text{I}$, and $M^*_{33} = (I - A^*_{31}A^*_{12}A^*_{23})^{-1} - \text{I}$. CLE measures the magnifying effect of an exogenous shock on endogenous accounts after the circular travel is completed. The shock travels all endogenous accounts and then returns to the original account, namely, from the production block (activities and commodities) to households account, then to factors block (capital and labor) and then back to the original production block. In the case of a change in energy price, the closed－loop effect demonstrates the effect of this change on the price levels of production sectors after affecting household price level (cost of living), then factor incomes (revenues from rendering of capital and labor services), and the costs of production.

2.2.2. Structural Path Analysis

The multiplier analysis is useful in examining the pass-through effects of a shock in an exogenous variable. However, they do not reveal information about the mechanism through which such effects operate. Structural path analysis, introduced by Defourney and Thorbecke (1984), fills this gap. As Thorbecke (2000: 29) argues, "...multipliers do not clarify the "black box," i.e., the structural and behavioral mechanism responsible for these global effects. From a policy standpoint, knowledge of the magnitude of multipliers is important but becomes of even greater operational usefulness if it is complemented by structural path analysis that identifies the various paths along which a given injection travels."

Structural path analysis examines the paths along which the effects arising from an exogenous price shock travel before reaching the endogenous account of the final destination. Roland-Holst and Sancho (1995) formulated the structural path analysis for the SAM price model. For brevity, we do not provide full details about the structural path analysis which can also be found in Parra and Wodon (2009: 66-69) and Li et al. (2004). We suffice with a brief overview of this technique. A graphical representation of this technique cited from Li et al. (2004) involving five sectors, i, k, r, m, and j is shown in Figure 1. The figure shows some possible paths through which a shock to the destination sector j from the sector of origin i may work. The a terms such as a_{km} show the intensity of a path. The direct path from i to j shown by the intensities of the paths from sector i to k and then to the destination sector j through the sector m ($i \rightarrow k \rightarrow m \rightarrow j$) is named the direct influence. An influence is calculated as the product of its constituent intensities. Therefore, direct influence is shown as $a_{ki}a_{mk}a_{jm}$.

In addition to the direct influence, there may be indirect effects. The intensities a_{ki} and a_{jm} are part of the direct influence for the shock of i on j. The influence running from k to m, however, may involve, other than the direct influence a_{mk}, circular relations of paths as shown by the intensities a_{km}, a_{kr}, and a_{rm}. These paths demonstrate the complicated indirect influences running from k to m through r. These influences run for several rounds. After the first round, the influence from k to m is shown as follows: $a^2_{mk}\ (a_{km}+a_{rm}\ a_{kr})^t$. After t rounds, this influence is found as follows: $a_{mk}\ (a_{mk})(a_{km}+a_{rm}a_{kr})^t$. With help from the knowledge of geometric series, the total influence is then found as follows: $a_{ki}a_{mk}a_{jm}\ (1-a_{mk}(a_{km}+a_{rm}a_{kr}))^{-1}$. Here, the term $a_{ki}a_{mk}a_{jm}$ is the direct influence, and $(1-a_{mk}(a_{km}+a_{rm}a_{kr}))^{-1}$ is named the path multiplier.

Finally, global influence represents the impact of a shock from sector i to j as shown by the inverse matrix $(I-A')^{-1}$. The results of the structural path analysis in section 5 present the results for direct influence, path multiplier, total influence, and global influence.

To summarize, direct price influence measures the effect of the production block (activities and commodities blocks) on itself. Path multipliers extend this direct impact to a combination of sectors that make up a path via intersectoral relations. Total price influence on the destination sector is measured by the product of the direct effect and path multiplier. The structural path analysis allows us to trace the paths through which the energy price shocks impact on the prices of other activities.

3. Data

The data for the SAM pricing model is organized into a SAM for 2007, for which the official input-output tables were available to us. The data from the input-output tables are combined with other related data to construct the SAM. The SAM has two 35 production accounts (activities and commodities), two factors of production (capital and labor), three institutions (households, firms, and government), a saving-investment account, and a rest of the world account. A list of sectors is presented in Table 1.

To construct the SAM, data from different sources (including the Input-Output Tables of China, Flow-of-Funds Statistics, and Balance of Payments statistics) were combined and balanced.[4] All these data are available in the China Statistical Yearbooks published by the National Bureau of Statistics. We assume that current transfers from the rest of the world to domestic sectors (except for government) are all destined to firms.

4. Results of the Analysis

In what follows, for the purpose of exposition, we examine the results by increasing the producer prices of petroleum, coal, gas, and electricity by 1 percent.[5]

4.1. Empirical Results

Table 3 shows the effect (price multipliers) of the 1 percent increase in energy prices on prices of the individual industry for coal, oil, electricity, and gas (c.f. columns of PM). As expected, the impact of the price increase in one of the four energy prices on itself is the most significant. The rise in the price of coal impacts the electricity, non-metallic mineral products and gas sectors more strongly than others. 1 percent increase in coal price increase electricity prices by about 0.202 percent. The oil price increase affects the refined oil products sector (0.396 percent) and gas sector (0.357 percent) the most, as expected, since the stated sectors are the main users of oil as input. On the other hand, natural gas prices do not impact the price levels in economic activities much. A rise in electricity prices is the most significant of all energy prices. Increasing electricity price by 1 percent increases the price level of 28 economic sectors by more than 0.1 percent. The increases in producer prices are relatively higher for electricity price shock. This is evidence of the importance of electricity in production activities.

