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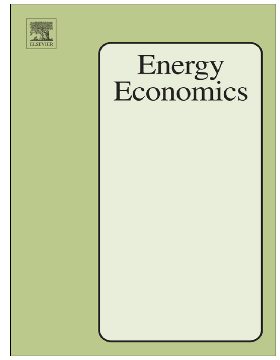

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[Title Page]

The pass-through effects of oil price shocks on China's inflation: A time-varying analysis

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Abstract

Using a time-varying parameter structural vector autoregression with stochastic volatility (TVP-SVAR-SV) model, we decompose the structural shocks of oil price fluctuations into four types: oil supply shocks, global demand shocks, domestic demand shocks and oil-specific demand shocks. We then analyze the time-varying effects of these oil price shocks on China's inflation at the import, production and consumption stages using monthly data from January 1999 to December 2016. The results show that the pass-through effects of the four types of oil price shocks on China's inflation at each stage are time-varying and that there are significant differences at different time horizons and points in time. The analysis of the variance decomposition shows that the effects of oil price shocks on China's inflation at each stage are incomplete and decrease along the price chain. The increase in oil prices driven by oil-specific demand shocks is the most important cause of China's inflation at the import and production stages during the full sample period, while China's inflation at the consumption stage is mainly affected by domestic demand shocks. In addition, the inflationary effects of oil price shocks have been dramatically weaker since the international financial crisis compared with before the crisis.

Keywords: Pass-through effect; oil price shocks; inflation; TVP-SVAR-SV model

1. Introduction

As an important component of production and transportation costs, oil price plays an indispensable role in inflation (Prat and Uctum, 2011; Myers et al., 2018). In recent years, with the acceleration of China's industrialization and urbanization, the demand for crude oil has been very high, and China has become the second largest crude oil consumer after the U.S., consuming 578.7 million tons, or approximately 13.1% of global oil demand, in 2016 (BP Statistical Review of World Energy, 2017). Therefore, China's sustainable economic development is highly dependent on oil (Wen et al., 2016; Gong and Lin, 2017; Zhang et al., 2017; Gong and Lin, 2018a). However, domestic production cannot supply the amount of oil required for economic growth, and China must import a large amount of crude oil from the international market. Thus, its dependence on crude oil imports is relatively high. In 2016, China imported 381 million tons of crude oil, and its dependence on foreign crude oil increased to 65% (China Petroleum Enterprise Association, 2017), exceeding the security limit of 50%. In addition, with the adjustment of the domestic oil price formation mechanism in 2001, China's oil prices gradually integrated with international oil prices (Li et al., 2017). Due to the effects of high foreign dependence and domestic and international oil price linkage mechanisms, international oil price fluctuations have an important impact on China's inflation (Du et al., 2010; Zhao et al., 2016). However, this effect is gradually transmitted through a price chain that reflects intrinsic connections, and there are significant differences in this effect at different stages (e.g., import, production and consumption) (Fig. 1). Therefore, it is necessary to examine the differential impacts of oil price shocks on China's inflation at each stage from the perspective of the price chain.

Extensive studies have examined the impacts of oil price shocks on inflation. Hooker (2002), Doroodian and Boyd (2003), Hunt (2006) and Noord and Andre (2007) all found that oil price shocks had significant effects on the U.S. price, while Berument and Taşçı (2002) noted that the effect of the increase in oil price on inflation was limited under certain conditions. Ayadi (2005) concluded that oil price shocks had positive impacts on the consumer price index (CPI) of Nigeria. Cologni and Manera (2008) indicated that the impacts of oil price shocks on the inflation rate were significant for the G7 except for Japan and the U.K. Peersman and Robays (2009) found that the impacts of oil price shocks on inflation in the eurozone were mainly through wage growth. Valadkhani (2014) concluded that the marginal effects of international oil price fluctuations on consumer energy prices in the U.S. increased significantly after the western U.S. energy crisis of 2000. Jiranyakul (2016) provided evidence that the impacts of oil price shocks on consumer prices in Thailand were not significant in the long term. Since the 1990s, with the rapid development of industrialization and urbanization in China (Chen et al., 2019), the rapid increase in oil demand has been regarded as the driving force for oil price fluctuations, and many scholars have concluded that international oil prices significantly influence the price level in China (Sun, 2007; Meng and Zhang, 2008; Tang et al., 2010; Du et al., 2010; Kim et al., 2017; Wei, 2019). In addition, several studies have documented different shock effects in different countries. Fang et al. (2013) found that the effects of oil price shocks on inflation in the BRICS countries differed at different time scales. Over the long term, oil price shocks led to noteworthy inflation in Russia, and in the short term, high oil price resulted in high inflation in Russia, India and China. Sakashita and Yoshizaki (2016) concluded that the effects of oil price shocks on the CPI in emerging countries depended on where the changes originated.

Kilian (2009) and Peersman and Robays (2012) structurally decomposed oil price shocks into three components: oil supply shocks, aggregate demand shocks and oil-specific demand shocks. Oil price fluctuations driven by different sources may have different effects on inflation. Oil supply shocks mainly affect inflation through the cost channel. Because crude oil is an important factor in production, a rise in oil price will undoubtedly increase marginal production costs and push up the prices of production and consumption, leading to inflation (Hamilton, 1983; Zhong et al., 2019). Because oil price increases caused by aggregate demand shocks generally occur in prosperous economic environments, the prices of production and consumption will increase simultaneously through demand-driven inflation (Cashin et al., 2014; Tan et al., 2015). An oil-specific demand shock is driven by supply and demand expectations and financial speculation (Gupta and Modise, 2013), and an increase in oil price caused by such a shock will increase marginal production costs, resulting in cost-driven inflation (Anzuini et al., 2015). This decomposition framework has been widely applied to study the effects of different types of oil price shocks on inflation. Melolinna (2012) found that the effects of oil demand shocks on U.S. inflation were greater than those of oil supply shocks. Cashin et al. (2014) concluded that the increase in oil price driven by oil demand shocks led to inflationary pressures in the long term, while the impacts of oil supply shocks on inflation were significant only in certain oil importing countries (e.g., China, the eurozone, Japan, and the U.S.). Cunado et al. (2015) found that due to oil price regulation and government subsidization, the responses of consumer prices in India and Indonesia remained stable to different types of oil price shocks. Ekong and Effiong (2015) showed that oil price shocks from different sources had different impacts on Nigeria's CPI. Sek and Lim (2016) suggested that an increase in oil price driven by oil supply shocks led to inflation in oil importing countries, while the effects of oil demand shocks on inflation were insignificant in most countries.

