Energy Economics xxx (2010) xxx–xxx

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Oil price shocks and their short- and long-term effects on the Chinese economy

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A R T I C L E   I N F O

Article history:
Received 12 July 2009
Received in revised form 6 January 2010
Accepted 7 January 2010
Available online xxxx

JEL classification:
Q43
Q41
Q48
O13
O53
P22
E22
E23

Keywords:
Structural vector auto-regressive model
Unit root test
Error-correction model
Oil-price shocks
Price transmission mechanisms
Investment
Output
Producer/consumer price index
Census X-12 approach
China

A B S T R A C T

A considerable body of economic literature shows the adverse economic impacts of oil-price shocks for the developed economies. However, there has been a lack of similar empirical study on China and other developing countries. This paper attempts to fill this gap by answering how and to what extent oil-price shocks impact China's economy, emphasizing on the price transmission mechanisms. To that end, we develop a structural vector auto-regressive model. Our results show that an oil-price increase negatively affects output and investment, but positively affects inflation rate and interest rate. However, with price control policies in China, the impact on real economy, represented by real output and real investment, lasts much longer than that to price/monetary variables. Our decomposition results also show that the short-term impact, namely output decrease induced by the cut in capacity–utilization rate, is greater in the first 6 periods (namely half a year), but the portion of the long-term impact, defined as the impact realized through an investment change, increases steadily and exceeds that of short-term impact in the 7th period. Afterwards, the long-term impact dominates, and maintains for quite some time.

1. Introduction

1.1. Oil prices and economic activities

The world has witnessed a continuous oil-price climb that lasts as long as astonishingly 5 years before a sharp downturn, leaving a historical record of US$147 per barrel in July 2008. The adverse impact of such oil-price shocks on the global economy has long been observed. Intuitively, rising oil prices preceded almost all of the recessions since 1965 (see the periods between dotted lines in Fig. 1). Analytically, Hamilton (1983) argued that oil-price increases were at least partially responsible for every post-World War II (WWII) U.S. recession except the one in 1960; Brown and Yücel (2002) pointed out that rising oil prices preceded eight of the nine post-WWII economic recessions.

Over the past three decades, a considerable body of economic studies has been devoted, following Hamilton's seminal paper, to exploring the relationship between oil-price shocks and the aggregate economic performance of various nations (Burbidge and Harrison, 1984; Gisser and Goodwin, 1986; Mork, 1989, 1994; Mork et al., 1994; Lee et al., 1995; Lee et al., 2001a,b; Cologni and Manera, 2008). All of these studies can broadly be classified into the three categories. The first category includes those studies that have investigated the theoretical mechanisms and channels through which the oil-price increase may retard economic activity (Bruno and Sachs, 1982; Hooker, 1996; Hamilton, 1996; Brown and Yücel 2002). The second category of studies has focused mainly on the empirical investigation of the relationship

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doi:10.1016/j.eneco.2010.01.002

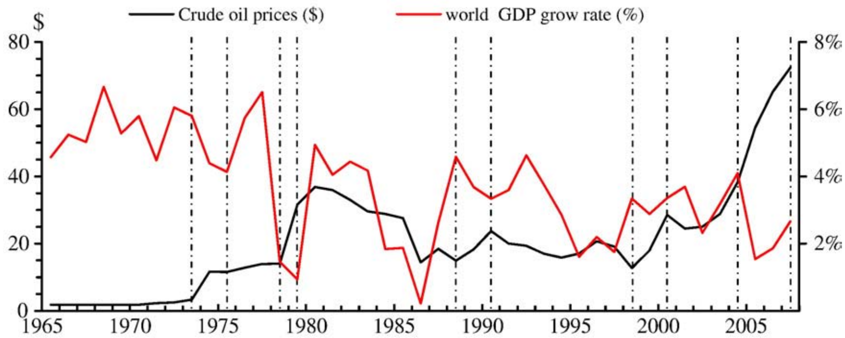

Fig. 1. Crude oil price and world economic growth.
Sources: Crude oil price data are from *BP Statistical Review of World Energy*; the world GDP growth rate data are from the World Bank's *WDI database.*

between oil-price change and national aggregate economic activity. Either linear or non-linear, either symmetric or asymmetric, the mathematical relationship were verified for most of the developed countries over the 1970s to the 1990s (Mory, 1993; Cunado and Perez de Gracia, 2003; Lee et al., 2001a,b; Lee and Ni, 2002; Lardic and Mignon 2006). The remaining studies in this field have targeted on the role of macroeconomic policies in dealing with the oil-price shock. They have examined the possibility of a weakening relationship between oil-price fluctuation and aggregate economic activity (Huang et al., 2005; Cologni and Manera, 2008; Leduc and Sill, 2004). Given that the slowdown of total output and inflation are widely considered as the two inevitable impacts of oil-price fluctuations, the majority of studies are seeking to design appropriate monetary policies aimed at coping with the oil supply shock.

1.2. What is going on in China?

Rapid increase of oil price since 2003 has caused great concerns worldwide. Most of the theoretical and empirical studies so far have acknowledged that sharp increase of oil price may exert an influence on the economic activity and macroeconomic policies. However, in an international context, such influence may vary country by country due to their different economic structure, energy intensity, energy mix and dependence on international energy market. China's oil consumption doubled over the past decade, and the economic growth is highly energy intensive (see Fig. 2). Energy consumption per US$1000 GDP of China in 2007 was 0.57 tonnes of oil equivalent (toe), higher than those of Germany (0.09), Japan (0.12) and the U.S. (0.17). The energy efficiency of industries in China is also very low: energy consumption per unit of output for cement is 53% higher than the world's average; that of glass is 47% higher; Petro-chemicals 45%; and alkali 34%. Moreover, China's dependence on imported oil increased to over 52% in 2007 (BP, 2008). Therefore, China could not have avoided the oil shock without any economic losses. However, the empirical evidence seems to suggest otherwise. Like most of the emerging economies, China has accomplished spectacular economic development in the new century. Over the period 2000–2007, China's GDP had grown at the average annual rate of 9.76% per year, the rate topping all the economies groupings in Fig. 3.

Does that suggest that China is less vulnerable to oil shocks than other economies? If not, is there any possibility for hysteresis in the impact of oil shock? Unfortunately, most of the empirical studies to date have been conducted for the developed nations, and there has been a lack of empirical evidences for developing countries. In this paper, we attempt to fill this gap by answering how and to what extent oil-price shocks impact China's economy. The paper emphasizes on the investigation of the transmission mechanisms. Specifically, it will focus on the following two issues: 1) how are the conventional transmission mechanisms modified in the specific context of China? and 2) how do the adverse impact of oil-price shock and its robustness change in the long run in China?

The paper is organized as follows. Section 2 discusses the transmission channels through which oil-price changes affect the macroeconomic variables. Section 3 provides a partial equilibrium analysis of such transmission mechanisms and their effects on the macroeconomic indices of China. The overall impact of oil-price shock

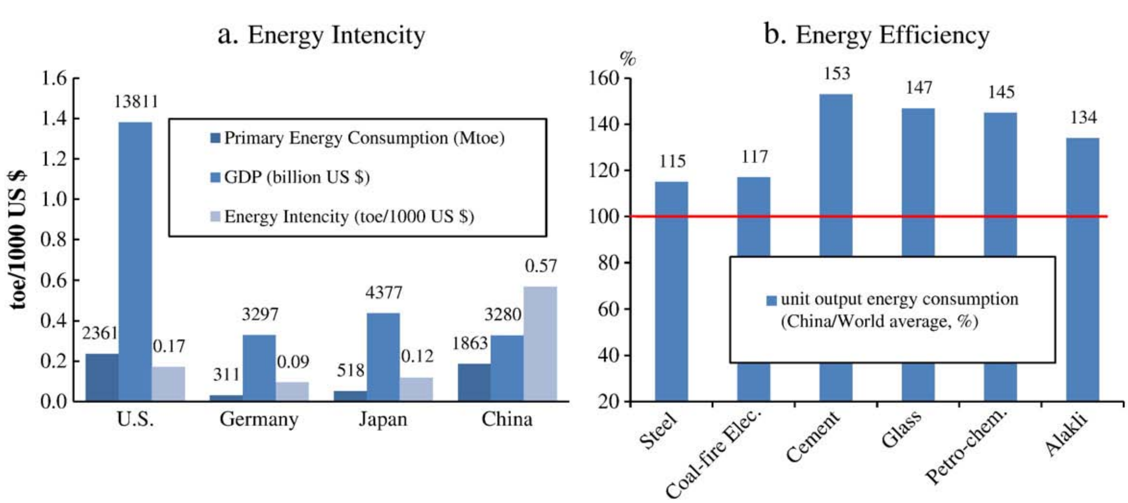

Fig. 2. Cross-nation comparison of energy intensity and efficiency.
Sources: Energy consumption data are from *BP Statistical Review of World Energy (2008)*; GDP data are from the World Bank's *WDI database*; and energy efficiency data are from *China Energy Statistical Yearbook, 2008.*