An important result of this study is that the impact of changes in natural gas prices on other sectors' price levels is minimal. This finding begs for further explanation. One reason is that the share of natural gas in intermediate input demand by many sectors is extremely small. This finding also reflects the recent reforms of the government in the gas market. The government still provides various subsidies and implements relevant preferential policies regarding the consumption of natural gas. A number of firms including gas-fired power companies, heat suppliers, and even transportation firms enjoy such subsidies. Accordingly, natural gas remains highly underpriced in China.

4.2. Decomposition of Price Multipliers

The price multipliers are further decomposed into transfer effect and closed-loop effect as described in section 3.2.1 (Table 3). In a related study, Akkemik and Li (2015b) have conpared the decom position results for 2002 and 2007. This subsection builds on those results. Open-loop effects are not reported for production accounts because they are equal to zero since the origin and destination are in the same block. In addition, since we are not interested in income distribution, we do not report in detail the results for the institutions accounts (households). The impact of the price shocks on the households account reflects the effect on households' cost of living, which is negligibly small, between 0.001 and 0.032 percentage points. However, among the impacts of energy prices on the cost of living, the impact of electricity prices is significantly higher.

Transfer effects account for the largest portion of price multipliers. Strong transfer effect indicates strong intersectoral interaction and hence a high level of integration between the shock-giving sector and the destination sector. The transfer effects of the gas price shock were relatively low compared to the transfer effects of coal, oil, and electricity prices indicating a smaller degree of importance of gas as an energy source for the production sectors.

Closed-loop effects account for the remaining portion of the price multipliers after the transfer accounts are counted. Closed-loop effects are relatively small and they amount to about one-third of the price multipliers for the coal, oil, and electricity price shocks. This reflects the degree of forward linkages by these energy sectors. Closed-loop effects by coal and electricity dominate significantly only in agriculture. In addition, the services sectors and food manufacturing (food, beverages, and tobacco) generally exhibit large closed-loop effects in response to energy shocks compared to other production sectors. This finding reflects the strong forward linkages by these sectors with the rest of the economy. In the remaining sectors, closed-loop effects are relatively small, implying relatively small forward linkages.

The above-mentioned results indicate that the dependence of production sectors on electricity was large and much of the price influence arising from energy price shocks work through transfer effects while closed-loop effects are less significant. Energy price shocks are dictated mainly through intersectoral input relations and less through the circular flow.

4.3. Structural Path Analysis Results

Structural path analysis results are reported in Table 4. There are four panels in the table, each reporting the results for the different origin of the price shock. The first column reports the destination sector which the price shock affects. We report the results of the unitary price shocks for all sectors. The second column reports the paths through which the shock works. In each path, the unitary energy price shocks are allowed to travel across sectors as shown by the arrows. For the convenience of calculation and interpretation, we allow a path consisting of six sectors at the maximum.

Price shocks are decomposed into direct price shock and the path multipliers. The direct price influence (third column) measures the immediate impact of the price shock on the destination sector (first on production costs and then on the consumer prices of the destination sector). The path multipliers (fourth column) magnify this effect to reflect the impact on the whole economy. The product of the destination sector is used as inputs in other sectors, and therefore the direct impact on the price level of the destination sector is transmitted to other sectors via intersectoral transactions in the economy. Total price influence (fifth column) is obtained by multiplying the direct influence by the path multiplier. The percentage shares of the total influences of the specified paths in global influences are reported in the seventh column. For brevity, we only report the paths whose share exceeds 10 percent of total influence.

The structural path analysis includes important information about how the energy price shocks are transmitted via intersectoral paths. In interpreting the results in Table 4, an illustrative example is useful. The third row (panel: origin - coal) examines the impact of a 1 percent increase in the price of coal on the price level in the oil sector using the path starting from the coal sector and ending in the oil sector through the electricity sector. The direct price influence of the coal price shock is to increase agricultural prices by 0.7 percent (0.007) and this impact is expanded by the intersectoral transactions of the oil sector in the economy through the price multiplier (1.92). While the price level of the oil sector changes, this affects the price levels in the other sectors the oil sector interacts with (i.e., input use by the oil sector from other sectors such as machinery and the use of the oil sector's products as inputs by other sectors). Subsequently, the price level in the oil sector is affected more than the direct impact of the price shock, as demonstrated by the path multiplier. The total influence is to increase the prices by 1.4 percent (0.014). The global influence is 0.036, and the total influence of the path from coal to electricity to oil (*Coal→Electricity→Oil*) explains 38.3 percent of the impact of the coal price shock in the oil sector's price level. The other paths are far less important.

In addition, the results of the structural path analyses (panel: origin - coal) show that the coal price shock affects the prices in other production activities mainly and more strongly through its effect on electricity prices. This finding reflects the heavy reliance of electricity generation in China on coal. Although the Chinese government maintains its price interventions, the electricity tariffs have been deregulated gradually and reflect the changes in coal prices more significantly. In other words, coal, as a primary energy, its price shock affects other sectors through direct production input interrelations held by electricity.