Although the effects of oil price shocks on inflation have been discussed extensively, previous studies have two shortcomings. First, scholars concentrate on the effects of oil price shocks on producer prices or consumer prices(Long and Liang, 2018), but they do not consider prices at the import stage when examining the impacts of oil price shocks on inflation from the perspective of the complete price chain, which makes it difficult to accurately understand the conduction path of oil price shocks on inflation. In the sequence of oil price transmission to China's inflation, under cost-driven or demand-driven action, an increase in oil price directly affect the price of imported products, and the effects then pass to domestic prices (Zhu et al., 2019). Under the premise that the market is mature and free, the effect will be smooth along the price chain, and the import, production and consumption prices will rise evenly. However, in China, there are price controls and regulations on refined oil (Li et al., 2017), and domestic refined oil price adjustments still have a large time lag relative to oil price fluctuations, meaning that they do not have a smooth price transmission mechanism, and manufacturers cannot quickly transfer cost pressures to the consumer segment (Qian et al., 2014). Moreover, due to insufficient demand and fierce market competition in China's market, manufacturers are reluctant to raise prices under the cost pressures, further increasing the resistance of price transmission (Li and Wu, 2011). As a result, the impacts of oil price shocks on domestic prices, especially consumer prices, are relatively weak. Therefore, it is necessary to include import prices to examine whether the effects of oil price shocks on China's inflation at each stage are incomplete and decrease along the price chain.

Second, prior studies have mainly used vector autoregression (VAR) and structural vector autoregression (SVAR), which assume that the relationship between oil price and inflation does not change over time. However, oil supply and demand situation in different periods is different, so changes in oil price caused by supply and demand factors would have dynamic impacts on the macroeconomic variables (Gong and Lin, 2018b). In fact, recent studies have captured the time-varying relationship between oil price and macroeconomic variables in developed countries (Valcarcel and Wohar, 2013; Baumeister and Peersman, 2013; Riggi and Venditti, 2015; Aye et al., 2015; Boldanov et al., 2016; Wen et al., 2018; Demirer et al., 2018), and several scholars have also discovered that oil price shocks have dynamic impacts on China's macroeconomy (Gong and Lin, 2018b; Wen et al., 2019a). Therefore, it is necessary to study the pass-through effects of oil price shocks on China's inflation from a time-varying perspective.

Given the rapid growth of China's oil imports and the considerable demand for oil products (Chen, 2016a;Yu and Zhang, 2019), according to Tan et al. (2015) and Li et al. (2017), we incorporate domestic demand shocks into multistructural oil price shocks proposed by Kilian (2009) and decompose the structural shocks of oil price fluctuations from 1999 to 2016 into four types: oil supply shocks, global demand shocks, domestic demand shocks and oil-specific demand shocks. In addition, we consider import prices, producer prices and consumer prices in China to construct a price chain that reflects the intrinsic connections. We utilize the TVP-SVAR-SV model to investigate the time-varying effects of the four types of oil price shocks on China's inflation at each stage and compare the differential impacts of oil price shocks on China's inflation at different stages.

This paper provides two main contributions to the existing literature. First, we incorporate import prices into the price chain and construct an SVAR analytical framework for multistructural oil price shocks and multiple price variables. We then comprehensively quantify the differential impacts of the four types of oil price shocks on China's inflation at different stages. Second, we further use the TVP-SVAR-SV model with different time horizons and points in time to capture the time-varying effects of the four types of oil price shocks on China's inflation at each stage, which provides a dynamic perspective for effectively addressing the inflationary effects of oil price shocks. The remainder of this paper is organized as follows. Section 2 describes the methodology and the data used in the analysis. Section 3 discusses the empirical results, and Section 4 concludes with a summary and a discussion of the policy implications.

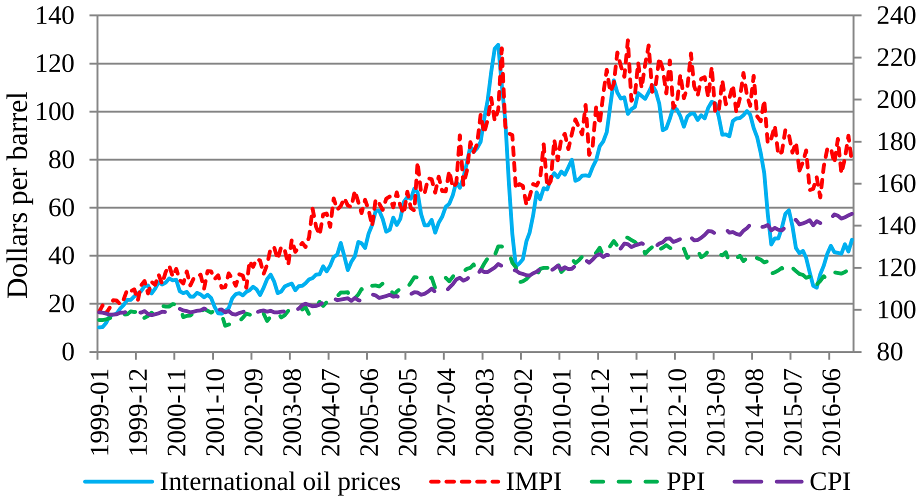

Fig. 1. International oil prices and inflation in China at each stage.

Note: The left axis depicts the international oil prices, and the right axis depicts the import price index (IMPI), producer price index (PPI) and CPI; 1998=100.

2. Data and empirical methodology

2.1. Data specifications

Our dataset consists of monthly data of the oil supply, global demand, domestic demand, real oil price (ROP), import prices, producer prices and consumer prices from January 1999 to December 2016. To reflect the changes in oil supply, world oil production (WOP) provided by the U.S. Energy Information Administration (EIA) is selected, and the data are sourced from the Wind database. Because the Kilian economic index (KI), which was developed by Kilian (2009), can effectively reflect the global economic conditions (Klovland, 2002), following Gupta and Modise (2013) and Hu et al. (2017), we use this index to measure global demand. The year-on-year growth rate of China's industrial added value (IAV) can effectively reflect China's economic conditions; thus, following Tan et al. (2015) and Li et al. (2017), the IAV is chosen to represent the domestic demand. Following Gupta and Modise (2013) and Kim et al. (2017), the ROP is defined as the U.S. refiners' acquisition cost for imported crude oil, for which data are obtained from the U.S. Department of Energy, and it is deflated using the U.S. CPI.

Based on Shi and Zhao (2016) and Chen and Liao (2017), the IMPI is selected as the proxy for China's inflation at the import stage. This index measures the changes in China's imported commodity prices. Following Shi and Zhao (2016) and Zhu et al. (2019), the PPI is chosen to reflect China's inflation at the production stage. This index measures the changes in the ex-factory price of industrial products. To analyze the effects of oil price shocks on China's inflation at the consumption stage, we consider the CPI in our analysis. The data of IMPI, PPI and CPI are sourced from the Wind database. To avoid seasonal fluctuations, we select the type of price index compared to the same month of the previous year. To eliminate heteroscedasticity, all of the variables except the KI are transformed into logarithmic values.

We use the augmented Dicky–Fuller (ADF), Phillips and Perron (PP) and Kwiatkowaski–Philips–Schmidt–Shin (KPSS) tests to check the stationarity of the variables. The results of the unit root tests are shown in Table 1. At the 5% significance level, the variables IMPI and PPI are stationary for all of the tests, while the WOP, KI, IAV, ROP and CPI are stationary in terms of the first differences; therefore, we use the first-order differences of the WOP, KI, IAV, ROP and CPI for the empirical study.

