Economic impacts and challenges of China's petroleum industry: An input–output analysis

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Abstract

It is generally acknowledged that the petroleum industry plays an important role in China’s national economic and social development. The direct, indirect, and induced impacts of China’s petroleum industry are analyzed in this study by using the Input–Output approach. The study also considers the main challenges that China's economy might face in the future. The research results suggest the following: (1) The total economic impacts coefficients on output, given each unit of final demands change in extraction of petroleum and processing of petroleum, are 1.9180 and 3.2747 respectively, and the corresponding economic impacts coefficients on GDP are 1.0872 and 0.9001 respectively; (2) Extraction of petroleum has a more direct impact on GDP, while processing of petroleum has a greater effect on the total output; (3) Extraction of petroleum’s total economic impacts coefficients on both output and GDP have remained stable in recent years after a period of long decline; processing of petroleum’s total economic impacts coefficient on output is steadily increasing; (4) Import uncertainty, the likelihood of rising oil prices, and net oil exports caused by items manufactured with petroleum products (i.e. “Made in China” goods) are the main challenges the petroleum industry will cause for China’s overall economy.

1. Introduction

The consistently high growth rate of the Chinese national economy is supported by energy consumption, including oil. In the past ten years from 1999 to 2009, the average annual growth rate of China’s economy was 9.8 percent and the annual growth rate of oil consumption was 6.8 percent, while the annual growth rate of oil production was merely 1.7 percent. The global financial crisis has had significant impacts on China’s economy because of the inter-connected nature of economic globalisation; however, China is still the most populous and economically flourishing developing country in the world, China’s energy including oil demand has a strong impact on the global energy balance and this impact is set to increase further in the future as pointed by Toshihide Ito et al. [1], Lu W et al. [2], Liao H et al. [3].

According to the BP Statistical Review of World Energy 2010 [4], China’s national oil consumption increased by 6.7% in 2009 compared to 2008. Nevertheless, world oil consumption in 2009 dropped by 1.7%, which was largest decline since 1982; oil consumption in developed countries declined even more severely. Taking the US for example, oil demand dropped by 4.9% in 2009 compared to 2008, and oil consumption hit its lowest level since 1997. As the world’s second largest oil importer, China is of significant interest for researchers. It is vitally important to analyze China’s petroleum industry’s economic impacts on the national economy. Although many researchers have already done study on this topic, there are very few studies evaluating China’s petroleum industry’s different kinds of economic impacts in detail. This paper seeks to address this gap, economic impacts of China’s petroleum industry are divided into three parts: direct, indirect, and induced impacts. The three different kinds of economic impacts, the main affected sectors given change of petroleum industry are analyzed, and the main challenges that China's economy might face caused by the petroleum industry in the future are also considered in this study. In order to study the details carefully, the petroleum industry is divided into extraction of petroleum and processing of petroleum.

2. Methodology and data

The Input–Output (IO) model is used to examine the economic interrelationship between the petroleum industry and other sectors.
IO model is useful in analyzing the economic relationship of linkages among sectors of an economy. Since Leontief [5]'s pioneer work in the 1930s, numerous studies of IO analysis have been completed, such as Miller and Blair [6], Ranko [7], Rong-Hwla and Chia-Yon [8], John [9], Maria [10]. There are specific assumptions in input–output model proposed by Leontief, such as constant returns to scale, linearity, sector homogeneity, and no capacity constraints which affect the model's accuracy as pointed out by Davis [11]. Due to these assumptions, this model is only reliable in the short to medium term.

The basic IO model consists of rows showing "who gives to whom" and columns showing "who receives from whom" in an economy as pointed out by Christian and Klaus [12]. From the perspective of row i, the output of sector i can be computed as follows:

\[ x_i + x_{i2} + \ldots + x_{ij} + \ldots + x_{in} + y_i = X_i \]  \hspace{1cm} (1)

Where: \( x_{ij} \) = purchases by the sector \( j \) of the goods produced by sector \( i \), \( y_i \) = sales from sector \( i \) to final demand, \( X_i \) = total output of sector \( i \).