Finally, in the case of electricity price and gas price increases, the paths are generally shorter and hence the direct impacts are more significant. Oil prices, on the other hand, affect the prices in other sectors mainly through its impact on refined oil products sector as the impacts on the activity prices more strongly as an input used in production.

5. Conclusion

In this paper, we examined the impact of the changes in energy prices on the price levels of other sectors in the Chinese economy using the SAM price model. SAM price model is an ex-ante model based on the parameters obtained from the SAM. Among the energy sectors, a change in the electricity generation cost affects the consumer prices the most while the impact of natural gas prices is the least significant and negligibly small. The magnitudes of the impacts of coal and oil prices fall in between electricity and gas. Electricity price appears to play an important role, especially by transmitting the impacts of the coal price changes. This is due to the fact that the electricity sector is the main buyer of coal in China.

The findings of this study have important policy implications for China's energy policies. The energy prices have long been set at a low level to facilitate rapid industrialization and protect end-users in China; however, recent reforms have increased the energy prices and therefore may have exerted an impact on inflation. Particularly, the findings for the economic impacts of the changes in the prices of coal and electricity have two policy implications regarding China's industrial upgrading. First, due to the dependence on thermal power generation, coal seems to remain the main source of primary energy consumption in China in the near future. The impacts of any price shock in the energy sectors on the Chinese economy will most probably come from coal, and consequently, the electricity sector. This will obviously have environmental repercussions as well. Although environmental issues are out of the scope of this paper, our results call for the change towards a greener economic structure. More specifically, our results justify the increasing investments in clean technology and renewables.

Second, increases in electricity tariffs will have an impact on production activities. Since the mid-1990s, the industrial structure in China has shifted from light industries to heavy industries. The increasing importance of heavy industries naturally induces more electricity consumption. This paper quantifies how producer prices will be affected by energy price increases. The results suggest that the increases in producer prices might dampen production activities significantly in the future. Therefore, the promotion of energy-efficient and energy-saving production techniques is a vitally important issue. On the other hand, the increase in energy prices may be accompanied by a reduction in subsidies the government provides to energy companies. If the rise in energy price also leads to greater energy efficiency, in the long run, social welfare can be expected to improve.

The findings and the conclusions of this paper should be understood as a rough estimate of the impact of energy price shocks and interpreted carefully due to methodological issues. The SAM price model keeps quantities fixed to allow price changes. Therefore, the production levels are not affected and as with all SAM models, there is the assumption of excess supply, i.e., an increase in demand is immediately met by supply. These assumptions underlying the SAM model may have created a bias and the increase in price levels might have been overestimated. In addition, the well-known limitations of SAM modeling prevail. SAM modeling does not allow for substitution among different energy sources due to the strict Leontief production function assumption. In other words, when the price of one energy sector changes, the other sectors are not allowed to substitute one energy source with another. Therefore, the results of the analysis in this study should be interpreted with caution. More sophisticated multi-sector models such as computable general equilibrium (CGE) models as in Akkemik and Li (2015) allow for substitution among energy sources. Policy analysis emphasizing such substitution relations should rather use CGE models.

Note

[1] Historically, coal prices were set at low levels to protect the power plants as well as mitigate the pressure of passing on higher coal prices to electricity generators, grid companies, and end-users. The NDRC set the prices for long-term purchasing contracts between coal mines and power plants until 2006.

[2] In 2002, China initiated the reform to separate transmission and distribution functions from power generation. The State Power Corporation of China was divided into the State Grid Corporation of China and financially independent power plants.

[3] See Pyatt and Round (1979) for the decomposition of the SAM multipliers in the quantity-based SAM models.

[4] For brevity, we abstain from the full description of each account in the SAM. We follow the standard SAMs widely used in policy analyses, e.g., Sadoulet and de Janvry (1995: 273-301) and Thorbecke (2000).

[5] Energy prices are expected to rise with deregulation and rising pressure on prices. Assuming that energy prices were below their costs, reduction in subsidies may lead the energy prices to get closer to marginal cost. Deregulation may allow firms enjoying substantial market power to abuse their market power by increasing prices. In addition, excessive entry may cause an increase in the average cost in the energy sector and hence equilibrium prices. Potential energy shortages may also put upward pressure on energy prices. Since the industrial sector consumes about two-thirds of the energy, supply shortages are likely.