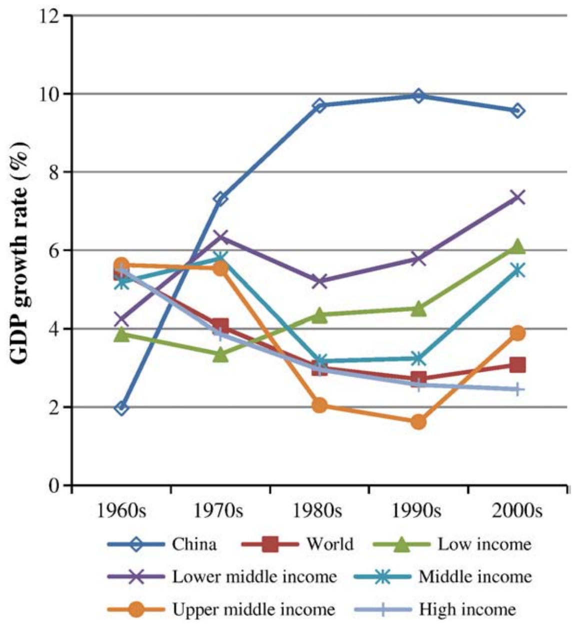

Fig. 3. Average annual GDP growth rates for the past five decades.
Source: The World Bank's *WDI database*.

is analyzed in Section 4 using a structural vector auto-regressive model. On that base, we disentangle the long-term impact from the overall impact in Section 5. Section 6 presents key findings and conclusions.

2. The transmission mechanisms

2.1. Transmission channels

From a theoretical perspective, oil-price changes affect the performances of macroeconomic variables through the following six transmission channels (Brown and Yücel, 2002):

- Supply-side shock effect: focusing on the direct impact on output due to the change in marginal producing costs caused by oil-price shock;
- wealth transfer effect: emphasizing on the different marginal consumption rate of petrodollar and that of ordinary trade surplus;
- inflation effect: analyzing relationship between domestic inflation and oil prices;
- real balance effect: investigating the change in money demand and monetary policy;
- sector adjustment effect: estimating the adjustment cost of industrial structure, which is mainly used to explain the asymmetry in oil-price shock impact; and
- unexpected effect: focusing on the uncertainty over oil price and its impact.

These channels have been proved to be valid in industrialized countries. However, whether they still hold in China is an open question. Fig. 4 holds the main idea.

Crude oil is one of the most fundamental and crucial raw materials for industrial production, and the change in its price can affect the output directly. As Arrow ① in Fig. 4 indicates, oil-price shocks can increase the marginal cost of production in many industries, and thus reduce the production. This is referred to as the supply-side shock effect. The reduction of output due to the cut in capacity utilization can recover quickly within the range of capacity. However, oil-price shocks also have long-term effect on output which is carried out through Price/Monetary Transmission Mechanism (Arrow ③).

Cost shocks in the upper-stream industry can be transmitted from producers and sectors to end-users. A well developed industrial chain can transmit inflationary shock from upper-stream to down-stream, leaving the producers' profit rate slightly affected. That can raise the overall cost for consumers and producers, thus reducing the consumers' real balance. This transmission ends up with the reduction of consumption and the real output as well. This is the story witnessed in most developed countries. But in China, hackneyed price controls, surplus production due to limited domestic demand and tough price competition in exporting sectors make the output prices very sticky (Arrow ④).

Because of the limited space for mark-up, down-stream producers could only reduce their profit to assimilate the cost increase, which would doubtlessly cause the decrease in their investment. Since investment determines the increase of production capacity, i.e. the potential output ability, which cannot recover in a short period of time even when the cost shock disappears, a decrease in investment would abate output in the long run. In our view, this channel is more important and dominant in China.

Real balance decrease can enlarge money demand in the market while investment decrease can lessen it, so the net impact of an oil-price shock on interest rate is unclear, neither does the corresponding monetary policy needed. But in the present age, monetary authorities

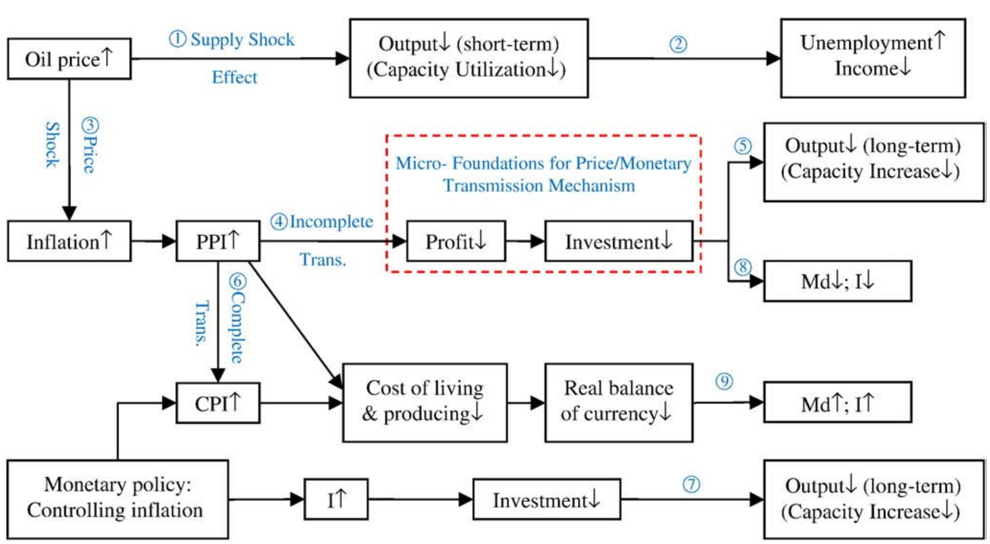

Fig. 4. Transmission channels of oil-price shocks.

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set the target of their policy as controlling inflation. When the observed inflation is caused by cost shocks including oil-price increases, a tight monetary policy can worsen the long-term output by increased interest rate and decreased investment. Bernanke et al. (1997) find that a positive innovation in oil price is followed by a rise in the federal fund rate, and this kind of monetary policy tightening accounted for about two-thirds to three-quarters of the reduction in U.S. output subsequent to an oil shock. A tight monetary policy can also be found in China since 2003, illustrated by continuously raising interest rates. To what extent the tightening monetary policy has affected China's output is an interesting question, but that goes beyond the scope of the paper.

3. Partial equilibrium analysis of the transmission mechanisms

In this section, we will test the validity of transmission mechanisms of oil price shock in China, by checking the statistical relationships between key variables on transmission chains shown in Fig. 4 step by step.

We start checking the relationship between oil price and domestic price indices including CPI and PPI. This relationship is corresponding to the arrows 3 and 6 in Fig. 4. Significant positive relationship indicates complete transmission of oil price shock, while insignificant relationship indicates incomplete transmission. Then, we will test the direct impact of oil price change to economic output, i.e. the short-term impact, indicated by arrow 1 in Fig. 4. Finally, we will test the relationship between domestic price indices, profit rate of industry, investment and output. These relationships can reveal the validity of long term impact of oil price shock, as shown in Fig. 4 (arrows 4 and 5).