Table 1. Unit root tests.

Variables	ADF test		PP test		KPSS test	
	Levels	First differences	Levels	First differences	Levels	First differences
WOP	-3.41*	-13.17***	-3.31*	-15.82***	0.12*	0.02
KI	-2.75*	-10.77***	-2.57*	-11.00***	0.53**	0.11
IAV	-3.63**	-15.16***	-5.63***	-28.91***	0.37***	0.07
ROP	-3.01**	-8.97***	-2.78*	-8.37***	1.03***	0.27
IMPI	-3.95***	-6.08***	-3.41**	-14.11***	0.44*	0.03
PPI	-3.86***	-5.87***	-3.07**	-5.95***	0.30	0.05
CPI	-2.64*	-6.30***	-2.90**	-14.04***	0.48**	0.05

Note: The null hypotheses for the ADF and PP tests are that the series has a unit root, while the null hypothesis for the KPSS test is that the series is stationary. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. For the WOP and IAV, a linear trend and an intercept are included in the test equations. For the other variables, an intercept is included in the test equations.

2.2 Construction of the TVP-SVAR-SV model

Before constructing the TVP-SVAR-SV model to investigate the time-varying effects of oil price shocks on China's import prices, producer prices and consumer prices, we extend the method proposed by Kilian (2009) by incorporating domestic demand into the SVAR analysis framework and decompose the structural shocks of international oil prices fluctuations into four types: oil supply shocks, global demand shocks, domestic demand shocks and oil-specific demand shocks. We construct an SVAR model that includes seven variables as follows:

$$Ay_t = \beta_0 + \sum_{i=1}^{n} \beta_i y_{t-i} + \varepsilon_t \quad (1)$$

where $y_t = (WOP_t, KI_t, IAV_t, ROP_t, IMPI_t, PPI_t, CPI_t)'$, β_0 and β_i represent 7×7 matrices of the coefficients, and ε_t is the structural shock vector. We assume that A is reversible, insert matrix A^{-1} into Eq. (1) and derive the reduced-form VAR model:

$$y_t = \mathrm{A}^{-1}\beta_0 + \mathrm{A}^{-1}\sum_{i=1}^{n}\beta_i y_{t-i} + \mathrm{A}^{-1}\varepsilon_t = \phi_0 + \sum_{i=1}^{n}\phi_i y_{t-i} + e_t \tag{2}$$

where e_t is the disturbance term, and $e_t = A^{-1}\varepsilon_t$. Then, following Kilian (2009), Chen et al. (2016b), Hu et al. (2017), Li et al. (2017) and Wen et al. (2019b), we impose restrictions on A^{-1} to identify the SVAR model. First, due to the long cycle of oil production, it is not possible to make rapid adjustments to changes in demand (Kilian, 2009; Hu et al., 2017). Thus, we assume that the oil supply will not be contemporaneously affected by any shock except a shock that originates from the oil supply. Second, changes in global demand are constrained by changes in the oil supply and global economic activity. China's economy has relied on exports for a long time, and domestic demand is insufficient (Li et al., 2017); therefore, contemporary global demand will not be influenced by domestic demand. An oil-specific demand shock mainly reflects the changes in expectations regarding supply and demand factors and financial speculation; it has a delayed effect and does not affect global economic activity immediately(Hu et al., 2017). In addition, we assume that China's inflation at each stage has no impact on the contemporary global economic activity. Third, following Li et al. (2017), changes in domestic demand are contemporaneously affected by the oil supply, global demand and itself. Fourth, oil price is determined by the equilibrium between supply and demand; thus, the current oil price is affected by the oil supply and demand shocks. However, although China's demand for oil is large, China lacks international oil pricing power; therefore, following Li et al. (2017), we assume that domestic demand shocks have no immediate impacts on oil price. Finally, oil price directly affects import prices and has important effects on PPI and CPI because changes in oil price can lead to significant changes in production costs and consumer expenditure patterns (Prat and Uctum, 2011; Myers et al., 2018). In the price chain, the downstream price is always affected by the upstream price; thus, the current PPI is affected by the IMPI, and the current CPI is affected by the IMPI and PPI. Based on these assumptions, the errors e_t of the reduced form are described in Eq. (3).

$$e_t = \begin{pmatrix} e_t^{WOP} \\ e_t^{KI} \\ e_t^{IAV} \\ e_t^{ROP} \\ e_t^{IMPI} \\ e_t^{PPI} \\ e_t^{CPI} \end{pmatrix} = \begin{pmatrix} \alpha_{11} & 0 & 0 & 0 & 0 & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 & 0 & 0 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & 0 & 0 & 0 & 0 \\ \alpha_{41} & \alpha_{42} & 0 & \alpha_{44} & 0 & 0 & 0 \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & \alpha_{55} & 0 & 0 \\ \alpha_{61} & \alpha_{62} & \alpha_{63} & \alpha_{64} & \alpha_{65} & \alpha_{66} & 0 \\ \alpha_{71} & \alpha_{72} & \alpha_{73} & \alpha_{74} & \alpha_{75} & \alpha_{76} & \alpha_{77} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{oil\ supply\ shock} \\ \varepsilon_t^{global\ demand\ shock} \\ \varepsilon_t^{domestic\ demand\ shock} \\ \varepsilon_t^{oil-specific\ demand\ shock} \\ \varepsilon_t^{IMPI} \\ \varepsilon^{PPI} \\ \varepsilon_t^{CPI} \end{pmatrix} \tag{3}$$

Based on the SVAR model, this paper further adopts the TVP-SVAR-SV model. This model can fully capture the time-varying effects of oil price shocks on China's inflation at each stage by setting the time-varying parameters in the SVAR model.

According to Primiceri (2005), Omori et al. (2007), Nakajima et al. (2011) and Pan(2017), Eq. (1) can be written as follows:

$$y_t = X_t\beta + A^{-1}\Sigma\varepsilon_t \quad (4)$$

where β is a $(49i+7)\times 1$ vector, $X_t = I_i \otimes (y'_{t-1},...y'_{t-i})$, and Σ is a 7×7 -dimensional diagonal matrix with a diagonal of $[\sigma_1,\sigma_2,...\sigma_7]$. We incorporate the time factor into Eq. (4), and the TVP-SVAR-SV model is given by:

$$y_t = X_t\beta_t + A_t^{-1}\Sigma_t\varepsilon_t \quad (5)$$

Eq. (5) forms the observation equation of the TVP-SVAR-SV model. According to Primiceri (2005), Nakajima et al. (2011), Cao (2012), Jebabli et al. (2014), Pan(2017) and Wen et al. (2019b), the parameters are assumed to follow a random walk process as follows:

$$\begin{cases} \beta_{t+1} = \beta_t + u_{\beta t} \\ \alpha_{t+1} = \alpha_t + u_{\alpha t} \\ h_{t+1} = h_t + u_{ht} \end{cases} \quad (6)$$

with:

$h_t = (h_{1t}, h_{2t}, h_{3t}, h_{4t}, h_{5t}, h_{6t}, h_{7t})'$, where $h_{jt} = \log\sigma_{jt}^2, j = 1,...7$

$$\begin{aligned} \beta_{s+1} &\sim N(u_{\beta_0}, \Sigma_{\beta_0}) \\ \alpha_{s+1} &\sim N(u_{\alpha_0}, \Sigma_{\alpha_0}) \\ h_{s+1} &\sim N(u_{h_0}, \Sigma_{h_0}) \end{aligned} \quad (7)$$

The variance covariance matrix of the model's innovations is a block diagonal.

$$\begin{pmatrix} \varepsilon_t \\ u_{\beta t} \\ u_{\alpha t} \\ u_{ht} \end{pmatrix} \sim N\left(0, \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_\alpha & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix}\right) \quad (8)$$

where Σ_β, Σ_α and Σ_h are assumed to be diagonal matrices.

Following Primiceri (2005), Aye et al. (2015), Kang et al. (2015), Pan(2017), Cross and Nguyen (2018) and Gong and Lin (2018b), Bayesian inference is used to estimate the TVP-SVAR-SV model via the Markov chain Monte Carlo (MCMC) method. To obtain the estimated posterior, following Cao(2012), we adopt the Gibbs sampling algorithm described in Primiceri (2005) to discard the first 1000 samples as the burn-in and then draw 10,000 samples.

3. Empirical results and analysis

3.1 Estimation of selected parameters

We establish a TVP-SVAR-SV model in which the lag length is set to 2 based on Akaike's information criterion (AIC), the final prediction error (FPE) and the Hannan-Quinn information criterion (HQ). Table 2 shows the estimated results of the selected parameters. The posterior means of the parameters are within the 95% confidence intervals. The results of Geweke's convergence diagnostics statistics are within the critical value of 5%, which means that the null hypothesis regarding the convergence of the posterior distribution cannot be rejected. In addition, the inefficiency factors of the parameters are all less than 100, which is valid in MCMC samples that include 10,000 samples. According to Nakajima(2011), Mwabutwa et al.(2016), Gong and Lin(2018b) and Wen et al.(2019a), these results suggest that the posterior draws efficiently.

Table 2. Estimation of selected parameters in the TVP-SVAR-SV model.

Parameter	Mean	Stdev	95% confidence interval	Geweke	Inef.
$(\Sigma_\beta)_1$	0.0225	0.0026	[0.0180 , 0.0282]	0.9460	12.98
$(\Sigma_\beta)_2$	0.0230	0.0026	[0.0184 , 0.0288]	0.8730	10.70
$(\Sigma_\alpha)_1$	0.0564	0.0143	[0.0354 , 0.0898]	0.9270	37.00
$(\Sigma_\alpha)_2$	0.0552	0.0141	[0.0353 , 0.0921]	0.9200	43.44
$(\Sigma_h)_1$	0.3035	0.0904	[0.1567 , 0.5075]	0.0410	90.75
$(\Sigma_h)_2$	0.5337	0.1020	[0.3472 , 0.7510]	0.7970	39.73

Notes: Mean denotes posterior means; Stdev denotes standard deviations; and Inef. denotes the inefficiency factor.

Fig. 2 shows the sample autocorrelation, sample paths and posterior densities for selected parameters. Discarding the 1000 samples of the burn-in period, the sample autocorrelations decrease steadily, and the sample paths appear to be stable. According to Nakajima (2011) and Mwabutwa et al. (2016), these results imply that the samples obtained by the MCMC sampling are uncorrelated valid samples.

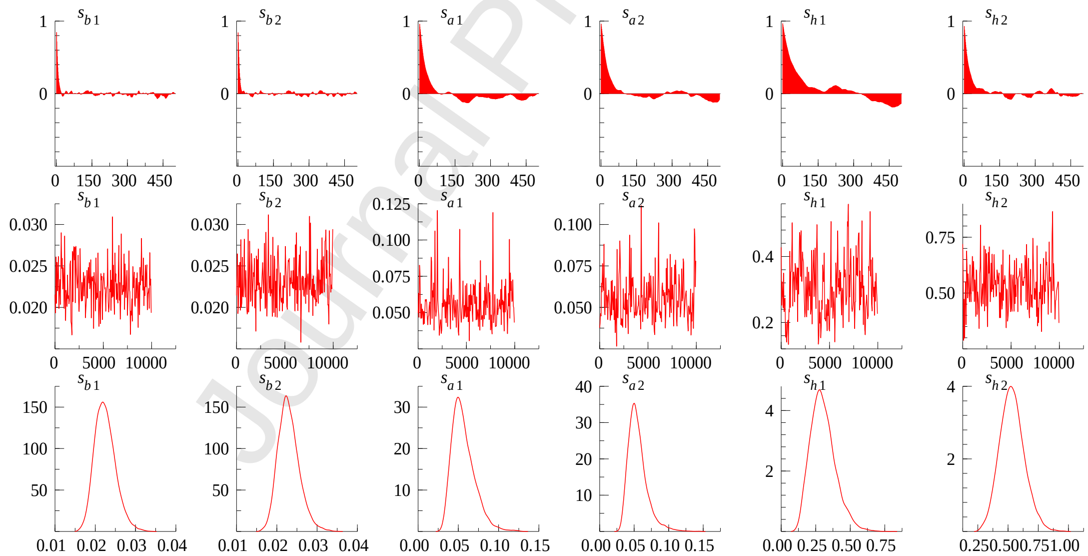

Fig. 2. Sample autocorrelation, sample paths and posterior densities for selected parameters.

3.2 Pass-through effects of oil price shocks on China's inflation at different time horizons

To investigate the dynamic effects of oil price shocks on China's import prices, producer prices and consumer prices, the time-varying impulse response function is used for further analysis. We create one standard deviation shock in the oil supply, global demand, domestic demand and oil-specific demand and observe the responses of China's import prices, producer prices and consumer prices. Following Gupta and Modise (2013) and Cashin et al. (2014), the oil supply shock is set as a negative shock, while the global demand shock, domestic demand shock and oil-specific demand shock are set as positive shocks; therefore, all four types of oil price shocks will increase the oil price.

The time-varying response trajectories are presented in Figs. 3-6, which show the impulse responses of China's import prices, producer prices and consumer prices to the four types of oil price shocks in the TVP-SVAR-SV model after 1 month, 3 months and 12 months, respectively. The 1-month, 3-month and 12-month impulse responses can be referred to as the short-, medium- and long-term responses, respectively.