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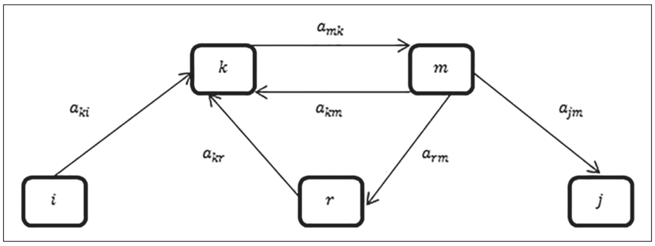
Figure 1. Structural path analysis



Source: Adopted from Li et al. (2004) and modified

Table 1. List of sectors and codes in the I-O Tables

	Acronym	Sector description	I-O codes
1	AGR	Agriculture	1
2	COAL	Coal mining and processing	2
3	OIL	Crude petroleum and natural gas products	3
4	MIN1	Metal ore mining	4
5	MIN2	Non-metal ore mining	5
6	FOOD	Manufacture of food products and tobacco processing	6
7	TEX	Textile	7
8	CLOT	Wearing apparel, leather, furs, down and related goods	8
9	WOOD	Wood processing and furniture manufacture	9
10	PAPER	Paper, printing, cultural, educational, sports products	10
11	REFOIL	Petroleum processing, coking, nuclear fuel	11
12	CHEM	Chemicals	12
13	MINR	Non-metallic mineral products	13
14	SMEL	Metal smelting and pressing	14
15	METAL	Metal products	15
16	MACH	Machinery and equipment	16
17	TRAN	Transport equipment	17
18	ELMACH	Electric equipment and machinery	18
19	TEL	Telecommunication equipment	19
20	PREC	Instruments, meters, cultural and office machinery	20
21	OTHMAN	Other manufacturing products	21
22	SCRAP	Scrap and waste	22
23	ELEC	Electricity, steam, hot water production and supply	23
24	GAS	Gas production and supply	24
25	WATER	Water production and supply	25
26	CONS	Construction	26
27	TRNS	Transport and warehousing	27
28	POST	Postal services	28
29	ICT	Information, communication, computer services	29
30	TRADE	Wholesale and retail trade	30
31	HOTRES	Hotel and restaurant businesses	31
32	FIN	Financial services	32
33	EST	Real estate	33
34	BUS	Leasing and business services	34
35	OTHSER	Other services	35-42

Table 2. Price shocks: percentage change in activity prices

		Producer prices up by 10 percent in			
		Coal	Oil	Electricity	Gas
1	AGR	0.3	0.3	1.3	0.1
2	COAL	11.5	0.3	2.0	0.0
3	OIL	0.4	10.4	1.8	0.0
4	MIN1	0.6	0.6	3.1	0.1
5	MIN2	0.5	0.6	2.0	0.1
6	FOOD	0.3	0.3	1.2	0.0
7	TEX	0.4	0.4	1.6	0.0
8	CLOT	0.3	0.3	1.2	0.0
9	WOOD	0.4	0.4	1.5	0.0
10	PAPER	0.4	0.3	1.4	0.0
11	REFOIL	0.9	4.0	1.4	0.0
12	CHEM	0.6	0.8	2.0	0.1
13	MINR	1.1	0.5	2.2	0.1
14	SMEL	0.7	0.5	2.1	0.1
15	METAL	0.5	0.4	2.1	0.0
16	MACH	0.4	0.4	1.6	0.0
17	TRAN	0.4	0.3	1.3	0.0
18	ELMACH	0.4	0.4	1.4	0.0
19	TEL	0.2	0.2	0.9	0.0
20	PREC	0.3	0.3	1.0	0.0
21	OTHMAN	0.4	0.4	1.5	0.1
22	SCRAP	0.1	0.1	0.3	0.0
23	ELEC	2.0	0.5	16.5	0.0
24	GAS	1.0	3.6	1.3	10.5
25	WATER	0.6	0.3	4.0	0.1
26	CONS	0.5	0.5	1.6	0.0
27	TRNS	0.3	0.9	0.9	0.0
28	POST	0.3	0.4	1.2	0.0
29	ICT	0.2	0.2	0.9	0.0
30	TRADE	0.2	0.2	0.8	0.0
31	HOTRES	0.3	0.3	1.2	0.1
32	FIN	0.1	0.2	0.6	0.0
33	EST	0.1	0.1	0.4	0.0
34	BUS	0.3	0.4	1.0	0.0

