Is oil consumption constrained by industrial structure? Evidence from China

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Abstract. This paper examines whether oil consumption is constrained by output value, applying a cointegration test and an ECM to the primary, secondary, and tertiary sectors in China during 1985-2013. The empirical results indicate that oil consumption in China is constrained by the industrial structure both in the short run and in the long run. Regardless of the time horizon considered, the oil consumption constraint is the lowest for the primary sector as well as the highest for the tertiary sector. This is because the long-term industrial structure formation and the technological level of each sector underlines the existence of long run equilibrium and short run fluctuations of output value and oil consumption, with the latter being constrained by adjustments in industrial structure. In order to decrease the constraining effect of output value on oil consumption, the government should take some measures to improve the utilization rate, reducing the intensity of oil consumption, and secure the supply of oil.

1. Introduction
In the past 20 years, oil has become one of the most important types of energy driving the global economic to develop. The wide use of oil makes economic development more rapidly and it also improves people’s living standard. The oil crisis in the 1970s fully demonstrates the crippling nature of dependence of economic development on oil. The supplying and demand of oil have already influenced the global economic development. In China, oil plays a critical role in national economic develop. Oil consumption rose from 90.8 Mt in 1978 to 492.7 Mt in 2013, with an annual average growth rate of 5.0% (National Bureau of Statistics of China, 2014).

During the process of modernization, industrial structure affects the oil consumption shares in the three sectors, as well as total oil consumption. Great attention has been paid to explore the relationship among industrial structure, economic growth, and energy consumption. China is facing a constraint on resource consumption, and, in particular, on energy consumption, required for industrial structural adjustment. It also faces the problem of coordinating structural adjustment with the energy consumption constraint [12]. Thus, this study focuses on investigating whether oil consumption is constrained by the industrial structure in China.

The remainder of this paper is organized as follows. Section 2 presents a literature review of the relationship between oil consumption and economic growth and between industrial structure and oil consumption. Section 3 shows the methodology adopted here and explains the data employed. Section 4 presents and discusses the empirical results obtained from analyzing the “constrained” relationship between industrial structure and oil consumption. Some conclusions and policy recommendations are offered in the final section.
2. Literature review

A small literature investigates the constraint relationship between industrial structure and oil consumption. Chinese researchers mainly focus on the influence of structural adjustment on oil consumption. Shi [13, 14] proved, using index analysis and regression analysis, that structural change was an important factor in rapid economic growth and low energy consumption growth in China. Wu et al [15] found that energy intensity would decrease by 0.33%, if the industrialization level increased by 1%. In the long run, improvement on industrialization promotes greater efficiency in energy utilization. While the process of structural adjustment dramatically increased the demand for energy, the energy supply in China remained limited, implying both a "flow constraint" and a "stock constraint" [8]. Zeng et al (2006), Guo et al [6], and Yan and Du [17] examined the short run and long run causality between energy consumption and output value in the three sectors, employing correlation, co-integration, and ECM, respectively. Ou [12] found that energy consumption constrained structural adjustment in China, both in the long run and in the short run. In addition, the correlation between industrial structure and oil consumption in China was investigated by Liu et al [8] and Wu [16]. Zheng [18] found that in the long run, the tertiary sector displayed the highest elasticity of total oil consumption with respect to output value, followed by the secondary sector. The negative effects of the primary sector on total oil consumption resulted from the "crowding out effects" in other sectors. However, the short term inhibition impacts on oil consumption were limited, and oil consumption growth in China displayed a high degree of continuity and inertia.

3. Econometric methodology and data

Co-integration and an ECM (error correction model, ECM) will be used to identify the constraint effect of oil consumption on the output value of the three sectors in the long run as well as in the short run.