Technical coefficient \( a_{ij} \) can be calculated as follows:

\[ a_{ij} = \frac{x_{ij}}{X_j} \]  \hspace{1cm} (2)

Where: \( X_j \) = total output of sector \( j \).

So, Eq. (2) can be expressed as follows:

\[ x_{ij} = a_{ij}X_j \]  \hspace{1cm} (3)

We rewrite Eq. (1) as follows:

\[ a_{1i}X_1 + a_{2i}X_2 + \ldots + a_{ji}X_j + \ldots + a_{ni}X_n + y_i = X_i \]  \hspace{1cm} (4)

If we use matrix notation as follows:

\[ A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2j} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix}; \quad X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix}; \quad Y = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} \]

Where, \( A \) is the technical coefficient matrix, \( X \) is the vector of output, \( Y \) is the vector of final demand. So, the basic IO model can be expressed as follows:

\[ AX + Y = X \]  \hspace{1cm} (6)

Eq. (6) can be written as follows:

\[ (I - A)X = Y \]  \hspace{1cm} (7)

Where, \( I \) is identity matrix, the matrix \( (I - A) \) is called Leontief matrix.

Eq. (7) can be expressed further as follows:

\[ X = (I - A)^{-1}Y \]  \hspace{1cm} (8)

Where, the matrix \( (I - A)^{-1} \) is called Leontief inverse matrix (key matrix). Eq. (8) is the solution equation of the input–output analysis.

In this study, the final demand is further divided into final consumption, investment, net export etc. So Eq. (6) can be further expressed as follows:

\[ AX + CX + TX + FD = X \]  \hspace{1cm} (9)

Where, \( C \) is the matrix of final consumption coefficients; \( CX \) is the vector of final consumption; \( T \) is the matrix of net export coefficients; \( TX \) is the vector of net export; \( FD \) is the vector of other final demand beside final consumption and net export, such as investment.

Both \( C \) and \( T \) are diagonal matrixes, they can be expressed as follows:

\[ C = \begin{bmatrix} c_{11} & 0 & \cdots & 0 \\ 0 & c_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & c_{nn} \end{bmatrix} \]  \hspace{1cm} (10)

\[ T = \begin{bmatrix} t_{11} \\ t_{22} \\ \vdots \\ t_{nn} \end{bmatrix} \]  \hspace{1cm} (11)

Where, \( c_{ii} \) measures the share of sector \( i \)'s final consumption in sector \( i \)'s output; \( t_{ii} \) measures the share of sector \( i \)'s net exports in sector \( i \)'s output; all of the other elements in matrixes \( C \) and \( T \) are 0.

Eq. (9) can also be described as Eq. (12):

\[ (I - A - C - T)X = FD \]  \hspace{1cm} (12)

Eq. (13) can be obtained from Eq. (12), provided that \((I - A - C - T)\) is a nonsingular matrix:

\[ X = (I - A - C - T)^{-1} \times FD \]  \hspace{1cm} (13)

When \( FD \) changes, \( X \) will change correspondingly as follows:

\[ \Delta X = (I - A - C - T)^{-1} \times \Delta FD \]  \hspace{1cm} (14)

Eq. (14) measures all of the economic impacts including direct, indirect and induced impacts; If \( C = 0 \), it will just measure the direct and indirect impacts, because final consumption \( CX \) is not considered. In this case, Eq. (14) can be described as Eq. (15):

\[ \Delta X = (I - A - T)^{-1} \times \Delta FD \]  \hspace{1cm} (15)

The difference between Eq. (14) and (15) is referred to as the induced impact:

\[ \Delta X_{\text{inducing}} = (I - A - C - T)^{-1} - (I - A - T)^{-1} \times \Delta FD \]  \hspace{1cm} (16)

The data used in this study are based on China's statistical yearbook and Input–Output table. They are both released by the National Bureau of Statistics of China. For the difference in statistical caliber, the industry data in China's statistical yearbook are converted into the statistical caliber of the I–O table.