Source: Authors' calculations

Table 3. Price multiplier decomposition

	Coal price up by 1%			Oil price up by 1%			Electricity price up by 1%			Gas price up by 1%		
	PM	TE	CLE	PM	TE	CLE	PM	TE	CLE	PM	TE	CLE
AGR	0.031	0.011	0.020	0.034	0.014	0.020	0.128	0.044	0.083	0.005	0.001	0.004
COAL	0.147	0.137	0.010	0.034	0.024	0.010	0.198	0.154	0.044	0.004	0.002	0.002
OIL	0.036	0.029	0.007	0.042	0.035	0.007	0.178	0.149	0.029	0.004	0.002	0.001
MIN1	0.058	0.050	0.008	0.061	0.053	0.008	0.311	0.277	0.034	0.009	0.007	0.002
MIN2	0.045	0.037	0.009	0.057	0.048	0.009	0.203	0.166	0.037	0.009	0.008	0.002
FOOD	0.030	0.017	0.013	0.030	0.017	0.013	0.115	0.060	0.055	0.004	0.002	0.003
TEX	0.041	0.030	0.011	0.036	0.026	0.011	0.156	0.110	0.045	0.005	0.002	0.002
CLOT	0.035	0.024	0.011	0.034	0.023	0.011	0.124	0.079	0.045	0.004	0.002	0.002
WOOD	0.042	0.032	0.010	0.035	0.025	0.010	0.152	0.108	0.044	0.004	0.002	0.002
PAPER	0.040	0.032	0.008	0.034	0.026	0.008	0.143	0.108	0.034	0.004	0.002	0.002
REFOIL	0.088	0.082	0.006	0.396	0.390	0.006	0.139	0.114	0.025	0.005	0.003	0.001
CHEM	0.061	0.054	0.007	0.082	0.074	0.007	0.198	0.166	0.032	0.007	0.005	0.002
MINR	0.108	0.100	0.008	0.051	0.043	0.008	0.224	0.189	0.034	0.005	0.003	0.002
SMEL	0.070	0.064	0.006	0.052	0.046	0.006	0.207	0.181	0.026	0.005	0.004	0.001
METAL	0.054	0.047	0.007	0.042	0.035	0.007	0.212	0.182	0.030	0.005	0.003	0.002
MACH	0.044	0.037	0.007	0.036	0.029	0.007	0.156	0.125	0.030	0.004	0.003	0.002
TRAN	0.037	0.029	0.007	0.034	0.026	0.007	0.133	0.102	0.032	0.004	0.003	0.002
ELMACH	0.042	0.036	0.006	0.038	0.031	0.006	0.145	0.118	0.027	0.004	0.003	0.001
TEL	0.023	0.018	0.005	0.023	0.017	0.005	0.091	0.069	0.022	0.003	0.002	0.001
PREC	0.030	0.024	0.006	0.027	0.021	0.006	0.103	0.076	0.026	0.004	0.002	0.001
OTHMAN	0.045	0.035	0.010	0.038	0.028	0.010	0.151	0.108	0.042	0.005	0.003	0.002
SCRAP	0.007	0.005	0.002	0.006	0.004	0.002	0.027	0.017	0.010	0.001	0.000	0.001
ELEC	0.202	0.194	0.007	0.053	0.046	0.007	0.648	0.616	0.032	0.004	0.003	0.002
GAS	0.099	0.092	0.007	0.357	0.351	0.007	0.130	0.101	0.029	0.049	0.048	0.001
WATER	0.060	0.050	0.010	0.034	0.024	0.010	0.399	0.357	0.043	0.007	0.005	0.002
CONS	0.054	0.046	0.009	0.047	0.038	0.009	0.161	0.124	0.037	0.004	0.002	0.002
TRNS	0.034	0.026	0.007	0.089	0.081	0.007	0.094	0.063	0.032	0.004	0.002	0.002
POST	0.031	0.017	0.014	0.042	0.029	0.014	0.119	0.060	0.058	0.005	0.002	0.003
ICT	0.017	0.011	0.006	0.016	0.009	0.006	0.086	0.060	0.026	0.003	0.001	0.001
TRADE	0.018	0.011	0.007	0.022	0.015	0.007	0.081	0.049	0.031	0.003	0.001	0.002
HOTRES	0.027	0.016	0.011	0.027	0.017	0.011	0.122	0.077	0.045	0.006	0.004	0.002
FIN	0.014	0.007	0.008	0.016	0.009	0.008	0.065	0.032	0.033	0.002	0.001	0.002
EST	0.010	0.005	0.005	0.012	0.007	0.005	0.039	0.019	0.020	0.001	0.000	0.001
BUS	0.027	0.019	0.008	0.036	0.028	0.008	0.101	0.067	0.034	0.004	0.002	0.002
OTHSER	0.033	0.020	0.013	0.035	0.022	0.013	0.127	0.072	0.055	0.005	0.002	0.003

Note: PM: Price multiplier, TE: Transfer effect, CLE: Closed-loop effect, PM = TE + CLE.
Source: Authors' calculations