3.1. Data

In order to test the validity of transmission mechanisms, we employ some macroeconomic variables of China, denoted as follows:

- Real Oil-Price (RP) is the adjusted WTI spot crude price in 1995 Chinese Yuan. Aside from RP, we introduce Positive/Negative Difference of Oil-Price (PDP/NDP) and Net Oil-Price Increase (NPI), which were put forward by Hamilton (1996), to capture the asymmetry in the impact of oil-price shock on economy[1];
- Consumer/Producer Price Index (CPI/PPI) are in chain-indices;
- Real Rate of Return for Industrial Companies (RRT) is the ratio of profit and capital occupation of product, minus PPI;
- Real Interest Rate (RI) is one year loan rate, minus CPI;
- Real Investment toward Industry (INV) is in constant price (1995 Chinese Yuan);
- Real Industrial Added Value (IAV) is employed to indicate aggregate output, also in constant price (1995 Chinese Yuan).

Since the oil pricing system is reformed in June 1998, the sample period is set from June 1998 to August 2008, including 123 original observations. The oil prices data are taken from the U.S. Energy Information Administration (http://tonto.eia.doe.gov); the macroeconomic variables of China are derived from the *Wind Financial Database* named WindDB (http://www.wind.com.cn/en/product/windDB.htm). A multiplicative Census X-12 approach[2] is utilized to eliminate seasonal fluctuations from INV, IAV and RRT. There are no evidences for seasonal patterns in CPI, PPI and RP series (see Table 1).

Before further econometric analysis, we also test the unit root features of all those aforementioned series, in order to check their stationarity. Augmented Dickey-Fuller Test with Schwarz Info Criterion for lag-length is utilized for addressing the stationarity, and all the results (see Table 1) are at the 1% significance level.

3.2. Crude oil price and domestic inflation rate

Our empirical study shows the stickiness of price change in China. According to Auto-regressive Distributed Lag (ADL) model, PPI is positively related to both NPI and the first-order difference of log(RP), denoted as D(LRP). As column (1) of Table 2 indicates, the coefficients of NPI to PPI is 0.073 and that of NPI(−1) is 0.113, both are significant at the 1% level according to the t-statics test. This positive relationship fades away after 2 periods. None of the coefficients of NPI(−2), NPI(−3) and NPI(−4) passed the t-statistics test at the 10% significance level. This trend also exist for those of D(LRP)s (see column (3) in Table 2). Granger Causality test shows the robust relationship between oil price and PPI (see the lower half of Table 2). Furthermore, the coefficients of immediate period items (D(LRP), NPI) are smaller and less significant than those of lagged items (D(LRP(−1)), NPI(−1)). This means that the impact of oil-price shock emerges gradually, and it takes about 2–3 months to complete the inflationary transmission.

While the impact of oil price on PPI is robust and significant, its impact on CPI is very weak (see columns (2) and (4) in Table 2). There is no evidence for direct relationship between oil price and China's CPI. But PPI does have impact on CPI, which enables the oil-price shocks to transmit through to CPI, though very indirectly and lagged. That illustrates the aforementioned incompleteness in the price transmission in China. Thanks to the stickiness and hysteresis, PPI would increase along with oil price, while CPI is more likely to remain stable. As a result, consumption would not be severely affected by oil price. However, if we interpret PPI as price index for industrial outputs, most of which are intermediate goods and will be ploughed into reproduction, then an increase in PPI will surely boost the production costs and reduce producers' profit. That will cause the reduction in both short-term and long-term outputs. In developed countries where commodity prices are flexible and market-oriented, the oil shock affects more on consumption but less on production. Compared with that, the price transmission mechanism in China is stickier, and that makes the adverse impact of oil-price shocks in China last much longer. Section 5 provides more discussion on this issue.

3.3. Crude oil price and industrial output

The increase in crude oil price raises the input costs of production and thus reduces production. Aimed at maximizing their profits,

Table 1
Data processing and the testing results.

Variable	Seasonal adjustment (*_SA)	Logarithm conversion (L-*)	Stationarity
RP		√	I(1)
NPI/PDP/NDP			I(0)
CPI		√	I(0)
PPI		√	I(0)
RRT	√	√	I(0)
RI			I(1)
INV	√	√	I(1)
IAV	√	√	I(1)

Notes: "√" indicates that the corresponding series are adjusted or converted before being employed in the following econometric analysis.
I(0) indicates stationary series; I(1) stands for the first-order integrated series.

[1] NPI is defined as the ratio of the current oil price to the highest price in the previous 12 months if the ratio is greater than unity and zero otherwise.

[2] The census X-12 approach is developed by the U.S. Census Bureau in the late 1990s, for decomposition/adjustment of seasonal time series. It is adapted from the Bureau's well known X-11 procedure (Shiskin et al., 1967; Findley et al., 1998). The core algorithm of Census X-12 approach is based on an Auto-Regressive Integrated Moving Average (ARIMA) model. The multiplicative form of decomposition was used in this analysis:

$$Y_t = TC_t \cdot S_t \cdot \delta_t$$

where Y_t is the original series, TC_t is the trend cycle, S_t is the seasonal factors, and δ_t stands for irregular component.

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Table 2
Statistical relationship between CPI, PPI and real oil price.

	PPI (1)	CPI (2)		PPI (3)	CPI (4)
NPI	0.071775*	−0.023462	D(LRP)	0.008321**	−0.000776
	(2.759009)	(−0.852296)		(1.932861)	(−0.160449)
NPI(−1)	0.111706*	−0.014695	D(LRP(−1))	0.025372*	−0.002029
	(4.267163)	(−0.507374)		(5.690238)	(−0.369377)
NPI(−2)	−0.013886	−0.004797	D(LRP(−2))	0.015299*	−0.003468
	(−0.526438)	(−0.174392)		(3.404294)	(−0.681754)
NPI(−3)	−0.021335	0.000526	D(LRP(−3))	−0.004319	0.001896
	(−0.813285)	(0.019370)		(−0.965777)	(0.391462)
NPI(−4)	0.011693	0.004093	D(LRP(−4))	0.006682	−0.001581
	(0.435550)	(0.145906)		(1.529433)	(−0.321726)
PPI	/	0.166983**	PPI	/	0.167371
		(1.775017)			(1.639565)
Trend	6.91E−05*	3.84E−05*	Trend	6.59E−05*	3.87E−05*
	(4.494769)	(3.064193)		(4.844819)	(3.024030)
C	4.593901*	3.830790*	C	4.594958*	3.828735*
	(1642.687)	(8.863996)		(1886.662)	(8.162182)
AR(1)	0.344093*	0.028428	AR(1)	0.305345*	0.041649
	(3.921601)	(0.291852)		(3.432220)	(0.426671)
Granger Causality Test					
NPI → PPI*			D(LRP) → PPI*		
PPI → NPI			PPI → D(LRP)		
NPI → CPI			D(LRP) → CPI		
CPI → NPI			CPI → D(LRP)		
PPI → CPI**			PPI → CPI**		
CPI → PPI*			CPI → PPI*[a]		

Notes: *1% significance level; **5% significance level; ***10% significance level.
t-statistics are listed in parentheses.
[a] The significant causality from CPI to PPI can be explained by demand effect. On the one hand, increased CPI can boost the costs of living, and thus promote the workers to demand for higher wage. On the other hand, CPI includes the price of services like transportation which is also an important part of production.

producers choose a proper capacity–utilization rate with respect to their marginal cost and profits. Once the disadvantageous situation disappears, the output can recover soon within the limit of capacity. So the oil-price shock can affect the aggregate output immediately and directly by pushing production costs up. We use the first-order difference equation to estimate the short-term relationship between variables. The results show that output is negatively related to both oil price and domestic inflation rate (CPI). The impact of oil price has hysteresis, illustrated by the significance of relationship between IAV and NPI(−1) (see the left column in Table 3).

While this short-term effect of oil-price shocks in China is perspicuous and statistically significant, in our view, the aforementioned long-term effect is more crucial, given the stickiness of price transmission in China. Concerning our assumption that investment determines potential output capacity, we check the cointegration relationship between IAV and INV (*t*-statistics are shown in parentheses below the coefficients):

$$IAV = \underset{(33.16596)}{3.602374} + \underset{(16.313233)}{0.461215} \cdot INV + \underset{(13.09282)}{0.007478} \cdot trend + \varepsilon \qquad (1)$$

The stationarity of the residual series is checked using the ADF,[3] PP and KPSS approaches, all indicating $I(0)$ at the 1% significance level. That indicates the existence of cointegration relationship between investment and output. Taking the long-term relationship into account, we can establish an Error-Correction Model (ECM), and the results are more legible (listed on the right column in Table 3).