3. Economic impacts of China's petroleum industry

3.1. Calculation of economic impacts coefficients

Economic impacts coefficients measure the economic impacts given each unit of FD change in China's petroleum industry. In this section of the paper, economic impacts coefficients of China's petroleum industry will be calculated according to the formulas above and China's I–O table.

The latest Chinese Input–Output table is the 2007 version, which was published in 2009. There are 42 sectors in China's 2007
Input–Output table (Brief Version). Extraction of petroleum is sector 3, and processing of petroleum is sector 11.

Matrixes $A$ and $T$ can be calculated according Eq. (2) and (11) respectively. $I$ is identity matrix, so $(I - A - T)^{-1}$ in Eq. (15) can be easily calculated. $(I - A - T)^{-1}$ is a $42 \times 42$ matrix, column 3 and column 11 represent extraction of petroleum and processing of petroleum respectively. Taking column 3 in matrix $(I - A - T)^{-1}$ for example, each element in this column measures extraction of petroleum’s direct and indirect impacts on corresponding sector. If all the elements in column 3 are summed up, the sum will mean extraction of petroleum’s total direct and indirect impacts on national economy. So the direct and indirect impacts coefficient of extraction of petroleum and processing of petroleum can be found by summing up all the elements in column 3 and column 11 respectively as follows:

$$e_{direct \rightarrow indirect(extraction)} = 1.4720$$

$$e_{direct \rightarrow indirect(processing)} = 2.5180$$

The change of vector $FD$ will directly affect the same amount of total output, which means petroleum industry’s direct impact coefficient is 1. So the indirect impacts coefficients of extraction of petroleum and processing of petroleum are 0.4720 and 1.5180 respectively.

$(I - A - C - T)^{-1} - (I - A - T)^{-1}$ in Eq. (16) is also a $42 \times 42$ matrix, which measures the induced impacts; so the induced impacts of extraction of petroleum and processing of petroleum can be found by summing up all the elements in column 3 and column 11 respectively as follows:

$$e_{induced(extraction)} = 0.4460$$

$$e_{induced(processing)} = 0.7567$$

The economic impact coefficients calculated above measure economic impacts on output given each unit of final demands change in petroleum industry. Table 1 shows the summarized calculation results:

In order to analyze the petroleum industry’s economic impacts on GDP (Gross Domestic Product), the value-added coefficient is used in this paper. It indicates how much GDP is created given one unit of output increase. It can be calculated as follows:

$$Z_i = N_i/X_i \quad (17)$$

Where, $Z_i$ stands for the value-added coefficient in sector $i$; $N_i$ stands for value-added in sector $i$; $X_i$ stands for the total output in sector $i$.

By using the value-added coefficient in Eq. (17), the petroleum industry’s economic impact coefficient on the total output in Table 1 can be converted to its economic impact coefficient on GDP (Table 2).

It can be seen from Tables 1 and 2: the total economic impacts coefficient on output in processing of petroleum is 70.7% higher than it in extraction of petroleum; with respect to the indirect economic impacts coefficient on output, the previous is about 3 times higher than the latter. Usually indirect and induced impacts reflect the relationship among sectors; this means that the processing of petroleum has a significantly closer sector relationship in the national economy system than the extraction of petroleum. In terms of the economic impacts coefficient on GDP, the total economic impacts coefficient on GDP in the processing of petroleum is 17.2% lower than in the extraction of petroleum, the main reason is that processing of petroleum’s direct impacts coefficient on GDP is 79.6% lower than the extraction of petroleum because of different profit margins in the upstream and downstream of the petroleum industry in China. However, the processing of petroleum’s indirect and induced impacts coefficient on GDP are still much higher than the extraction of petroleum.