3.1. Methodology

3.1.1. ADF unit root test. In order to examine the stationarity of each variable, the Augmented Dickey Fuller (ADF) test [2, 4] is used to decide whether unit roots exist in a time series. The ADF test formulation is

\[ \Delta Y_t = \alpha + \beta t + \phi Y_{t-1} + \sum_{i=1}^{p} \psi_i \Delta Y_{t-i} + \epsilon_t \]  

where \( Y_t \) is the level of the variable, \( \alpha \) is a drift term, and \( \beta, \phi, \psi \) are the parameters to be estimated. \( T \) is the time trend with the null hypothesis \( H_0: \phi = 0 \), and the alternative hypothesis \( H_1: \phi \neq 0 \). \( \epsilon_t \) is a normally distributed random error term with mean zero and constant variances. \( p \) is the number of lags necessary to obtain white noise.

If time series appear to be non-stationary processes with one unit root, i.e., \( I(1) \) series, the direction of Granger causality may be decided upon via standard F-tests in the first differenced VAR framework. Then, the test equation takes the form

\[ \Delta Y_t = \lambda + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \sum_{j=1}^{n} \beta_j \Delta X_{t-j} + \epsilon_t \]  

where \( \lambda \) is a constant, \( m \) and \( n \) are the lengths of lags necessary to obtain white noise, \( t \) is time, and \( \epsilon_t \) is a disturbance term with mean zero.

However, two or more time series of non-stationary \( I(1) \) processes may have linear combinations which are stationary, i.e. \( I(0) \). In this case, the variables are said to be cointegrated. According to the Granger representation theorem [3, 5], if two times series of non-stationary processes with one unit root are cointegrated, their long-run equilibrium relationship should be represented by an ECM. In addition, cointegration means that there is at least a unidirectional Granger causality between the series [3, 5].

3.1.2. Co-integration. The series \( y_{1t}, y_{2t}, ..., y_{nt} \) are cointegrated of order \( d, b \), denoted by \( y_t \sim CI(d, b) \), if the time series \( y_{it}, y_{2t}, ..., y_{nt} \) are \( I(d) \) and a vector \( \alpha = (\alpha_1, \alpha_2, ..., \alpha_n) \) exists such that \( \alpha^\prime y_t \sim I(d - b), d \geq b \geq 0 \). \( \alpha \) is a cointegrating vector. In order to prove a cointegrating relationship between time series \( x_t \) and \( y_t \), Engle and Granger [3] proposed the Engle-Granger two-
step test, denoted by EG test. If time series $x_t$ and $y_t$ are $I(d)$, a regression of $x_t$ on $y_t$, the following equation can be obtained from a regression of $y_t$ on $x_t$

$$y_t = \alpha + \beta x_t + \epsilon_t$$

The estimated of regression coefficients are $\hat{\alpha}$ and $\hat{\beta}$, respectively. The estimated residual error in the model is

$$\hat{\epsilon} = y_t - \hat{\alpha} - \hat{\beta} x_t$$

The two time series $x_t$ and $y_t$ are cointegrated if $\hat{\epsilon}$~$I(0)$. $(1,-\beta)$ is the vector of cointegration; Eqs. (3) is a cointegration regression equation.

3.1.3. Error correction model. The ECM, first proposed by Davidson, Hendry, Srba, and Yeo in 1978, is a specific econometrics model. Error Correction Models (ECMs) are a category of multiple time series models that directly estimate the speed at which a dependent variable $Y$ returns to equilibrium after a change in an independent variable $X$. ECMs are a theoretically driven approach useful for estimating both short term and long term effects of one time series on another. Thus, ECMs are useful models when dealing with cointegrated data, but can also be used with stationary data.