The cointegration relationship reinforces the argument that investment determines long term output. To separate the long-term effect from the overall effect of an oil price shock, a rigorous analysis is carried out using a structural vector auto-regressive model in section 4. But before that, we first investigate the determinants of investment, in both the short term and long term.

Aside from economic aggregates, interest rate and profit rate also determine investment by changing the costs and benefits of investment. Since profit rate (RRT) is trend stationary, we test the cointegration relationship among INV, IAV and RI (t-statistics are shown in parentheses below the coefficients):

$$INV = \underset{(-8.561757)}{-4.189275} + \underset{(16.16539)}{1.507334} \cdot IAV - \underset{(-1.364883)}{0.007621} \cdot RI - \underset{(-3.507834)}{0.005733} \cdot trend + \varepsilon \qquad (2)$$

Table 3
Oil price, inflation and short-term output.

	Difference equation	Error-correction model (ECM)
	IAV	IAV
D(INV)	0.042294	0.106043*
	(1.086429)	(2.776873)
CPI	−4.276505*	−3.573045*
	(−5.454025)	(−4.563234)
PPI	2.041760*	1.002688
	(2.841892)	(1.359800)
NPI	−0.246770	−0.172689
	(−1.056468)	(−0.805769)
NPI(−1)	−0.431236**	−0.381431***
	(−1.779239)	(−1.713262)
Trend	/	0.000175***
		(1.733048)
C	10.31189*	11.82609*
	(2.596383)	(2.686835)
ECM	/	−0.337751*
		(−4.710549)

t-statistics are listed in parentheses.
* 1% significance level.
** 5% significance level.
*** 10% significance level.

[3] Since what we test here is the residual series of cointegration regression, it is more likely to reject the null hypothesis according to the ordinary critical level of *t*-values. So here we apply the critical *t*-values put forward by MacKinnon (1991).

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Table 4
Determinants of investment.

	D(IAV)	D(RI)	RRT	EC[a]
D(INV)	0.529455*	−0.021864**	0.001715**	−0.534252*
	(3.021580)	(−2.026463)	(1.149730)	(−6.511355)

Notes: *1% significance level; **5% significance level; ***10% significance level. *t*-statistics are listed in parentheses.
[a] EC is the 1 stage lagged series of the residual series in Eq. (2).

The residual series is $I(0)$ according to ADF, PP and KPSS tests at the 1% significance level, indicating the strong cointegration relationship between INV and IAV, RI. Taking the cointegration relationship into account, we can establish an Error Correction Model with the stationary residual series, to test the dynamic relationship between investment (INV), economic output (IAV), interest rate (RI) and rate of return (RRT). Table 4 provides the ECM results about the determinant of investment. As we can see, investment is related to profit rate and interest rate.

Further empirical research reveals that there is a negative relationship between industrial companies' profit rate and domestic inflation rate[4], and oil price as well (see Table 5).

3.4. Brief summary of transmission mechanisms in China

An increase in crude oil price can affect the short term output of an economy by directly raising the marginal cost for industrial production and change the profit-maximizing capacity–utilizing rate. Once the disadvantageous situation disappears, the production can recover soon within the limit of capacity. But there are some effects of oil-price shock that cannot recover quickly. Change in production cost would affect profit rate of producers, which is the primary profit of investment. Given the fact that investment determines output in the long run, the long-term effect of oil shock is more important than the short-term effect.

Price controls, surplus production caused by limited domestic demand, excessive price competition in international trade make the CPI very sticky in China. The stickiness and hysteresis of the inflationary shock transmission cut the profit rate of producers which cause the reduction in both short-term and long-term outputs. Compared with developed countries, the baffled price transmission mechanism in China makes the adverse impact of inflationary shocks more serious and permanent.

4. General equilibrium analysis by the SVAR model

4.1. Specification of the SVAR model

For a general equilibrium analysis for longer term, we establish a Structural Vector Auto-Regressive (SVAR) model.

We start with a reduced-form Vector Auto-Regressive (VAR) model, in order to describe the transmission system of oil-price shock in China. According to the aforementioned transmission mechanisms, oil-price shock can affect output directly, and at the same time increase domestic inflation rate. Given the stickiness of price transmission in China, the increased inflation rate will cut producers' profit rate which, together with interest rate, determines investment. Fig. 5 summarizes the transmission mechanism. Four key explanatory variables (NPI, CPI, I, INV) that have direct impact on output and one explained variable (IAV) are introduced into the VAR(k) model:

$$\mathbf{X}_t = \mathbf{c}_0 + \textstyle\sum_{i=1}^{k} \mathbf{A}_i \mathbf{X}_{t-i} + \mu_t. \quad (3)$$

$\mathbf{X}_t$ is the vector of the five endogenous variables, $\mathbf{X}_t = \{IAV_t, INV_t, I_t, CPI_t, NPI_t\}$;

$\boldsymbol{\mu}_t$ is the vector of residuals, which are used to estimate the structural restrictions;

$\mathbf{c}_0$ and $\mathbf{A}_i$ are vector/matrix for constants and coefficients which need to be estimated;

k is the number of lagged terms. VAR estimations are very sensitive to lag structure of variables. A sufficient lag length does help to reflect the long-term impact of variables on others, but adding lag length will cause collinearity problems, let alone lessen the degrees of freedom (DOF). For any $k \geq 11$, the model will become divergent with at least one Auto-Regressive Roots greater than unit. According to sequential modified Likelihood Ratio test static (LR), lag order of 1–3 is the best for our model ($k=3$)[5].

Since only the lagged terms are listed on the right-hand side of VAR equation, a reduced-form VAR model is unable to analyze the contemporanous relationship among variables, which causes cross-correlation among residual series, i.e. the covariance matrix of residuals $\sum = E(\mu_t \mu_t') \neq \mathbf{I}$. Although it does not affect the unbiasness and efficiency of the estimation, the contemporoneous relationship may affect the impulse response ramarkably. So we introduce the contemporaneous coefficients matrix $\mathbf{B}_0$ into the VAR model as structural restrictions:

$$\mathbf{B}_0 \mathbf{X}_t = \mathbf{c}_0 + \textstyle\sum_{i=1}^{k} \mathbf{B}_i \mathbf{X}_{t-i} + \varepsilon_t \quad (4)$$

$\mathbf{B_0}$ is a 5 5 non-identity matrix (note that if $\mathbf{B_0}$ is an identity matrix, then the SVAR model would retrogress into a reduced-form VAR model), $\mathbf{B}_0 = \begin{pmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} \end{pmatrix}$

$\boldsymbol{\varepsilon}_t$ is a *5*1* vector of residuals which satisfies the condition that $E(\varepsilon_t \varepsilon'_t) = \mathbf{I}$, that is, the residuals are uncorrelated white noise series. Rewrite a reduced-form VAR in lag operator:

$$\mathbf{A}(L)\mathbf{X}_t = \mu_t$$

Assume that there is a invertible matrix $\mathbf{B}_{5*5}$:

$$\mathbf{B}\mathbf{A}(L)\mathbf{X}_t = \mathbf{B}\mu_t = \varepsilon_t$$

Since $E(\varepsilon_t \varepsilon'_t) = E(\mathbf{B}\mu_t \mu'_t \mathbf{B}) = \mathbf{B} \sum \mathbf{B} = \mathbf{I}$, and $\sum$ is already identified by $\boldsymbol{\mu}_t$, we have actually applied $5(5+1)/2 = 15$ restrictions, and we need another $5^2 - 15 = 10$ restrictions to identify the structural restriction matrix $\mathbf{B}$.