The analysis above shows that extraction of petroleum is more concentrated on the economic impact on GDP by itself, while processing of petroleum is more focused on the spillover effects on the total output because of a higher associated degree with other sectors in the national economy system.

### 3.2. Further analysis of economic impacts coefficient

#### 3.2.1. Component analysis of the economic impacts coefficient

The analysis above indicates that the petroleum industry will affect 1.9180 units and 3.2747 units of the total output given each unit change of final demand in extraction of petroleum and processing of petroleum respectively, and in the same situation, they will affect 1.0872 units and 0.9001 units of GDP respectively. In fact, those impacts consist of all the impact on every sector in the national economy. Taking the petroleum industry’s economic impacts on output given each unit of final demand change, for example, components of the economic impacts coefficient are analyzed. Tables 3 and 4 show the top 10 output affected sectors, except the petroleum industry itself, given each unit change of final demand in the extraction of petroleum and the processing of petroleum respectively.

From Tables 3 and 4, the production and supply of electric power & heat power is the largest output affected sector given each unit change of final demand in the extraction of petroleum. The extraction of petroleum is the largest output affected sector given each unit change of final demand in the processing of petroleum.

#### 3.2.2. Analysis of economic impacts coefficient change over time

In addition to the 2007 input–output table, 1987, 1992, 1997 and 2002 input–output tables have also been published by the National Bureau of Statistics of China. The petroleum industry’s economic impacts coefficients by historical year have also been calculated by the same method as above according to other years’ input–output tables, which will benefit the analysis of economic impacts coefficients change over time.

Tables 5 and 6 show the change of economic impacts coefficients on output and GDP given each unit of final demand change in the extraction of petroleum respectively.

### Table 2

<table>
<thead>
<tr>
<th>Economic impacts coefficient on GDP</th>
<th>Extraction of petroleum</th>
<th>Processing of petroleum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total impacts coefficient</td>
<td>1.0872</td>
<td>0.9001</td>
</tr>
<tr>
<td>Direct impacts coefficient</td>
<td>0.7890</td>
<td>0.1610</td>
</tr>
<tr>
<td>Indirect impacts coefficient</td>
<td>0.1533</td>
<td>0.4832</td>
</tr>
<tr>
<td>Induced impacts coefficient</td>
<td>0.1449</td>
<td>0.2459</td>
</tr>
</tbody>
</table>

### Table 1

<table>
<thead>
<tr>
<th>Economic impacts coefficient on output</th>
<th>Extraction of petroleum</th>
<th>Processing of petroleum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total impacts coefficient</td>
<td>1.9180</td>
<td>3.2747</td>
</tr>
<tr>
<td>Direct impacts coefficient</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>Indirect impacts coefficient</td>
<td>0.4720</td>
<td>1.5180</td>
</tr>
<tr>
<td>Induced impacts coefficient</td>
<td>0.4460</td>
<td>0.7567</td>
</tr>
</tbody>
</table>
Table 3
Top 10 output affected sectors given each unit change of final demand in the extraction of petroleum.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Sector</th>
<th>Indirect and induced impacts</th>
<th>Indirect impacts</th>
<th>Induced impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Production and Supply of Electric Power and Heat Power</td>
<td>0.1346</td>
<td>0.1047</td>
<td>0.0298</td>
</tr>
<tr>
<td>2</td>
<td>Metals Smelting and Rolling Processing Industry</td>
<td>0.1298</td>
<td>0.1124</td>
<td>0.0174</td>
</tr>
<tr>
<td>3</td>
<td>Chemical Industry</td>
<td>0.1084</td>
<td>0.0708</td>
<td>0.0376</td>
</tr>
<tr>
<td>4</td>
<td>Manufacture of General and Special Purpose Machinery</td>
<td>0.0766</td>
<td>0.0683</td>
<td>0.0083</td>
</tr>
<tr>
<td>5</td>
<td>Processing of Petroleum</td>
<td>0.0641</td>
<td>0.0512</td>
<td>0.0129</td>
</tr>
<tr>
<td>6</td>
<td>Agriculture</td>
<td>0.0612</td>
<td>0.0165</td>
<td>0.0447</td>
</tr>
<tr>
<td>7</td>
<td>Manufacture of Foods, Beverages and Tobacco</td>
<td>0.0575</td>
<td>0.0139</td>
<td>0.0436</td>
</tr>
<tr>
<td>8</td>
<td>Transportation</td>
<td>0.0533</td>
<td>0.0363</td>
<td>0.0170</td>
</tr>
<tr>
<td>9</td>
<td>Manufacture of Communication Equipment, Computers and Other Electronic Equipment</td>
<td>0.0484</td>
<td>0.0213</td>
<td>0.0170</td>
</tr>
<tr>
<td>10</td>
<td>Manufacture of Textiles</td>
<td>0.0454</td>
<td>0.0179</td>
<td>0.0275</td>
</tr>
</tbody>
</table>