Table 4. The results of the structural path analysis

Destination	Paths	Direct inf.	Path multiplier	Total inf.	Global inf.	Total / Global (%)
			Origin - Coal			
AGR	COAL→ELEC→AGR	0.001	3.17	0.003	0.031	10.8
COAL	COAL→COAL	0.980	1.15	1.124	1.124	100.0
OIL	COAL→ELEC→OIL	0.007	1.92	0.014	0.036	38.3
MIN1	COAL→ELEC→MIN1	0.014	1.99	0.028	0.058	47.6
MIN2	COAL→ELEC→MIN2	0.007	1.99	0.013	0.045	29.3
FOOD	COAL→FOOD	0.002	1.66	0.004	0.030	12.0
TEX	COAL→TEX	0.004	1.86	0.007	0.041	18.2
	COAL→ELEC→TEX	0.002	3.00	0.007		17.0
WOOD	COAL→WOOD	0.005	1.61	0.008	0.042	18.9
	COAL→ELEC→WOOD	0.002	2.60	0.006		14.1
PAPER	COAL→PAPER	0.005	1.60	0.008	0.040	20.6
	COAL→ELEC→PAPER	0.002	2.58	0.006		14.9
REFOIL	COAL→REFOIL	0.052	1.27	0.066	0.088	75.3
CHEM	COAL→CHEM	0.013	1.90	0.024	0.061	38.9
	COAL→ELEC→CHEM	0.005	3.04	0.015		24.0
	COAL→REFOIL→CHEM	0.003	2.08	0.006		10.4
MINR	COAL→MINR	0.049	1.39	0.068	0.108	63.2
	COAL→ELEC→MINR	0.006	2.24	0.014		13.5
SMEL	COAL→SMEL	0.019	1.76	0.033	0.070	47.3
	COAL→ELEC→SMEL	0.005	2.82	0.014		19.4
METAL	COAL→SMEL→METAL	0.006	2.02	0.013	0.054	23.2
	COAL→ELEC→>METAL	0.005	2.15	0.010		18.7
MACH	COAL→SMEL→MACH	0.004	2.18	0.008	0.044	18.5
	COAL→ELEC→MACH	0.002	2.33	0.005		12.5
	COAL→MACH	0.003	1.45	0.005		10.8
TRAN	COAL→SMEL→TRAN	0.002	2.56	0.005	0.037	14.0
ELEC	COAL→SMEL→ELEC	0.005	2.04	0.010	0.042	23.7
TEL	COAL→ELEC→TEL	0.001	2.62	0.003	0.023	11.6
OTHMAN	COAL→OTHMAN	0.006	1.23	0.007	0.045	15.0
SCRAP	COAL→SCRAP	0.001	1.27	0.001	0.007	17.6
	COAL→ELEC→SCRAP	0.001	2.05	0.001		14.0
ELEC	COAL→ELEC	0.103	1.85	0.190	0.202	94.2
GAS	COAL→GAS	0.062	1.20	0.074	0.099	75.4
WATER	COAL→ELEC→WATER	0.020	1.92	0.039	0.060	64.9
CONS	COAL→MINR→CONS	0.010	1.41	0.014	0.054	26.5
TRNS	COAL→REFOIL→TRNS	0.009	1.40	0.013	0.034	37.4
TRADE	COAL→ELEC→TRADE	0.002	1.95	0.003	0.018	16.5
HOTRES	COAL→ELEC→HOTRES	0.003	1.95	0.005	0.027	19.1
FIN	COAL→ELEC→FIN	0.001	2.04	0.002	0.014	12.5
OTHSER	COAL→ELEC→OTHSER	0.002	2.14	0.004	0.033	11.5
			Origin - Oil			
AGR	OIL→REFOIL→AGR	0.003	1.63	0.004	0.034	12.6
	OIL→REFOIL→CHEM→AGR	0.001	2.64	0.004		10.5
COAL	OIL→REFOIL→COAL	0.005	1.28	0.006	0.034	17.2
	OIL→REFOIL→TRNS→COAL	0.003	1.42	0.004		12.5
OIL	OIL→OIL	0.619	1.04	0.645	0.645	100.0
MIN1	OIL→REFOIL→MIN1	0.020	1.21	0.024	0.061	39.3
	OIL→MIN1	0.007	1.12	0.008		12.8

MIN2	OIL→REFOIL→MIN2	0.013	1.21	0.016	0.057	27.9
	OIL→MIN2	0.008	1.12	0.008		14.9
TEX	OIL→REFOIL→CHEM→TEX	0.002	2.99	0.006	0.036	17.6
	OIL→CHEM→TEX	0.001	2.78	0.004		11.3
WOOD	OIL→REFOIL→CHEM→WOOD	0.002	2.60	0.004	0.035	11.4
PAPER	OIL→REFOIL→CHEM→PAPER	0.002	2.56	0.006	0.034	18.5
	OIL→CHEM→PAPER	0.002	2.39	0.004		11.9
REFOIL	OIL→REFOIL	0.349	1.13	0.393	0.396	99.3
CHEM	OIL→REFOIL→CHEM	0.021	1.85	0.038	0.082	46.8
	OIL→CHEM	0.014	1.72	0.025		30.1
MINR	OIL→REFOIL→MINR	0.010	1.37	0.013	0.051	26.6
	OIL→MINR	0.004	1.27	0.005		10.1
SMEL	OIL→REFOIL→SMEL	0.015	1.72	0.026	0.052	49.1
METAL	OIL→REFOIL→SMEL→METAL	0.005	1.98	0.010	0.042	23.4
MACH	OIL→REFOIL→SMEL→MACH	0.003	2.13	0.006	0.036	17.3
	OIL→REFOIL→MACH	0.003	1.42	0.005		12.7
TRAN	OIL→REFOIL→SMEL→TRAN	0.002	2.51	0.004	0.034	11.8
ELEC	OIL→REFOIL→SMEL→ELEC	0.004	2.00	0.008	0.038	20.7
TEL	OIL→REFOIL→CHEM→TEL	0.001	2.62	0.003	0.023	12.9
PREC	OIL→REFOIL→CHEM→PREC	0.002	1.91	0.003	0.027	12.6
SCRAP	OIL→REFOIL→CHEM→SCRAP	0.000	2.05	0.001	0.006	12.4
	OIL→REFOIL→SCRAP	0.001	1.24	0.001		11.2
ELEC	OIL→REFOIL→ELEC	0.013	1.84	0.024	0.053	45.2
	OIL→ELEC	0.007	1.71	0.012		22.5
GAS	OIL→GAS	0.309	1.09	0.338	0.357	94.5
WATER	OIL→REFOIL→ELEC→WATER	0.003	1.91	0.005	0.034	14.5
CONS	OIL→REFOIL→CONS	0.007	1.14	0.008	0.047	16.1
	OIL→REFOIL→TRNS→CONS	0.004	1.26	0.006		11.9
TRNS	OIL→REFOIL→TRNS	0.061	1.24	0.075	0.089	85.1
POST	OIL→REFOIL→POST	0.011	1.17	0.013	0.042	30.1
	OIL→REFOIL→TRNS→POST	0.006	1.29	0.007		17.0
TRADE	OIL→REFOIL→TRNS→TRADE	0.005	1.30	0.007	0.022	30.3
FIN	OIL→REFOIL→FIN	0.002	1.24	0.003	0.016	15.4
EST	OIL→REFOIL→EST	0.003	1.16	0.003	0.012	28.7
BUS	OIL→REFOIL→BUS	0.009	1.19	0.011	0.036	31.6
OTHSER	OIL→REFOIL→OTHSER	0.005	1.31	0.007	0.035	19.3
	OIL→REFOIL→CHEM→OTHSER	0.002	2.13	0.004		10.2
			Origin - Electricity			
AGR	ELEC→AGR	0.010	2.84	0.029	0.128	23.0
	ELEC→OIL→AGR	0.009	2.39	0.022		17.5
COAL	ELEC→COAL	0.062	1.85	0.115	0.198	58.4
OIL	ELEC→OIL	0.070	1.71	0.119	0.178	67.2
MIN1	ELEC→MIN1	0.135	1.77	0.239	0.311	76.7
MIN2	ELEC→MIN2	0.065	1.77	0.115	0.203	56.7
FOOD	ELEC→FOOD	0.011	2.38	0.026	0.115	22.3
	ELEC→AGR→FOOD	0.004	3.49	0.013		11.4
TEX	ELEC→TEX	0.022	2.67	0.060	0.156	38.6
	ELEC→CHEM→TEX	0.005	4.38	0.021		13.7
CLOT	ELEC→TEX→CLOT	0.007	3.20	0.022	0.124	18.1
WOOD	ELEC→WOOD	0.022	2.31	0.052	0.152	34.1
PAPER	ELEC→PAPER	0.022	2.30	0.052	0.143	36.2
	ELEC→CHEM→PAPER	0.006	3.76	0.021		14.8