For the extra 10 restrictions, we turn to the economic theory. Firstly, we can rewrite the left side of Eq. (4) as follows:

$$\tilde{\mathbf{X}}_t = \begin{pmatrix} b_{11} \cdot IAV_t + b_{12} \cdot INV_t + b_{13} \cdot I_t + b_{14} \cdot CPI_t + b_{15} NPI_t \\ b_{21} \cdot IAV_t + b_{22} \cdot INV_t + b_{23} \cdot I_t + b_{24} \cdot CPI_t + b_{25} NPI_t \\ b_{31} \cdot IAV_t + b_{32} \cdot INV_t + b_{33} \cdot I_t + b_{34} \cdot CPI_t + b_{35} NPI_t \\ b_{41} \cdot IAV_t + b_{42} \cdot INV_t + b_{43} \cdot I_t + b_{44} \cdot CPI_t + b_{45} NPI_t \\ b_{51} \cdot IAV_t + b_{52} \cdot INV_t + b_{53} \cdot I_t + b_{54} \cdot CPI_t + b_{55} NPI_t \end{pmatrix}$$

$\tilde{\mathbf{X}}_t$ contains all the items with subscript t, and their coefficinets b_{ij} represents contemporaneous relationships between variables.

[4] The impact of PPI on profit rate is unclear, due also to its duality. See Appendix A for details.

[5] The unit root test indicated that IAV, INV and I employed in the VAR model are $I(1)$ series, but the nonstationary problem can be absorbed by introducing more lagged terms, so the theoretical stationarity assumption is not very strict. The 3 stage lag length is sufficient to absorb the nonstationarity, for the residual series of 5 VAR equations are all stationary. We also utilize the VEC module to estimate the mutual relationship among variables, and the result is very similar to the VAR estimation. See Appendix B for detailed analysis.

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Table 5
Oil prices, inflation ratio and profit rate.

	CPI	NPI(−1)	NPI(−2)	NPI(−3)	Trend	C	AR(1)
RRT	−1.323886*	−0.114355**	−0.218689*	−0.089526***	10.63597*	0.000834*	0.702136*
	(−8.114843)	(−2.039538)	(−3.491513)	(−1.576213)	(14.17218)	(11.31925)	(10.61814)

t-statistics are listed in parentheses.
PPI and NPI are not included in the equation, because their coefficients fail to pass the significance test.
* 1% significance level.
** 5% significance level.
*** 10% significance level.

It is reasonable to assume that oil price is exogenous (only) at the contemporaneous period. , that means IAVt, INVt, CPIt and It are not determinants of NPI at period t (i.e. for $t=0$, $b_{51}, b_{52}, b_{53}, b_{54}=0$).

The second restriction is that CPI is only determined by oil price and CPI itself, which means a change in interest rate, investment and output can only affect CPI in the subsequent periods ($b_{41}, b_{42}, b_{43}=0$).

The third restriction specifies that interest rate does not respond to either IAV or INV, because of the time lag ($b_{31}, b_{32}=0$).

In the last restriction, we assume that output change does not affect investment immediately, but the investment change affect output instantly ($b_{21}=0$).

Rewriting these restrictions in matrix form, we get a set of recursive restrictions in an upper-triangle matrix $\mathbf{B}_0$, with 15 elements to be estimated:

$$\mathbf{B}_0=\begin{pmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ 0 & b_{22} & b_{23} & b_{24} & b_{25} \\ 0 & 0 & b_{33} & b_{34} & b_{35} \\ 0 & 0 & 0 & b_{44} & b_{45} \\ 0 & 0 & 0 & 0 & b_{55} \end{pmatrix}.$$

With these restrictions, we can estimate the elements in matrix **B** with the SVAR modle. The estimation is denominated as $\hat{\mathrm{B}}$:

$$\hat{\mathrm{B}}=\begin{pmatrix} 33.71^* & -1.76 & -0.26 & 100.14^* & 3.70 \\ 0 & 14.19^* & 1.72^* & -24.79 & -5.19 \\ 0 & 0 & 7.69^* & -20.08 & -7.33 \\ 0 & 0 & 0 & 257.54^* & 5.90 \\ 0 & 0 & 0 & 0 & 71.70^* \end{pmatrix}.$$

The cross-correlation among residual serial of the SVAR model is valid, which means that the structural restriction simulates the contemporaneous relationships among variables.

4.2. Economic meanings of the SVAR analysis

Fig. 6 shows the impact of oil-price shock, which equals to one standard deviation in NPI. According to the impulse response equation, in a short period of time, oil-price shock can negatively affect output and investment, but positively affect interest rate, leaving its impact on CPI unclear. Interest rate, namely one year loan rate, is a representation of monetary policy. In the short run, interest soars accordingly to mitigate the inflation rate which is boosted up by oil price. Though CPI is not affected, PPI is very sensitive to oil price according to our previous analysis. Since PPI covers a larger range of products than CPI does, the general inflation rate would also be sensitive to oil price. Moreover, it is reasonable for a forward looking monetary policy to react before any change in CPI is observed, because there is an expectation of inflation after a serious oil-price shock. However in a longer term, a lower interest rate is needed to counteract the adverse impact.[6]

[6] Bernanke et al. (1997) pointed out that a forward looking monetary policy tends to be tightening when oil price shock happens, and showed that the contractionary monetary policies have deteriorated the adverse impacts of high oil price.

5. Separation of long- and short-term impacts

5.1. Direct approach

Comparing the four graphs in Fig. 6, we can see that the impacts on real economy variables, namely output and investment, take more than 200 periods to recover (i.e. 16–17 years), which is far more permanent than that to price/monetary variables. Interest rate recovers to zero in about 2 years (24 periods) after an oil-price shock, and CPI recovers even faster. From a Keynesian perspective, interest and inflation rates impact real output through investment. The cointegration test and the ECM model in Section 3 have shown the steady relationship between investment and output in the long run, so it is reasonable to define the long-term impact as the impact realized through investment change. In the following section, we intend to separate the long-term impact ($\boldsymbol{L}_\mathrm{i}$) from the overall impact ($\boldsymbol{M}_\mathrm{i}$). In so doing, we follow the strategy adopted by Bernanke et al. (1997) while disentangling the impact of interest change from the overall impact of oil-price change.

The belt between dotted lines is ±2 Standard Error.

Oil-price change can influence investment significantly and permanently, which means that the level of investment in each period contains the impacts of oil-price shock in the previous periods. So, if there are no shocks other than oil-price change, investment series can be represented in a moving average form in term of oil-price shock:

$$INV_t = INV_0 + a_0 e_t + a_1 e_{t-1} + \Lambda + a_p e_{t-p}$$

e_{t-i} denotes the level of oil-price shocks, measured by times of NPI residuals (***Resid***$_{\mathrm{npi}}$) at each period to standard-deviation (**S.D.**$_{npi}$) of NPI in the SVAR model; the moving average parameter a_i equals to the

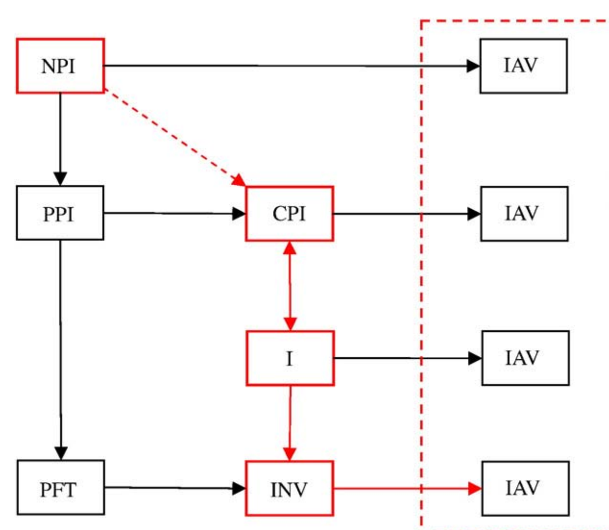

Fig. 5. Diagrammatic sketch for the transmission mechanisms of oil-price shock.