Table 4
Top 10 output affected sectors given each unit change of final demand in the processing of petroleum.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Sector</th>
<th>Indirect and induced impacts</th>
<th>Indirect impacts</th>
<th>Induced impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Extraction of Petroleum</td>
<td>0.4146</td>
<td>0.3911</td>
<td>0.0236</td>
</tr>
<tr>
<td>2</td>
<td>Production and Supply of Electric Power &amp; Heat Power</td>
<td>0.1710</td>
<td>0.1254</td>
<td>0.0456</td>
</tr>
<tr>
<td>3</td>
<td>Chemical Industry</td>
<td>0.1621</td>
<td>0.1032</td>
<td>0.0588</td>
</tr>
<tr>
<td>4</td>
<td>Metals Smelting and Rolling Processing Industry</td>
<td>0.1399</td>
<td>0.1105</td>
<td>0.0294</td>
</tr>
<tr>
<td>5</td>
<td>Transportation</td>
<td>0.1011</td>
<td>0.0708</td>
<td>0.0303</td>
</tr>
<tr>
<td>6</td>
<td>Mining and Washing of Coal</td>
<td>0.0997</td>
<td>0.0862</td>
<td>0.0136</td>
</tr>
<tr>
<td>7</td>
<td>Manufacture of Foods, Beverages and Tobacco</td>
<td>0.0952</td>
<td>0.0250</td>
<td>0.0702</td>
</tr>
<tr>
<td>8</td>
<td>Agriculture</td>
<td>0.0940</td>
<td>0.0250</td>
<td>0.0690</td>
</tr>
<tr>
<td>9</td>
<td>Manufacture of General and Special Purpose Machinery</td>
<td>0.0935</td>
<td>0.0784</td>
<td>0.0151</td>
</tr>
<tr>
<td>10</td>
<td>Wholesale and Retail Trades</td>
<td>0.0814</td>
<td>0.0417</td>
<td>0.0397</td>
</tr>
</tbody>
</table>

Tables 5 and 6 show that the total economic impacts coefficient given each unit of final demand change in the extraction of petroleum is declining generally. For example, the total economic impacts coefficient on output in 2007 is 19.3% lower than the highest in 1992; the total economic impacts coefficient on GDP in 2007 is 17.4% lower than the highest in 1987. However, the impacts coefficient in 2007 is slightly high than in 2002, and it has been stabilizing in recent years. On detailed petroleum's indirect and induced economic impacts coefficients on both output and GDP are declining, but its direct economic impacts coefficients on GDP are increasing generally.

Tables 7 and 8 show the change of economic impacts coefficients on output and GDP given each unit of final demands change in the processing of petroleum respectively.