If two variables are non-stationary, but become stationary after first differencing, and are cointegrated, the ECMs for the Granger-causality test can be accordingly specified as follows:

$$\Delta Y_t = \beta_{10} + \sum_{i=1}^{l_1} \beta_{1i} \Delta Y_{t-i} + \sum_{j=1}^{l_2} \beta_{1j} \Delta X_{t-j} + \beta_{13} \epsilon_{t-1} + u_{1t},$$

$$\Delta X_t = \beta_{20} + \sum_{i=1}^{l_2} \beta_{2i} \Delta Y_{t-i} + \sum_{j=1}^{l_2} \beta_{2j} \Delta X_{t-j} + \beta_{23} \epsilon_{t-1} + u_{2t}.$$

In Eqs. (5) and (6), $X_t$ and $Y_t$ represent natural logarithms of variables, $\Delta$ is the difference operator, $L_{11}$, $L_{12}$, $L_{21}$, and $L_{22}$ are the numbers of lags, $u_{1t}$ and $u_{2t}$ are the serially uncorrelated error terms, and $\epsilon_{t-1}$ is the error correction term (ECT), which is derived from the long run cointegration relationship.

The data on oil consumption and output value in the three sectors covering the period 1985-2013 are obtained from the China Statistical Yearbook and the China Energy Statistical Yearbook. Output value in the primary, secondary, and tertiary sectors during 1985-2012, denoted by PIOV, SIOV and TIOV, respectively, are taken from the China Statistical Yearbook 2013 (National Bureau of Statistics of China, 2014). Simultaneously, the oil balance sheet in the China Energy Statistical Yearbook provides annual data on oil consumption in the primary, secondary and tertiary sectors during 1985-2013, denoted by OC1, OC2, and OC3, respectively (Department of energy statistics in National Bureau of Statistics of China, 2014).

4. Empirical results and discussions

To prevent spurious regression, we first conduct stationary and counteraction tests of the time series variables. We then make use of the Engle-Granger approach for the short and the long run.

4.1. Unit root test

| Variables  | (C, T, K) | ADF  | D-W  | 5% Critical values | Prob.* |
|------------|-----------|------|------|--------------------|-------|
| LnOC1      | (C, T, 0) | -1.9036 | 1.7716 | -2.9719            | 0.3259 |
| LnOC2      | (C, T, 0) | -0.4415 | 2.1711 | -2.9719            | 0.8885 |
| LnOC3      | (C, T, 3) | -1.2663 | 1.9084 | -2.9862            | 0.6286 |
| LnPIOV     | (C, T, 1) | -1.1500 | 1.8594 | -2.9763            | 0.6806 |
| LnSIOV     | (C, T, 2) | -1.3583 | 1.9476 | -2.9810            | 0.5866 |
| LnTIOV     | (C, T, 4) | -1.6427 | 1.9739 | -2.9919            | 0.4463 |
| ΔLnOC1     | (C, T, 0) | -4.5171 | 1.9900 | -2.9763            | 0.0014 |
| ΔLnOC2     | (C, T, 0) | -5.4722 | 2.0370 | -2.9763            | 0.0001 |
| ΔLnOC3     | (C, T, 0) | -6.7404 | 1.9927 | -2.9763            | 0.0000 |
| ΔLnPIOV    | (C, T, 0) | -3.1905 | 1.8312 | -2.9763            | 0.0317 |
Δ LnSIOV \( (C, T, 0) \) -2.1772 1.5418 -2.9862 0.2185
Δ LnTIOV \( (C, T, 0) \) -2.8651 1.7855 -2.9862 0.0628

Notes:
- C, T, and K denote the constant, trend, and lag length in the unit root test, respectively. If the value is zero, it means that constants or trends do not exist or that the lag length is zero.
- MacKinnon (1996) one-sided p-values.

Table 1 reports the ADF unit root test results for the natural logarithms of six variables and their first differences. Considering that the ADF values for LnOC1, LnOC2, LnOC3, LnPIOV, LnSIOV and LnTIOV exceed the critical values at the 5% level, the null hypothesis of non-stationary cannot be rejected. However, non-stationary can be rejected at the 5% level for their first differences. Hence, we conclude that the time series for all six variables are non-stationary, while their first differences are stationary. Thus, these time series are integrated of order one. No structural breaks are found.