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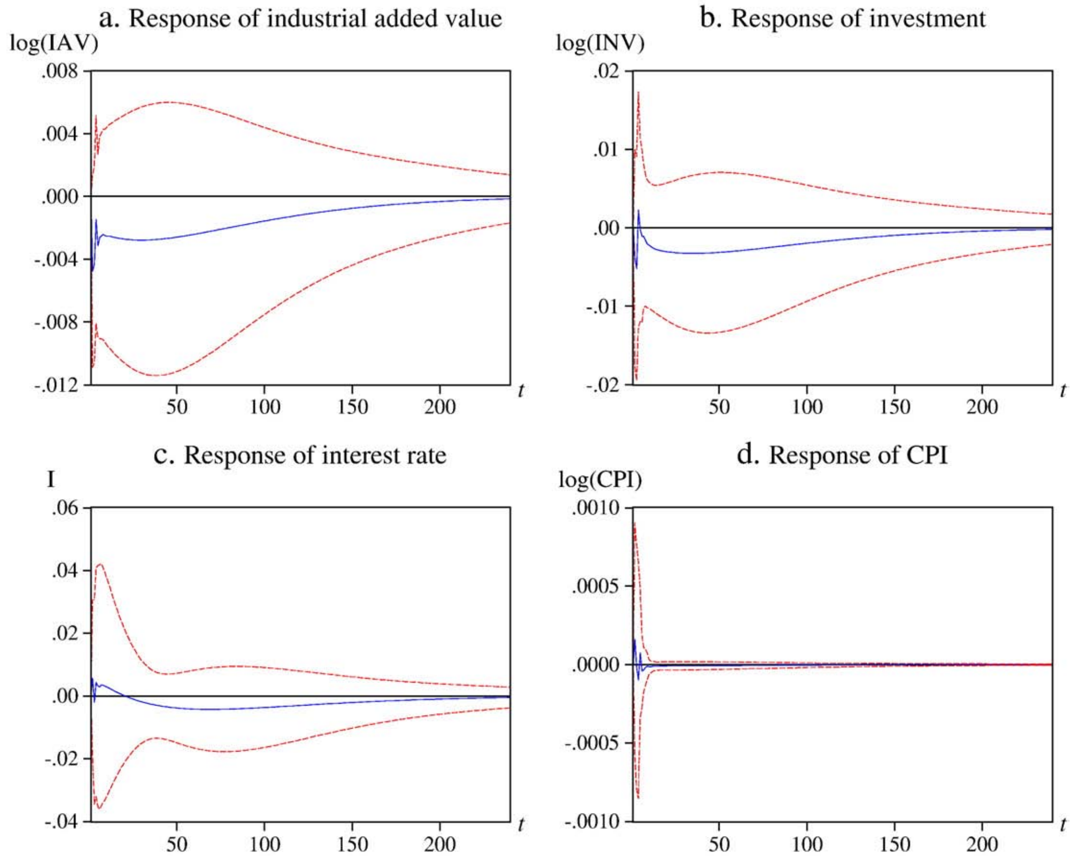

Fig. 6. Response of macroeconomic variables of China to oil-price shocks. Notes: Oil-price shock is defined as one standard deviation change in NPI.

corresponding lagged impulse response coefficients. For instance, a shock of one **S.D.** NPI will cause that response in INV equals to a_1 at the 1st period, a_2 at the 2nd period, etc. And p is the number of periods that oil-price impact on investment lasts. Thus, the fluctuation of investment that is attributed to oil price change equals to:

$$\sum_{i=1}^{p}\left(\frac{Resid_{p-i,npi}}{S.D._{npi}}\right)\cdot a_i, p\leq 121$$

As indicated in Fig. 6, the responses of investment converge to 0 after about 200 periods, which exceeds the sample range, so p is set to the limit of observations ($p=121$). This part needs to be eliminated from the original level (see Fig. 7).

On that base, we can generate a new series of adjusted investment (INVA) devoid of oil-price change:

$$INVA = INV - \sum_{i=1}^{p}\left(\frac{Resid_{p-i,npi}}{S.D._{npi}}\right)\cdot a_i, p\leq 121.$$

By employing the adjusted investment data to estimate the SVAR model, we get a new set of impulse responses (Fig. 8). Not surprisingly, the response of investment to NPI is less significant and converges faster, while the Standard Error is greater. This means that the adjustment has successfully eliminated the oil-price impact on investment. Besides, the response of IAV also converges quickly compared to the original model. Since the adjusted investment is free to oil-price shock, the response of output could not have carried out

Fig. 7. The fluctuation of investment that can be attributed to oil-price change.

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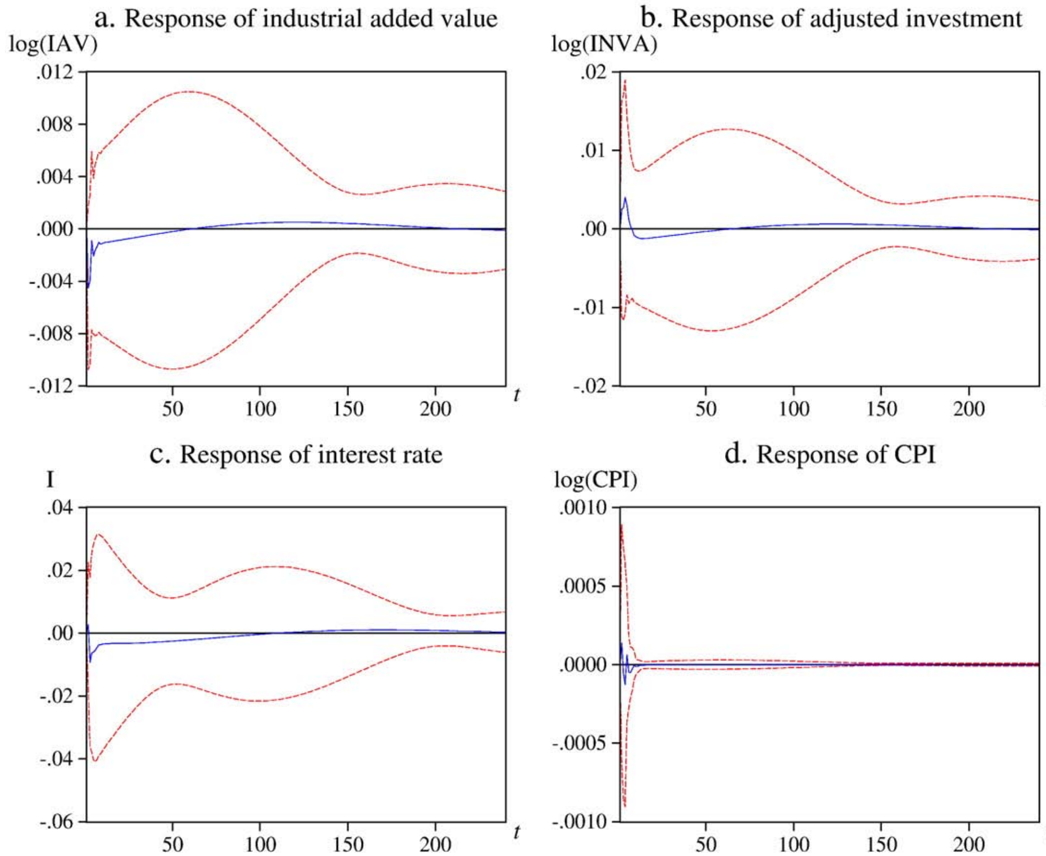

Fig. 8. Response of macroeconomic variables using adjusted investment data.

through an investment change. According to our definition, this response is the so-called short-term impact ($\boldsymbol{S}_i$).

Fig. 9 shows the result of the separation for a range of 200 periods ($\boldsymbol{L}_i = \boldsymbol{M}_i - \boldsymbol{S}_i$). In the first 6 periods, the short-term impact, namely direct output decrease induced by the cut of capacity–utilization rate, is greater, but the portion of long-term impact increases steadily and exceeds 50% after 7 periods. Afterwards, $\boldsymbol{L}_i$ dominates the overall impact.

In Fig. 9, we also note that after the 60 periods, the portion of $\boldsymbol{L}_i$ exceeds 100%, which seems to be unreasonable. A possible explanation has been brought forward by Kim and Kuijs (2007). They point out that energy efficiency in China has been significantly improved since 2002 because of the increased energy costs. The high oil price stimulates the producers to develop more energy-efficient or less energy-intensive technologies, and thus change the energy efficiency and energy intensity of China. However, this kind of technology improvement can only be observed while investigating the direct impact of oil price on output, while the long-term impact through a decrease in aggregate investment is unable to include this kind of change in investment structure and improvement in technology. The gap between $\boldsymbol{L}_i$ and $\boldsymbol{M}_i$ after the 60th period can be partially explained by this effect.