It can be found from Tables 7 and 8 that the total economic impacts coefficient on output given each unit of final demands change in the processing of petroleum is increasing generally, for example, the total economic impacts coefficient on output in 2007 is 76.5% higher than the lowest in 1987, the total economic impacts coefficient on GDP in 2007 is 14.9% higher than the lowest in 1987. However, the total economic impacts coefficient on GDP has been decreasing steadily since 1997, and its indirect economic impacts coefficient on GDP has been decreasing quickly since 1987.

In summary, extraction of petroleum's total economic impacts coefficients on both output and GDP has been stable in recent years after successive decrease for many years. The processing of petroleum's total economic impacts coefficient on output is still in the stage of steady increase, however, its direct economic impacts coefficient on GDP continues to decrease, obviously — whether we consider either the extraction of petroleum or the processing of petroleum, its induced economic impacts coefficients on both output and GDP have been decreasing since 1997.

4. Main challenges China's economy will face caused by petroleum industry

4.1 Uncertainty in oil import sources

Since 1993, China has been a net oil import country. As shown in Figs. 1 and 2, the gap between oil consumption and production has been increasing quickly in last decade, the degree of dependence on foreign oil since 1993 has increased step by step and now it is over 50%.
Table 7
The change of economic impacts coefficients on output given each unit of final demands change in the processing of petroleum.

<table>
<thead>
<tr>
<th>Year</th>
<th>Direct impacts coefficient</th>
<th>Indirect impacts coefficient</th>
<th>Induced impacts coefficient</th>
<th>Total impacts coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>1.0000</td>
<td>0.4520</td>
<td>0.4029</td>
<td>1.8550</td>
</tr>
<tr>
<td>1992</td>
<td>1.0000</td>
<td>0.7119</td>
<td>0.6692</td>
<td>2.3110</td>
</tr>
<tr>
<td>1997</td>
<td>1.0000</td>
<td>1.3190</td>
<td>0.8775</td>
<td>3.1965</td>
</tr>
<tr>
<td>2002</td>
<td>1.0000</td>
<td>1.3131</td>
<td>0.7750</td>
<td>3.0881</td>
</tr>
<tr>
<td>2007</td>
<td>1.0000</td>
<td>1.5180</td>
<td>0.7567</td>
<td>3.2747</td>
</tr>
</tbody>
</table>

Table 8
The change of economic impacts coefficients on GDP given each unit of final demand change in the processing of petroleum.

<table>
<thead>
<tr>
<th>Year</th>
<th>Direct impacts coefficient</th>
<th>Indirect impacts coefficient</th>
<th>Induced impacts coefficient</th>
<th>Total impacts coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>0.4027</td>
<td>0.2012</td>
<td>0.1794</td>
<td>0.7833</td>
</tr>
<tr>
<td>1992</td>
<td>0.2718</td>
<td>0.2770</td>
<td>0.2604</td>
<td>0.8093</td>
</tr>
<tr>
<td>1997</td>
<td>0.2206</td>
<td>0.4997</td>
<td>0.3324</td>
<td>1.0527</td>
</tr>
<tr>
<td>2002</td>
<td>0.1720</td>
<td>0.5105</td>
<td>0.3013</td>
<td>0.9838</td>
</tr>
<tr>
<td>2007</td>
<td>0.1610</td>
<td>0.4932</td>
<td>0.2459</td>
<td>0.9001</td>
</tr>
</tbody>
</table>

China’s domestic oil production has already entered the plateau stage, and the peak oil production will probably come before 2017 as pointed by Feng Lianyong et al. [13,14], Pang Xiongqi et al. [15] and Tang Xu et al. [16]. The giant oilfields’ production continues declining, such as the production at the country’s major Daqing field proposed by Tang Xu et al. [17], Mikael et al. [18], while oil demand in China is growing rapidly and the gap between oil consumption and production will continue increasing as pointed by Feng Lianyong et al. [14].

In the view of the whole world, oil production has also been increasing slowly in recent years. The peak of world conventional oil production will probably appear in about 2020 and the peak production will be about 4.2 billion tonnes as pointed by Feng Lianyong et al. [19], Tang Xu et al. [20].