In general, at each stage, the responses of China's inflation to the four types of oil price shocks change over time. As shown in Fig. 3, the responses of the IMPI to an oil supply shock are mostly negative before 2009 and positive afterwards at the 1-month horizon; at the 3-month and 12-month horizons, the responses are mostly negative before 2011 and positive afterwards, indicating that an increase in the ROP due to oil supply disruptions usually has an inhibitory effect on the IMPI. Following a shock to the oil supply, the responses of the PPI are mostly negative for the three time horizons except for the period 2009-2015. However, the function strengths differ at the different time horizons, and the most significant effects occur at the 1-month horizon. The response of the CPI to a shock in the oil supply is generally positive except for the periods 2002-2003 and 2011-2013 at the 1-month horizon; at the 3-month horizon, the CPI mainly has a positive response except for 2008-2012, while at the 12-month horizon, the response is nearly negligible.

The inhibitory effects of oil supply shocks on China's inflation are mainly concentrated at the stages of import and production. Several studies, such as Cashin et al. (2014) and Zhao et al. (2016), have shown that oil supply shocks had negative effects on price levels in China. Although we agree that an increase in the oil price due to oil supply disruptions produces a negative effect on inflation, especially at the stages of import and production, the effect is not stable and changes over time. In addition, we further discover that the impacts of oil supply shocks on China's inflation differ at different stages and time horizons, which is more realistic and provides more information.

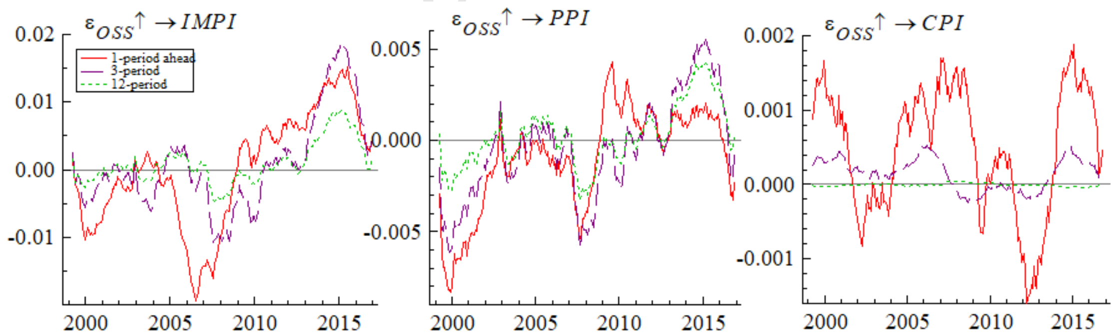

Fig. 3. Time-varying impulse responses of China's IMPI, PPI and CPI to oil supply shocks. Note: OSS represents oil supply shock.

The responses of China's IMPI, PPI and CPI to global demand shocks, domestic demand shocks and oil-specific demand shocks also show significant differences at different time horizons. As shown in Fig. 4, at the 1-month horizon, the response of China's IMPI to a global demand shock is generally positive; however, at the 3-month and 12-month horizons, the responses are negative except for the periods 1999-2003, 2006 and 2016. Following a shock to global demand, the responses of China's PPI are negative at all three time horizons except for the periods 1999-2003 and 2016, indicating that the pulling effects of global demand are not significant. However, the function strengths differ at the different time horizons, and the most significant effects occur at the 3-month horizon. When a positive shock in global demand occurs, the response of the CPI at the 1-month horizon is generally positive during the sample period. At the 3-month horizon, the response is positive except for the period 2008-2014. However, at the 12-month horizon, the response is almost negligible. These results imply that the pulling effects of global demand shocks on China's CPI vary for different lag periods and that as the duration of the lag increases, the impact gradually weakens.

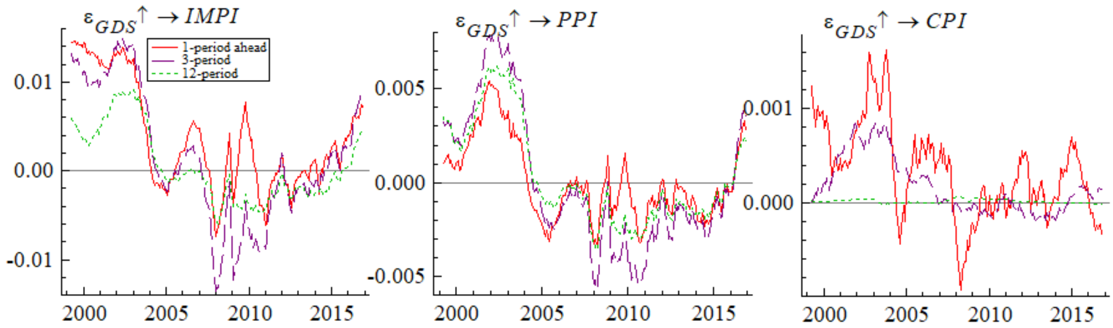

Fig. 4. Time-varying impulse responses of China's IMPI, PPI and CPI to global demand shocks. Note: GDS represents global demand shock.

Fig. 5 shows that at the 1-month horizon, the responses of China's IMPI to a domestic demand shock are generally negative except for the periods 1999 and 2007-2011; however, at the 3-month and 12-month horizons, the responses are mostly positive except for the periods 2003-2007 and 2014-2016. Following a shock to the domestic demand, the responses of China's PPI are mostly positive for the three time horizons over the sample period, but the function strengths differ at different time horizons, and the most significant effects occur at the 3-month horizon. When a positive shock in domestic demand occurs, the responses of the CPI are different at the different time horizons. At the 1-month horizon, the response of the CPI is negative during the sample period; at the 3-month horizon, the response is mostly positive except for the periods 1999-2002 and 2009-2012. However, at the 12-month horizon, the response is almost negligible. In general, China's IMPI, PPI and CPI usually have positive responses to domestic demand shocks, especially in the medium term. However, the impacts change from positive to negative around 2013; this occurs because China entered a new normal economic stage, the economic growth slowed, and the domestic demand for oil weakened, leading to decreases in China's IMPI, PPI and CPI (Wen et al., 2019b).

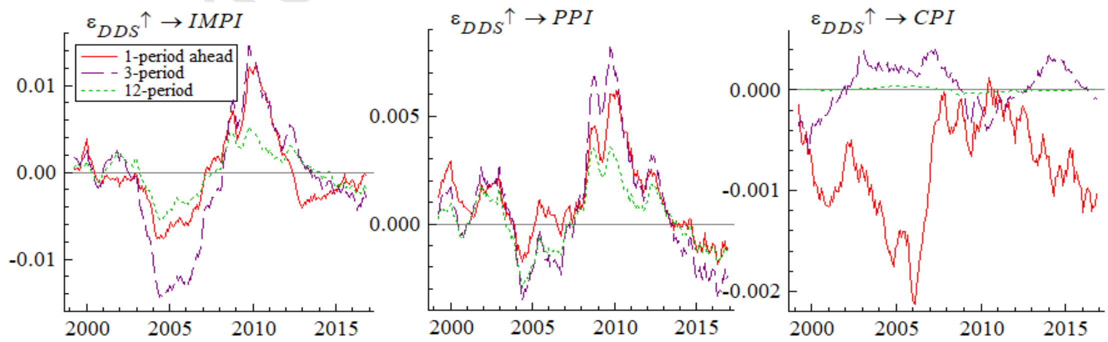

Fig. 5. Time-varying impulse responses of China's IMPI, PPI and CPI to domestic demand shocks. Note: DDS represents domestic demand shock.