6. Conclusions and discussion

6.1. The economic impact of oil price shock in China

Oil-price shocks have both the long-term and short-term effects on economic performance. The short-term effect is caused mainly by the

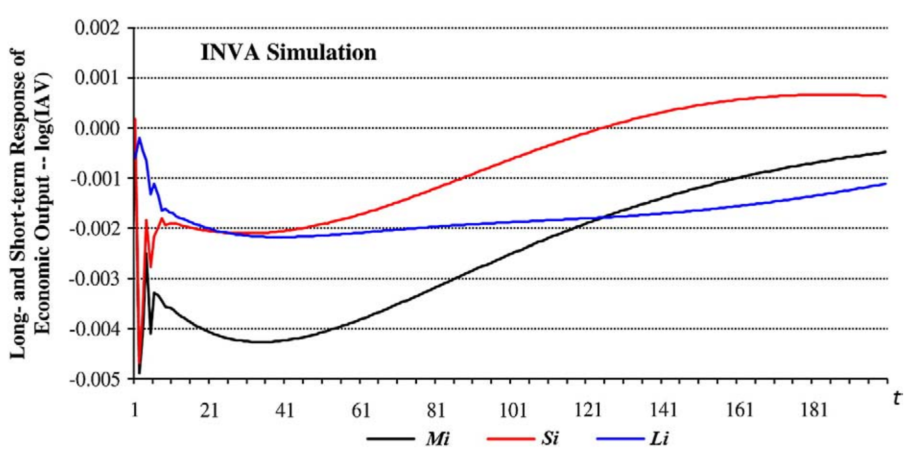

Fig. 9. The impact of oil-price change on output. Notes: $\boldsymbol{M}_i$, $\boldsymbol{S}_i$ and $\boldsymbol{L}_i$ indicate the overall impact, the short-term impact, and the long-term impact, respectively.

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change in capacity–utilization ratio, while the long-term effect is due to the change in capacity itself. Since investment determines the potential output capacity in the long run, the long-term impact of oil-price shock is attributed to the decrease of investment caused by higher input costs. Our ECM results clearly indicate the negative short-term relationship between oil price and output: 1% increase in oil price can decelerate the output growth by about 0.38%. But the significance of the coefficient is relatively small, compared to that of investment in the cointegration equation. This is an illustration of the importance of investment to the long-term impact in China.

In the free market economies, producers could mark up their products to offset the increased input costs due to oil-price shock, depending on the price elasticity of demand, and their profit rate would not be severely affected. When the disadvantageous situation fades away, production can recover very quickly within the range of output capacity. In most developed countries where markets are well established, this kind of adjustment can be realized very quickly. However in China, as well as in most other developing countries, this kind of adjustment is baffled by the distorted pricing mechanism, and oil-price shock impacts the economy differently. Our in-depth study on the difference in response of CPI and PPI to oil-price shock clearly indicates this unique price transmission mechanism in China.

Prevailing price controls in China have targeted at two kinds of goods: fundamental industrial raw materials and CPI commodities. Intermediate products are mostly free from price restrictions. The price controls toward raw materials used to be capable in stabilizing input costs for producers and strengthening the comparative advantage which fueled the remarkable economic growth in China. However, with the increasing dependence on imported industrial raw materials like crude oil, iron ore and certain kinds of farm products, it is becoming increasingly difficult and impractical to control the raw material prices in China. Meanwhile, the oil pricing system on domestic market went through two revolutions from the late 1990s to the early 2000s: the first was in 1998, which pegged the prices of crude and petrochemical products to Singapore market; the second was in 2001, two more markets, Rotterdam and New York were brought into equation. We can see that the domestic oil prices are becoming increasingly related to the world market, and price controls are losing their effectiveness gradually. According to our partial equilibrium analysis, PPI is positively related to oil price: 100% increase in oil price can cause 7.34% increase in PPI in the same month, and 11.33% in the following month. On the other hand, CPI commodities are still under strict restriction. Our empirical research finds no evidences for a direct relationship between oil price and CPI. This structure of price control keeps the price of final output under restriction, and at the same time leaves input costs floating. For consumers, the baffled price transmission mechanism stabilizes commodity prices even when oil-price shock happens. This can somewhat mitigate the short-term effect. For producers, their aggregate profit rate is more sensitive to oil-price shocks because of limited space for them to mark up their products. This would doubtlessly cause the decrease in investment, and thus amplify the long-term impact.

We establish a SVAR model to undertake a general equilibrium analysis of the impact of oil-price shock. According to the impulse response equation, oil-price increase can negatively affect output and investment, but positively affect inflation rate and interest rate. The impact on real economy, represented by real output and real investment, takes a lot longer to recover, which is far more permanent than that on price/monetary variables (CPI/PPI/I).

On the base of the SVAR model, the effect of oil-price shock is decomposed into the short-term and long-term impacts. Our decomposition results show that the short-term impact, namely output decrease induced by the cut of capacity–utilization rate, is greater in the first 1 or 2 years, but the portion of the long-term impact, defined as the impact realized through an investment change, increases steadily and exceeds 50% at the 20th period. After the 21 periods, the long-term impact dominates, and maintains for quite some time.

6.2. Further discussion about the indirect impacts of energy price distortion

6.2.1. Impacts of price control policy on energy conservation in China

Our paper clarifies the short-term and long-term transmission mechanisms of oil price shock on Chinese economy. The analysis result indicates that China could not be remitted from oil price shock even with the existence of price control system.

Theoretically speaking, the short-term price elasticity of energy consumption is very low due to high adjustment costs. But in the long run, it could get much higher when energy was substituted by capital or labor. Such mechanisms lead to short-term economic downturn and long-term energy efficiency improvement after oil shock. The experiences of many developed economies during the 20th century's oil shocks have provided empirical evidences to this argument.

A distorted pricing mechanism, however, would underestimate the true scarce value of energy commodity to the whole society, and sequentially lead to the overuse of energy and discourage the investment in energy conservation and efficiency improvement. While the key findings of this paper have proved that investment as a whole would be deterred by prevailing price control system, we cannot deduce the effects, such as energy overuse and lagged energy efficiency improvement, without further verification.

For this analytical purpose, energy decomposition analysis can offer useful information. Therefore, we adopt the logarithmic mean Divisia index (LMDI) decomposition model to separate the scale effects, structural effects and efficiency effects from total final energy consumption change. For more details about the LMDI approach, please refer to Wu et al. (2005).

Total energy consumption is divided into 3 sectors: industry, transportation and residential, while sectoral energy consumption is determined by its scale, structure and energy efficiency. The factors analyzed include energy structure, total economic output, industrial structure, industrial energy efficiency, vehicle number, vehicle utilization, population, per capita disposable income, and residential sector energy efficiency. The results of our analysis, as shown in Fig. 10, indicate that energy efficiency improvement in China has been slowed down over the period 2002–2007, especially in industrial sector and residential sector. These findings are what would be expected, given the differentiated price control in these two sectors. They are beneficial from the relatively low energy price and thus are lack of incentives to reduce energy use and improve energy efficiency.

6.2.2. Impacts of price control policy on industrial transformation in China

Energy price regulation can be taken as a form of subsidy to manufacturing industries. Over the past several years, the production and export of many energy-intensive commodities, such as steel, cement, synthetic ammonia, paraffin, flat glass have soared in China (Fig. 11). The relatively low energy costs in China have intensified their comparative advantages in international markets. In 2007, the 10 most energy-intensive sectors[7] accounted for 75.74% of total industrial energy consumption but only contributed 38.02% of total indusial added value in China. In fact, the share of these energy-intensive sectors in total industrial energy consumption had increased

[7] The 10 most energy-intensive sectors are manufacture of paper and paper products; processing of petroleum, coking, processing of nuclear fuel; manufacture of raw chemical materials and chemical products; manufacture of chemical fibers; manufacture of non-metallic mineral products; smelting and pressing of ferrous metals; smelting and pressing of on-ferrous metals; electric power, gas and water production and supply; production and distribution of gas; and production and distribution of water.