REFOIL	ELEC→OIL→REFOIL	0.024	1.84	0.045	0.139	32.4
	ELEC→REFOIL	0.023	1.82	0.042		30.0
CHEM	ELEC→CHEM	0.047	2.72	0.128	0.198	64.8
MINR	ELEC→MINR	0.063	2.00	0.126	0.224	56.2
SMEL	ELEC→SMEL	0.047	2.52	0.118	0.207	57.0
	ELEC→MIN1→SMEL	0.012	2.69	0.031		15.0
METAL	ELEC→METAL	0.046	1.92	0.088	0.212	41.6
	ELEC→SMEL→METAL	0.015	2.89	0.045		21.1
MACH	ELEC→MACH	0.023	2.08	0.048	0.156	30.6
	ELEC→SMEL→MACH	0.009	3.12	0.029		18.5
TRAN	ELEC→TRAN	0.011	2.41	0.027	0.133	20.0
	ELEC→SMEL→TRAN	0.005	3.66	0.018		13.7
ELEC	ELEC→ELEC	0.999	1.65	1.647	1.647	100.0
TEL	ELEC→TEL	0.010	2.33	0.023	0.091	25.7
	ELEC→CHEM→TEL	0.003	3.84	0.010		10.7
PREC	ELEC→PREC	0.008	1.70	0.014	0.103	13.5
	ELEC→CHEM→PREC	0.004	2.81	0.012		11.2
OTHMAN	ELEC→OTHMAN	0.018	1.76	0.031	0.151	20.7
SCRAP	ELEC→SCRAP	0.005	1.82	0.009	0.027	33.5
	ELEC→CHEM→SCRAP	0.001	3.00	0.003		10.0
ELEC	ELEC→ELEC	0.358	1.73	0.620	1.648	37.6
GAS	ELEC→OIL→GAS	0.022	1.79	0.039	0.130	29.8
	ELEC→GAS	0.017	1.73	0.029		22.1
WATER	ELEC→WATER	0.196	1.71	0.335	0.399	84.0
CONS	ELEC→MINR→CONS	0.013	2.03	0.027	0.161	16.5
	ELEC→CONS	0.013	1.67	0.022		13.7
	ELEC→SMEL→CONS	0.007	2.56	0.017		10.8
TRNS	ELEC→TRNS	0.011	1.84	0.020	0.094	21.5
POST	ELEC→POST	0.014	1.71	0.024	0.119	20.3
	ELEC→OIL→POST	0.007	2.39	0.017		14.1
ICT	ELEC→ICT	0.022	1.73	0.038	0.086	43.8
TRADE	ELEC→TRADE	0.015	1.73	0.026	0.081	32.7
HOTRES	ELEC→HOTRES	0.025	1.73	0.044	0.122	36.1
FIN	ELEC→FIN	0.003	2.50	0.008		12.9
EST	ELEC→EST	0.004	1.69	0.007	0.039	17.7
	ELEC→OIL→EST	0.002	2.34	0.004		10.1
BUS	ELEC→BUS	0.009	1.74	0.015	0.101	14.7
OTHSER	ELEC→OTHSER	0.017	1.91	0.033	0.127	26.0
	ELEC→OIL→OTHSER	0.006	2.47	0.015		11.9
		Origin - Gas				
AGR	GAS→AGR	0.001	1.84	0.003	0.005	50.8
COAL	GAS→COAL	0.001	1.71	0.001	0.004	24.0
	GAS→OIL→COAL	0.000	1.20	0.001		13.5
OIL	GAS→OIL	0.001	1.09	0.001	0.004	35.2
	GAS→OIL	0.000	1.55	0.001		14.0
MIN1	GAS→MIN1	0.005	1.13	0.006	0.009	64.3
MIN2	GAS→MIN2	0.005	1.13	0.006	0.009	63.3
FOOD	GAS→AGR→FOOD	0.001	2.27	0.001	0.004	26.3
	GAS→FOOD	0.001	1.52	0.001		18.6
TEX	GAS→TEX	0.000	1.71	0.001	0.005	17.9
	GAS→CHEM→TEX	0.000	2.81	0.001		14.3
	GAS→AGR→TEX	0.000	2.94	0.001		12.3