Fig. 6 shows that at the three time horizons, the responses of the IMPI and PPI to an oil-specific demand shock are mostly positive except for the period 2009-2013. An oil-specific demand shock mainly reflects the changes in expectations regarding supply and demand factors and financial speculation. Due to the strengthening of oil financialization and the increasing financial speculation activity, the oil price increases and leads to increases in the IMPI and PPI in most cases. However, during the international financial crisis and the European debt crisis, the market risks intensified, speculative funds evacuated from the oil market due to risk aversion, and the role of financial speculation weakened significantly, resulting in the negative impact of oil-specific demand shocks on the IMPI and PPI during 2009-2013. Because it is located in the downstream of the price chain and thus is less affected by financial speculation, the positive response of the CPI to an oil-specific demand shock is relatively small and displays alternating positive and negative responses at the three time horizons.

Sun and Qi (2011) claimed that aggregate demand and oil-specific demand shocks would push China's import prices to rise significantly. Cashin et al. (2014) noted that an aggregate demand shock produced a positive effect on China's consumer prices. Zhao et al. (2016) concluded that the pulling effects of aggregate demand shocks on China's consumer prices were observed in the long term, while the positive impacts of oil-specific demand shocks on consumer prices were significant only in several periods. Although we agree that the pass-through effects of the three types of oil demand shocks on inflation are mostly positive, we further find that the effects are time-varying and not always positive depending on the type of oil demand shock and the time horizon; therefore, our results are more consistent with reality and provide more information.

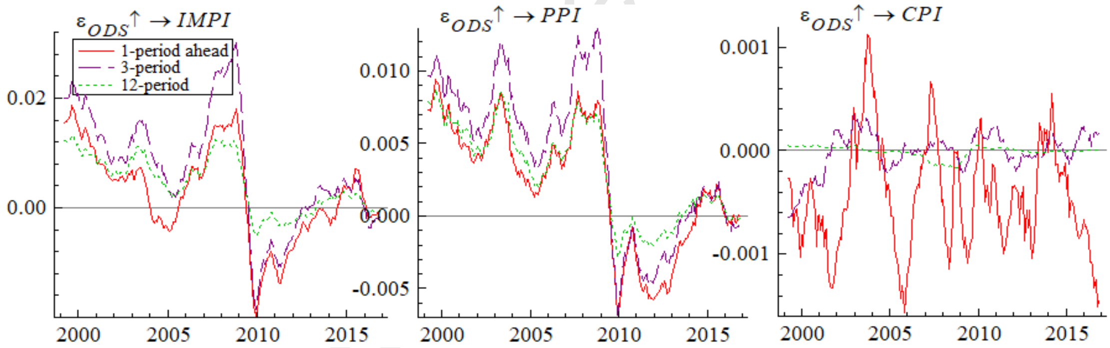

Fig. 6. Time-varying impulse responses of China's IMPI, PPI and CPI to oil-specific demand shocks. Note: ODS represents oil-specific demand shock.

3.3 Pass-through effects of oil price shocks on China's inflation at different points in time

The analysis presented above shows that the pass-through effects of the four types of oil price shocks on China's inflation are time-varying, which may be related to changes in the macroeconomic environment during different periods. To show the differential effects of oil price shocks on China's inflation during different periods, we select three points in time (i.e., October 2001, September 2008 and May 2014) to analyze the differences. October 2001 captures the time that China implemented a pricing mechanism for refined oil products that was linked to the oil prices in Singapore, Rotterdam and New York, September 2008 captures the outbreak of the international financial crisis (Zhao et al., 2013), and May 2014 captures the time that China's economic development entered a new normal. As shown in Fig. 7, oil supply shocks immediately result in positive impacts on China's IMPI and PPI in September 2008 and May 2014, while the positive impacts in September 2008 become negative after 1 month, and the negative impacts last for approximately one year. In October 2001, China's IMPI and PPI show negative responses in the short term, while the long-run effects are relatively small. We find that the responses of the CPI to oil supply shocks at the three points in time are mainly concentrated in the short and medium terms and alternate between positive and negative. In general, compared with normal times, oil supply shocks have a greater negative impact on China's inflation during the international financial crisis.

When a positive shock in global demand occurs, the responses of China's IMPI, PPI and CPI are positive in October 2001, while the responses are mainly negative in September 2008 and May 2014. Thus result is not surprising because China became integrated with the international market through the reform of the oil price mechanism in 2001. Since then, the global demand for oil has increased, leading to an increase in China's inflation. However, in September 2008 and May 2014, international oil prices plummeted, the global economy faced downward pressure, and the global demand for oil was weak, resulting in a decrease in China's inflation.

Fig. 7 shows that in October 2001 and September 2008, the responses of China's IMPI and PPI to domestic demand shocks are mainly positive, while in May 2014, due to the slowdown of China's economic growth under the new normal, China's IMPI and PPI show weak negative responses. When a shock to the domestic demand occurs, the responses of China's CPI are different at the three points in time. In particular, the domestic demand shock in May 2014 immediately produces a negative impact on the CPI that lasts for approximately 3 months, which means that the negative impacts are mainly concentrated in the short and medium terms.

As shown in Fig. 7, the responses of China's IMPI and PPI to an oil-specific demand shock are mainly positive at the three points in time. It is worth noting that the positive effect that occurred in September 2008 is the most significant of the three points in time. The responses of the CPI to an oil-specific demand shock at the three points in time are mainly concentrated in the short and medium terms and alternate between positive and negative.