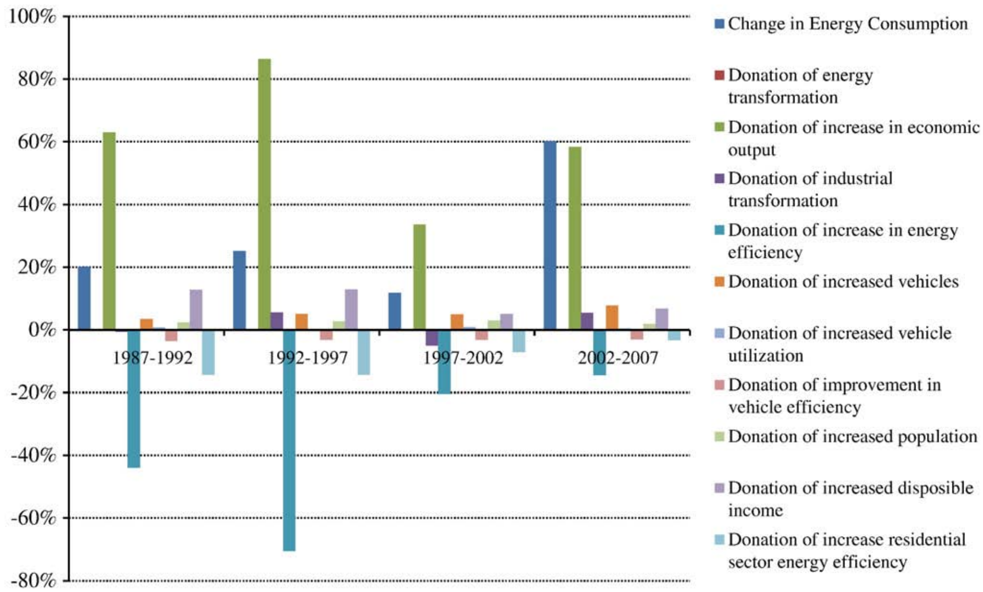

Fig. 10. LMDI decomposition of energy consumption in China since 1987.

by 5.96% from 1995 to 2007, while the percentage increase in total industrial added value was just 1.89% over the same period. Investment in energy-intensive sectors is also soaring in recent years, as shown in Fig. 12.

The rapid extension of these sectors and their increasing dependence on international markets had played vital role in driving up the international fuel commodity prices. The Chinese government had under great fiscal pressure to continue to subsidize these energy-intensive industries. These practices send the wrong signals to the Chinese corporate managers, encouraging them to overuse scarce resources and invest too much, risking overcapacity. At the same time, resource companies underinvested, leading to periodic electricity and fuel shortages. Indeed, all of the energy-intensive sectors are facing, to some extent, overcapacity after the financial crisis. Moreover, some of China's trading partners complain that keeping energy and resource prices controlled is, in effect, government subsidies to the Chinese companies. It is due to the energy subsidy and other type of financial or fiscal aids from government that the Chinese companies are receiving increasing anti-dampening accusations from their trading partners. There is a growing recognition that this kind of economic growth in China cannot sustain in the long run. As shown by a growing literature on the estimated social welfare loss from the development of energy-intensive sectors in China, while estimates vary among studies, the common finding is that such loss is not trivial (The World Bank, 2007).

Since 2006, the price level of gasoline and diesel in China's local market has been higher than that of the United States. According to the investigation by GTZ, China has been a country with medium-level gasoline or diesel taxation since 2006 (GTZ, 2005–2008). It seems that Chinese petroleum sectors are getting closer to the international market and trying to internalize part of the social welfare loss. However, there is still a long way to go to eliminate the market distortion completely. In the 10 most energy-intensive sectors, state owned enterprises (SOE) account for 66.96% of total economic output in 2007. On the other hand, in terms of the absolute number of units, SOE's share is only 33.67%, but they are accounting for 50.71% of the loss enterprises. These facts illustrate that although SOEs are comparatively larger than private or joint venture enterprises, many of them perform worse than other ownership types. As the main underpinnings of China's economic growth, SOEs are protected by many favorable fiscal and financial policies, which have led to crowding out effects to private enterprises. While the deregulation process of energy sector has been put on the recent agenda of China's reform, there must be many games among various interest groups.

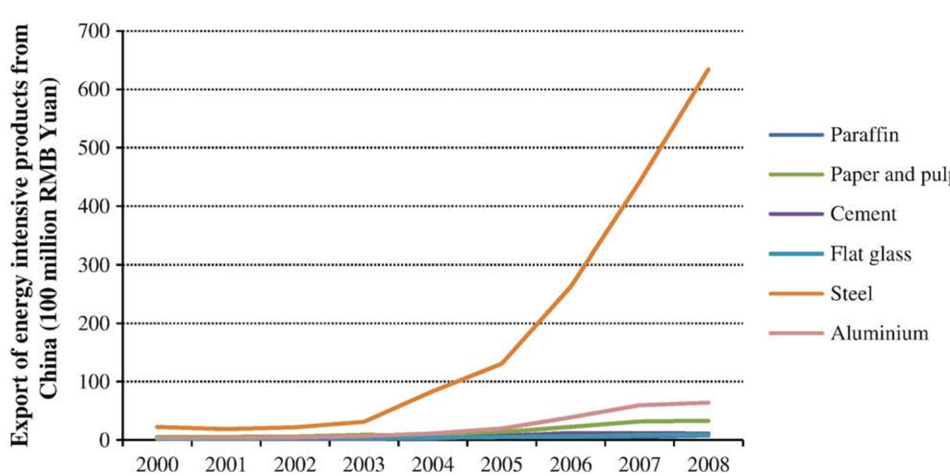

Fig. 11. Export of energy-intensive products from China (current prices).
Source: China Statistical Yearbook, various years. Available online at www.stats.gov.cn/english/statisticaldata/yearlydata/.

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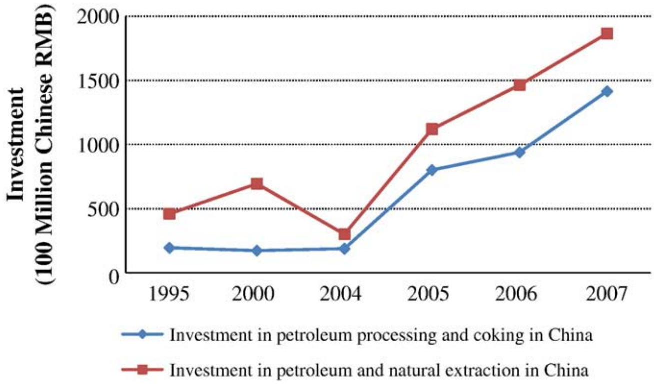

Fig. 12. Recent boom of investment in petroleum industries in China (current prices). *Source:* China Statistical Yearbook, various years.

SOEs in energy-intensive sectors might be main barriers to the elimination of prevailing price control for energy commodities in China.

In order to mitigate the long-term impact of oil-price shocks in China, we like to highlight some measures that need to be taken. First, removing some unnecessary price restrictions can improve the market structure and price transmission mechanisms. Price adjustment can cushion cost increases to producers and prevent their profit rates, as well as investment, from sharp decrease. Second, measures expanding domestic and export demands are needed. The expanded demand can offset the cost increase caused by oil-price shock and stimulate output. Third, since investment determines the long-term effect of oil-price shock, lower interest rate is needed to stimulate investment and counteract the adverse impact. A contractionary monetary policy subsequent to an oil-price shock can worsen the long-term output, being responsible for about two-thirds to three-quarters of the reduction in U.S. output subsequent to an oil shock. In our view, however, this is the area where more rigorous studies in China are needed to draw any further conclusion about the proper monetary policy in China. Last but not least, improving energy efficiency is widely considered as the most effective and lowest cost means of cutting energy use in responding to high energy prices. Strengthening energy-saving efforts via both technology improvements and sectoral adjustments towards a less energy-intensive economic structure and scaling up the use of renewable energies will enable China to sustain its economic growth while preserving the environment. That would be a win-win situation for China and the planet.

Acknowledgments

This study is sponsored by the “National Ministry of Education Key Research Center Projects Funding in China (project number: 08JJD790143)”. This paper has benefited from helpful comments from referees. That said, the views expressed here are those of the authors. The authors bear sole responsibility for any errors and omissions that may remain.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.eneco.2010.01.002.

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