Most of the studies above focus on oil reserve and production in China and the world. In this study, the changes of main countries’ oil exports are analyzed which focus on not only oil production but also oil consumption. Main countries’ oil exports ability change can affect China’s oil import safety. 9 main oil export countries in the world are selected: Canada, Mexico, Venezuela, the Russian Federation, Iran, Kuwait, Saudi Arabia, the United Arab Emirates, and Algeria. According to the BP Statistical Review of World Energy 2010 [4], the change of 9 countries’ oil exports can be calculated since 1993, which is the year China became a net oil import country.

In the 9 countries, most countries’ oil export capability is remaining stable since 1993 except for the increase in the Russian Federation and Canada and the decrease in Mexico (Fig. 3).

4.2. High probability of oil price increase

Oil products are used in almost every sector, so they will affect products prices of other sectors when the oil price fluctuates. The Input–Output model can be used to analyze the effect of oil price fluctuation as pointed out by Xiang Furong [21] as follows:

\[
\begin{align*}
\frac{\Delta P_1}{C_{n1}} &= \frac{c_{n1}}{C_{n1}} - \frac{c_{n2}}{C_{n2}} \\
\frac{\Delta P_2}{C_{n2}} &= \frac{c_{n2}}{C_{n2}} - \frac{c_{n3}}{C_{n3}} \\
\vdots
\frac{\Delta P_{n-1}}{C_{nn-1}} &= \frac{c_{nn-1}}{C_{nn-1}} - \frac{c_{nn}}{C_{nn}} \\
\frac{\Delta P_n}{C_{nn}} &= \frac{c_{nn}}{C_{nn}}
\end{align*}
\]

Where, \(\Delta P_n\) is the change rate of oil price; \(\Delta P_i\) is sector i’s price change rate caused by the change of oil price; \(c_{nj}\) is the
corresponding element in Leontief inverse matrix \((I - A)^{-1}\) which is calculated above.

When oil price changes, the price of each sector’s products will change, and of course the national price which measure the whole price level in China will change correspondingly. The national price change rate in China caused by oil price change can be calculated as follows:

\[
P = \sum_{i=1}^{n} \Delta P_i \times Q_i\tag{19}
\]

Where, \(P\) is the national price change rate in China caused by oil price change; \(\Delta P_i\) is sector \(i\)'s price change rate caused by oil price change; \(Q_i\) is the percentage of sector \(i\)'s output in the total national output.

According to Eq. (18), each sector’s price change rate can be calculated when oil price changes. Table 9 shows the top 10 affected sectors given a 10% increase of products price in the extraction of petroleum.

After the calculations above, the change of the national price can be calculated according to Eq. (19). The result is 0.93%, which means the national average price will increase 0.93% given a 10% increase of the products price in the extraction of petroleum. By using the same method, the petroleum products price change’s effects on the national average price in other years can be calculated based on the corresponding year’s table in China. The calculation results are shown in Table 10 as follows:

From Table 10, it can be found that the price change of petroleum products, including both upstream and downstream, has more and more impact on the national average price since 1987, which means the petroleum industry as a product supplier has more spillover effects than before on other sectors which use petroleum products as their intermediate inputs. It is also evident that the price change in the extraction of petroleum has a higher impact on the national average price than the processing of petroleum, mainly due to the extraction of petroleum having a closer relationship with other sectors — it can affect other sectors’ products price more directly.