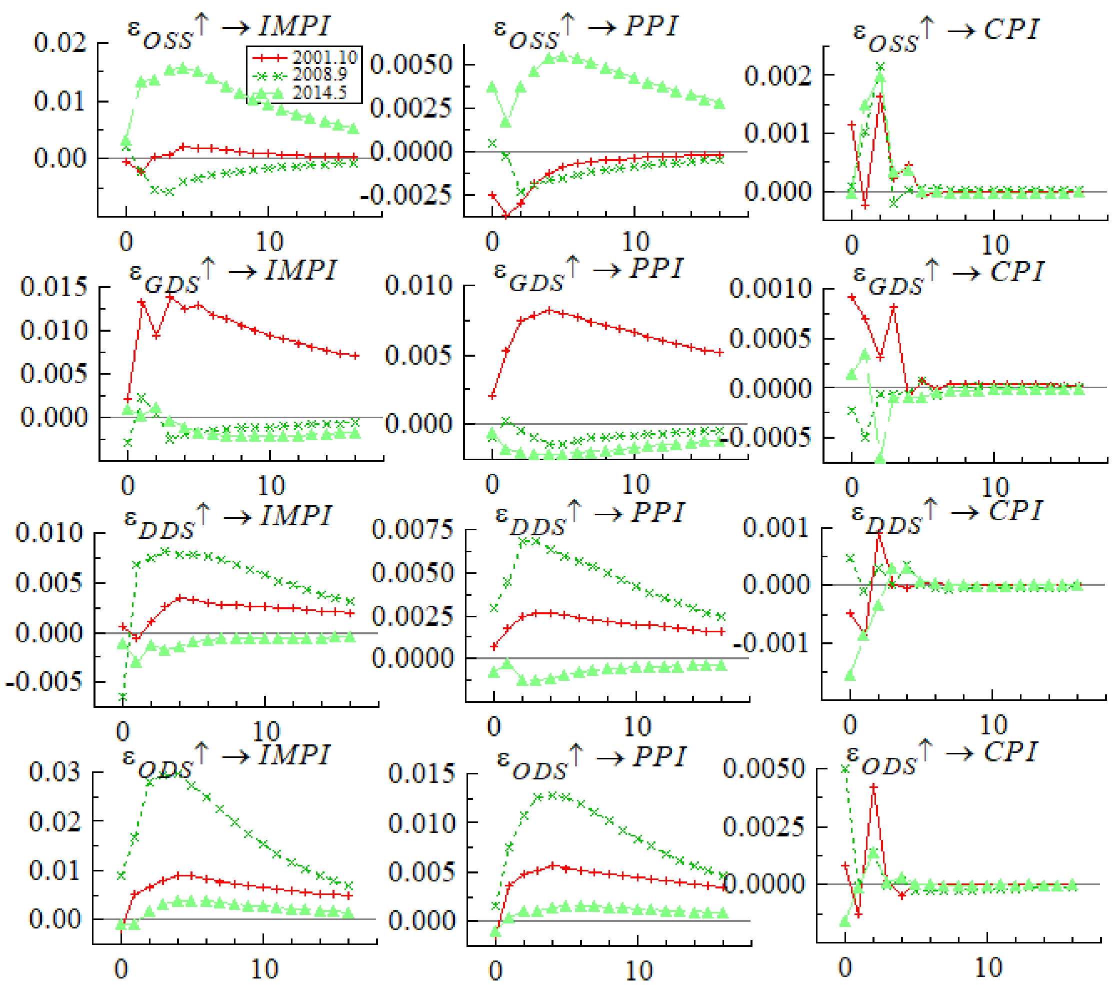

Fig. 7. Impulse responses of China's IMPI, PPI and CPI to the four types of oil price shocks at different points in time.

In general, there are significant differences in the responses of China's inflation to oil price shocks at the different points in time, which is mainly reflected in the direction of the response, the degree of action and the duration. Moreover, the oil price mechanism reform, financial crises and economic cycle fluctuations cause significant changes in the pass-through effects of oil price shocks on China's inflation. After China promotes the reform of the oil price mechanism, global demand shocks produce significant positive impacts on China's inflation at each stage. China's inflation is more vulnerable to the negative impact of an oil supply shock during the crisis than during the normal period. When China's economic development enters a new normal, the domestic demand for oil weakens, leading to the decrease in China's inflation at each stage.

3.4 Structural change in oil price shocks on China's inflation

To demonstrate whether a structural change occurred due to the international financial crisis, we further divide the full sample into two subsamples, 1999.1-2008.8 and 2008.9-2016.12, and analyze the differences. A comparison of Fig. 9 with Fig. 8 shows that the major differences between the two subsamples are the effects of domestic demand shocks on China's inflation, which are mainly reflected in the direction of the impact. Before the international financial crisis, the effects of domestic demand shocks on China's inflation are negative; however, the pulling effects of domestic demand shocks on China's inflation begin to appear after the international financial crisis; this phenomenon is particularly significant for China's IMPI and PPI. Moreover, the pulling effects of global demand shocks on China’s inflation are weaker after the financial crisis than before the crisis. These results are not surprising because in the early 21st century, China’s foreign economic policy emphasized the expansion of exports and the introduction of foreign investment. Since the international financial crisis, with the shrinking of external demand and the decline in export growth, China’s macroeconomic policies have increasingly focused on stimulating consumption and expanding domestic demand, which has led to this phenomenon.

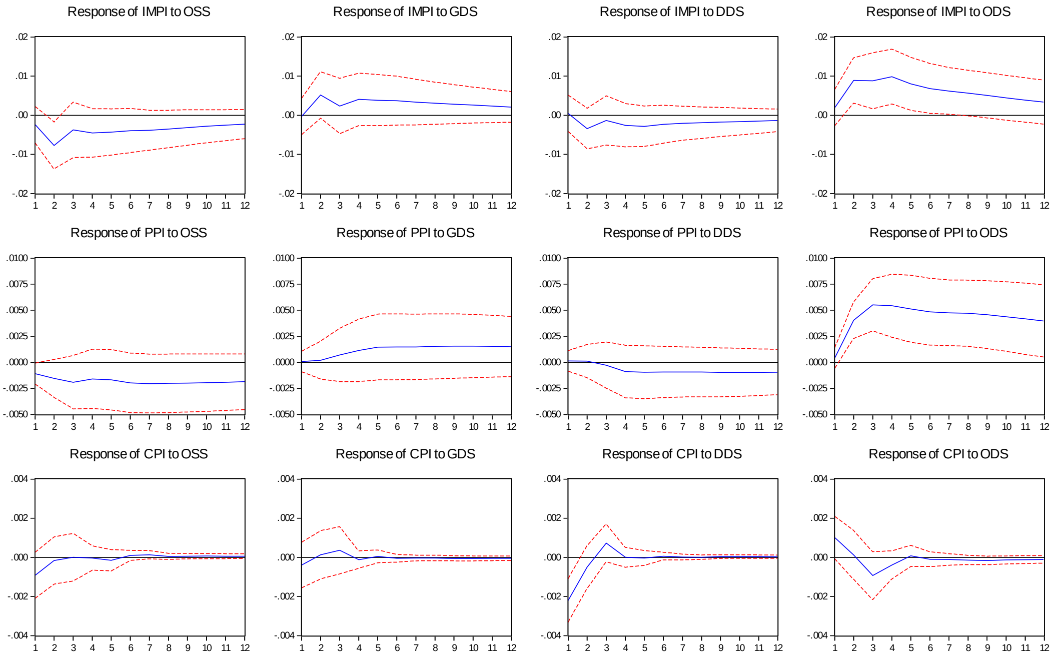

Fig. 8. Impulse responses of China’s IMPI, PPI and CPI to the four types of oil price shocks (1999.1-2008.8).