CLOT	GAS→CLOT	0.000	1.79	0.000	0.004	11.0
	GAS→OIL→CLOT	0.000	1.28	0.000		10.2
WOOD	GAS→WOOD	0.000	1.47	0.001	0.004	14.5
	GAS→WOOD	0.000	2.10	0.001		11.5
PAPER	GAS→CHEM→PAPER	0.000	2.42	0.001	0.004	17.3
	GAS→PAPER	0.000	2.08	0.000		11.6
	GAS→OIL→PAPER	0.000	1.47	0.000		10.6
REFOIL	GAS→REFOIL	0.002	1.17	0.002	0.005	44.7
	GAS→OIL→REFOIL	0.000	1.18	0.001		11.3
CHEM	GAS→CHEM	0.002	1.74	0.004	0.007	59.0
MINR	GAS→MINR	0.001	1.28	0.001	0.005	26.8
SMEL	GAS→SMEL	0.001	1.62	0.002	0.005	38.8
	GAS→MIN1→SMEL	0.000	1.73	0.001		14.6
METAL	GAS→METAL	0.001	1.23	0.001	0.005	21.7
	GAS→SMEL→METAL	0.000	1.86	0.001		15.5
MACH	GAS→MACH	0.001	1.33	0.001	0.004	22.8
	GAS→SMEL→MACH	0.000	2.01	0.000		11.1
TRAN	GAS→TRAN	0.001	1.54	0.001	0.004	18.4
ELEC	GAS→ELEC	0.001	1.23	0.001	0.004	14.4
	GAS→SMEL→ELEC	0.000	1.88	0.001		14.2
TEL	GAS→TEL	0.000	1.49	0.001	0.003	21.1
	GAS→OIL→TEL	0.000	2.12	0.000		10.5
	GAS→CHEM→TEL	0.000	2.47	0.000		10.4
PREC	GAS→PREC	0.001	1.09	0.001	0.004	16.4
	GAS→CHEM→PREC	0.000	1.80	0.000		10.2
OTHMAN	GAS→OTHMAN	0.001	1.12	0.001	0.005	20.5
SCRAP	GAS→SCRAP	0.000	1.66	0.000	0.001	22.7
	GAS→OIL→SCRAP	0.000	1.16	0.000		21.8
ELEC	GAS→ELEC	0.001	1.73	0.002	0.004	41.0
GAS	GAS→GAS	1.000	1.05	1.049	1.049	100.0
WATER	GAS→WATER	0.003	1.09	0.004	0.007	50.6
	GAS→OIL→WATER	0.001	1.56	0.001		11.7
CONS	GAS→CONS	0.000	1.52	0.000	0.004	10.5
TRNS	GAS→TRNS	0.001	1.18	0.001	0.004	29.9
	GAS→OIL→TRNS	0.000	1.65	0.001		12.7
POST	GAS→POST	0.001	1.55	0.001	0.005	31.1
	GAS→OIL→POST	0.001	1.09	0.001		16.5
ICT	GAS→ICT	0.000	1.10	0.001	0.003	20.6
	GAS→OIL→ICT	0.000	1.56	0.000		17.7
TRADE	GAS→TRADE	0.000	1.53	0.001	0.003	21.4
	GAS→OIL→TRADE	0.000	1.11	0.000		10.6
HOTRES	GAS→HOTRES	0.003	1.11	0.003	0.006	50.0
FIN	GAS→FIN	0.000	1.62	0.001	0.002	32.7
EST	GAS→EST	0.000	1.52	0.000	0.001	24.5
	GAS→OIL→EST	0.000	1.52	0.000		10.7
BUS	GAS→BUS	0.001	1.11	0.001	0.004	22.3
	GAS→OIL→BUS	0.000	1.57	0.000		11.0
OTHSER	GAS→OTHSER	0.001	1.61	0.001	0.005	28.7
	GAS→OIL→OTHSER	0.001	1.23	0.001		15.7

Source: Authors' calculations.