Petroleum products are directly affected by the crude oil price. In 2002, the crude oil price was as little as $20 a barrel. However, it increased quickly in the next few years, and it reached $147.27 a barrel in July 2008, 7 times higher than it in 2002. After that, although it plunged dramatically to less than $40 a barrel, amidst a global financial crisis, it shot up quickly to about $80 a barrel. In the future, there is a high probability that the oil price will continue to increase. The quick increase of future demand in developing countries including, the oil export countries, and the slow growth of further world oil production will be accompanied by wide swings of the oil price at a relatively high level. China imports roughly 4 million barrels of oil per day now. If the oil price increases $1 per barrel, the bill China pays will increase by about $4 million each day, or 1.45 billion each year. And the national average price will increase about 1% given a 10% increase of the oil price. That will provide China with a much heavier financial burden in the future, and China should take more attempts to adapt to the new state of affairs.

### 4.3. Net oil exports through “Made in China” products

In recent years, China’s international trade surplus has grown through exporting a large number of “Made in China” products. This brings upon China heavy international pressure, particularly the continuous pressure of RMB appreciation. The RMB exchange rate issue is beyond the scope of this paper; however, it is apparent that too great a trade surplus is not helpful for China. In fact, each “Made in China” product contains oil directly or indirectly, as each sector in the national economy is connected with the petroleum industry. Although China is the second largest oil consuming country in the world and needs to import about half of its oil from overseas every year, at the same time, China is exporting much oil through “Made in China” products. This is not often considered, even within China. In this part of this article, China’s net oil exports through “Made in China” products are calculated based on input–output tables. The model is as follows:

\[
E_o = \frac{C}{Y_i} \sum_{j=1}^{n} (E_j - I_j) \times b_{ij}\tag{20}
\]

Where, \(E_o\) is the net oil export through “Made in China” products; \(C\) is China’s total oil consumption, \(Y_i\) is the petroleum industry’s total output; \(E_j\) is exports in sector \(j\); \(I_j\) is imports in sector \(j\); \(b_{ij}\) is complete consumption coefficient, which measures how much petroleum industry output (sector \(j\)) will be used including direct and indirect use given each output increase in sector \(i\).

The complete consumption coefficient matrix \(B\) can be calculated as follows:

\[
B = (I - A)^{-1} - I\tag{21}
\]
Where, \( I \) is the identity matrix; \( A \) is the matrix of technical coefficients; \((I - A)^{-1}\) is the Leontief inverse matrix (key matrix).

According to Eq. (20), China’s net oil exports through “Made in China” products can be calculated (Table 11).

It can be found from Table 11 that China’s net oil exports through “Made in China” products have a close relationship with China’s international trade surplus. The more the trade surplus, the more the net oil exports through “Made in China” products. Taking 2007 for example, China’s net oil exports in the trade surplus are 49.5 million tonnes per year or about 1 million barrels per day.

During the global economic crisis, China’s trade surplus increased slowly in 2008 and decreased more dramatically in 2009. The surplus in 2008 and 2009 were $295.5 billion and $196.1 billion respectively, however, it was still at a relatively high level. If China’s trade structure and trade model are not changed fundamentally, China’s trade surplus will probably increase again with the recovery in the global economy. All indications are that China will continue exporting oil through “Made in China” products, which will bring more challenges to China in the future.

5. Conclusions

As a developing country, China’s economy can’t grow smoothly without the support of enough energy including oil. China’s petroleum industry will continue playing an important role in the national economy. The total economic impacts coefficients on output, given each unit of final demands change in extraction of petroleum and processing of petroleum, are 1.9180 and 3.2747 respectively, and the corresponding economic impacts coefficients on GDP are 1.0872 and 0.9001 respectively. The processing of petroleum has higher indirect and induced economic impacts than the extraction of petroleum because of its close association with other sectors in the national economy.

Domestic oil production in China has already entered the plateau stage, while oil demand is still growing rapidly; the gap between them will continue increasing. China’s economy will probably face challenges caused by the petroleum industry uncertainty in oil import sources, high probability of oil price increases and net oil exports through “Made in China” products. China should improve the efficiency of its petroleum consumption, and change the economic growth model — including the international trade model and the trade structure. Otherwise, the more important a role the petroleum industry plays, the higher the probability that China’s national economy will be adversely affected by overseas petroleum markets.

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