4.2. Cointegration test

| Variables | Eigenvalue | Trace Statistic | 5% Critical values | Prob. ** |
|-----------|------------|----------------|--------------------|---------|
| OC1, PIOV | H0: \( R=0^* \) | 0.2837 | 12.3757 | 15.4947 | 0.1398 |
| | H1: \( R<1 \) | 0.1172 | 3.3672 | 3.8415 | 0.0665 |
| | H2: \( R=0^* \) | 0.3380 | 11.6982 | 15.4947 | 0.1720 |
| | H3: \( R<1 \) | 0.0206 | 0.5624 | 3.8415 | 0.4533 |
| OC2, SIOV | H0: \( R=0^* \) | 0.3726 | 15.4680 | 15.4947 | 0.0505 |
| | H1: \( R<1 \) | 0.1012 | 2.8809 | 3.8415 | 0.0896 |

Notes:
- The trace test indicates no cointegration at the 5% level.
- Denotes rejection of the hypothesis at the 5% level.
- Mackinnon Haug-Michelis (1999) p-values; \( R \) denotes the number of cointegrating equations.

The results of Johansen cointegration of the six variables are shown in Table 2. The trace tests between OC1 and PIOV, OC2 and SIOV, and OC3 and TIOV, show that the null hypothesis of absence of cointegrating relations \( (R=0) \) can be rejected at the 5% level, but the null hypothesis of the existence of at most one cointegrating relation \( (R \leq 1) \) can be accepted at the 5% level. This implies that one cointegrating equation exists at the 5% level. Thus, we conclude that oil consumption and output value in China have a long-run cointegrating relationship in all three sectors.

4.3. The ECM

| Variables | Coefficient | Std. Error | t-Statistic | Prob. |
|-----------|-------------|------------|-------------|-------|
| LnOC1     | C           | 4.8508     | 0.3558      | 13.6351 | 0.0000 |
| LnPIOV    | LnIOV       | 0.2451     | 0.0373      | 6.5673  | 0.0000 |
|           | Adjusted R-squared | 0.6150 | -           | -       | -      |
|           | Durbin-Watson stat | 0.4237 | -           | -       | -      |
| LnOC2     | LnIOV       | 0.2872     | 0.0093      | 31.0094 | 0.0000 |
| LnSIOV    | Adjusted R-squared | 0.9727 | -           | -       | -      |
|           | Durbin-Watson stat | 0.5280 | -           | -       | -      |
| LnOC3     | LnIOV       | 0.5878     | 0.0097      | 60.4018 | 0.0000 |
| LnTIOV    | Adjusted R-squared | 0.9927 | -           | -       | -      |
|           | Durbin-Watson stat | 0.8000 | -           | -       | -      |

Notes: LnIOV represents LnTIOV, LnTIOV, and LnTIOV.
The Engle-Granger approach will be used to investigate the short run and long run relationships between OC1 and PIOV, OC2 and SIOV, and OC3 and TIOV. Based on OLS (ordinary least square) estimation, Table 3 shows a relationship between oil consumption and output value for each sector in China. This demonstrates that the relationship between oil consumption and output value in the three sectors for the period 1985-2013 is a long run equilibrium. The long run equilibrium equations are given by:

\[
\begin{align*}
\text{LnOC1} &= 0.2451 \text{LnPIOV} + 4.8508 \\
\text{LnOC2} &= 0.2872 \text{LnSIOV} + 6.3527 \\
\text{LnOC3} &= 0.5878 \text{LnTIOV} + 2.8894
\end{align*}
\]

The results indicate that the long run elasticities of oil consumption with respect to output value in the primary, secondary, and tertiary sectors are 0.2451, 0.2872, and 0.5878, respectively. If output value in each sector increased by 1%, oil consumption in the primary, secondary, and tertiary sectors would increase by 0.25%, 0.29%, and 0.59%, respectively. This means that oil consumption in China is constrained by structural adjustment in the long run. The long run oil consumption constraint is highest for the tertiary sector, which has replaced the secondary sector as the major driver of the long run demand for oil. The secondary and tertiary sectors have the largest shares in oil consumption in China; therefore, they will be the main sources of future growth in the demand for oil.

Table 4 Reports the ECM.

| Variables | Coefficient | Std. Error | t-Statistic | Prob. |
|-----------|-------------|------------|-------------|-------|
| ΔLnOC1    | -0.1201     | 0.2952     | -0.4067     | 0.6877|
| C         | 0.0400      | 0.0394     | 1.0144      | 0.3201|
| V(-1)     | -0.2296     | 0.3125     | -0.7349     | 0.4692|
| Adjusted R-squared | 0.0289     | -          | -           | -     |
| Durbin-Watson stat | 1.8287     | -          | -           | -     |
| ΔLnOC2    | 0.1656      | 0.1155     | 1.4337      | 0.1641|
| C         | 0.0176      | 0.0193     | 0.9147      | 0.3691|
| V(-1)     | -0.0832     | 0.1242     | -0.6702     | 0.5089|
| Adjusted R-squared | 0.0880     | -          | -           | -     |
| Durbin-Watson stat | 2.1921     | -          | -           | -     |
| ΔLnOC3    | 0.1829      | 0.2028     | 0.9018      | 0.3758|
| C         | 0.0637      | 0.0350     | 1.8183      | 0.0810|
| V(-1)     | -0.3790     | 0.1488     | -2.5473     | 0.0174|
| Adjusted R-squared | 0.2152     | -          | -           | -     |
| Durbin-Watson stat | 2.2463     | -          | -           | -     |

Table 4 reports the ECM results. In the model, the dependent variable is the first difference of the natural logarithm of oil consumption in the three sectors, while the independent variable is the first difference of the natural logarithm of output value in the three sectors. The results imply that the short run rate of change of oil consumption (expressed in natural logarithms) with respect to (the natural logarithm of) output value in the primary sector is -0.1201, indicating that if last year’s oil consumption exceeded the level predicted by the short run fluctuation by 1%, this could lead to a 0.12% reduction in oil consumption this year. The short run rate of change of oil consumption (in the natural logarithms) with respect to (the natural logarithm of) output value in the secondary and tertiary sectors are 0.1656 and 0.1829, respectively. The short run constraint on oil consumption is obvious. In the short run, the oil consumption constraint is higher in the secondary and tertiary sectors than in the primary sector. The main cause of high oil consumption in the short run is the increase of output value in the secondary and tertiary sectors.

Furthermore, the results of the ECM also reveal that the short run fluctuations in output value and oil consumption in the three sectors are constrained by their long run equilibrium. In other words, the long run equilibrium between output value and oil consumption in the three sectors plays the role of...
smoothing short run fluctuation in oil consumption. The accommodation coefficients from long run equilibrium to short run fluctuations in the three sectors are -0.2296, -0.0832, and -0.3790. In conclusion, structural adjustment will continue to lower oil consumption intensity in China.

5. Conclusion and policy recommendations

We attempted to prove the existence of a “restraint” relationship between oil consumption and industrial structure in China, using the annual data for the period 1995-2013. Using a cointegration test and constructing an ECM, we find evidence of a constraint relationship. The long run elasticities of oil consumption with respect to output value in the primary, secondary, and tertiary sectors are 0.2451, 0.2872, and 0.5878, respectively. The short run rates of change of (the natural logarithm of) oil consumption with respect to (the natural logarithm of) output value in the primary, secondary and tertiary sectors are -0.1201, 0.1656, and 0.1829, respectively. We can conclude that the oil consumption constraint is lowest in the primary sector and highest in the tertiary sector in both the short and the long run. This is because long-term industrial structure formation and the technological level of each sector underline the existence of long run equilibrium and short run fluctuations of output value and oil consumption, with the latter being constrained by adjustment in industrial structure.

Some policy recommendations may help ease the constraint. Implementing scientific policies that discourage high energy consumption and pollution aim to raise the utilization rate of oil resources. We also need to optimize the industrial structure, radically change the nature of the industry production function, induce technical innovation, and reduce the intensity of oil consumption. In addition, ensuring sufficient domestic oil supply to meet demand is an effective approach to reduce the effect of the constraint.

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