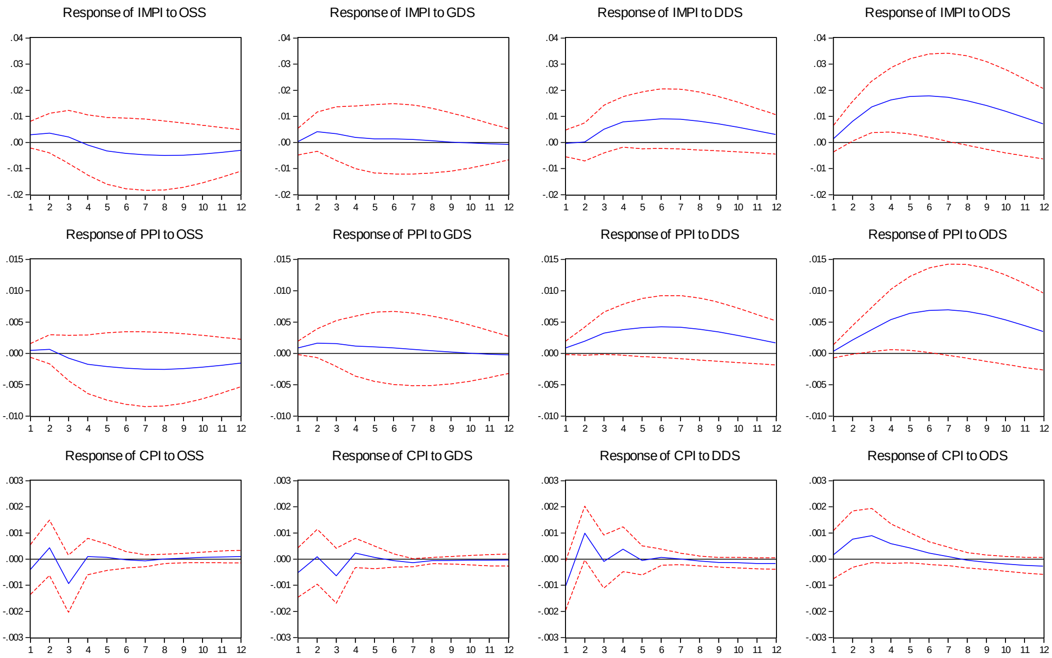

Fig. 9. Impulse responses of China’s IMPI, PPI and CPI to the four types of oil price shocks (2008.9-2016.12).

3.5 Variance decomposition analysis

We use variance decomposition to quantify the function strengths of different types of oil price shocks on inflation at various stages. Table 3 presents the variance decomposition of changes in China's IMPI, PPI and CPI due to different sources of oil price shocks. The data are presented for 1-month, 3-month and 12-month horizons. In the 1st month, 0.07%, 0.07%, 0.01% and 1.18% of the variability in the IMPI can be explained by an oil supply shock, a global demand shock, a domestic demand shock and an oil-specific demand shock, respectively. In the 3rd month, the contributions of these shocks to the variability in the IMPI increase to 0.14%, 1.93%, 0.18% and 13.72%, respectively, while in the 12th month, 20.30% of the variability in the IMPI can be explained by an oil-specific demand shock, 1.34% by a global demand shock, 0.22% by an oil supply shock, and only 0.07% by a domestic demand shock. These results suggest that of the four types of oil price shocks, an increase in oil price driven by oil-specific demand shocks has the most important impact on China's IMPI. For the PPI, oil-specific demand shocks also make the largest contribution of the four types of oil price shocks, with a contribution of 19.04% in the 12th month; these results are supported by Chen and Liao (2017). However, domestic demand shocks contribute the most of the four types of oil price shocks to the CPI, and the contribution decreases from the 1st month (10.13%) to the 12th month (9.86%). This result is partially consistent with the result of Yang and Jiang (2009), who showed that China's CPI was mainly affected by demand shock caused by output gap.

As shown in Table 3, in the 12th month, the aggregate contributions of aggregate oil price shocks to the changes in the IMPI, PPI and CPI are 21.93%, 21.00% and 13.85%, respectively. This result shows that at each stage, the pass-through effects of oil price shocks on China's inflation are incomplete and gradually weaken from upstream to downstream along the price chain; this result is in line with theoretical expectations.

Table 3. Variance decomposition of China's inflation due to the four types of oil price shocks (%).

	Period	1	3	12	1	3	12	1	3	12
			IMPI			PPI			CPI	
Full sample	Oil supply shock	0.07	0.14	0.22	0.11	0.29	0.56	0.33	0.69	0.69
	Global demand shock	0.07	1.93	1.34	0.47	0.83	0.76	0.26	0.35	0.37
	Domestic demand shock	0.01	0.18	0.07	0.97	1.07	0.64	10.13	10.02	9.86
	Oil-specific demand shock	1.18	13.72	20.30	0.91	13.41	19.04	2.05	2.58	2.93
	Aggregate	1.33	15.97	21.93	2.46	15.6	21.00	12.77	13.64	13.85
Sub-sample one	Oil supply shock	0.94	5.56	5.65	4.06	3.87	4.38	2.15	2.07	2.18
	Global demand shock	0.01	2.24	3.58	0.02	0.29	2.22	0.39	0.71	0.77
	Domestic demand shock	0.03	0.96	1.53	0.07	0.06	0.89	12.29	13.35	13.09
	Oil-specific demand shock	0.61	11.13	14.98	0.57	25.01	26.90	2.60	4.54	5.08
	Aggregate	1.59	19.89	25.74	4.72	29.23	34.39	17.43	20.67	21.12
Sub-sample two	Oil supply shock	1.32	0.99	1.37	0.69	0.37	1.91	0.69	3.94	3.69
	Global demand shock	0.02	1.09	0.31	2.46	1.76	0.41	1.15	2.17	2.25
	Domestic demand	0.02	1.01	4.02	2.46	4.56	5.35	4.57	6.52	6.64

shock									
Oil-specific demand shock	0.32	9.82	17.49	0.36	5.85	14.13	0.13	4.55	6.38
Aggregate	1.68	12.91	23.19	5.97	12.54	21.80	6.54	17.18	18.96

Comparing the second subsample (2008.9–2016.12) with the first subsample (1999.1–2008.8), the aggregate contributions of the four types of oil price shocks to changes in the IMPI, PPI and CPI decrease by 2.55%, 12.59% and 2.16%, respectively, in the 12th month. This result indicates that after the international financial crisis, the pass-through effects of oil price shocks on China's inflation at each stage became weaker compared with before the financial crisis. This result can be explained by the adjustment of the economic structure and the implementation of stimulating domestic demand policies after the international financial crisis. Therefore, the Chinese government could accelerate the transformation of the economic structure with a focus on stimulating domestic demand because it is helpful to reducing the risk of external shocks such as oil prices. In addition, we conclude that the PPI is most sensitive to a decrease in the contribution of oil price shocks. Of the four types of oil price shocks, the aggregate decreases in the IMPI and PPI are mainly attributed to the decrease in the impacts of oil supply shocks and global demand shocks, while the impacts of domestic demand shocks increase by 2.49% and 4.46%, respectively, which is consistent with the result of the impulse response function. The aggregate decrease in the CPI is mainly attributed to the contribution of domestic demand shocks, which decreases by 6.45%, implying that expanding domestic demand by stimulating consumption remains an important challenge for China.

3.6 Robustness check

3.6.1 Alternative measure of oil price

We investigate the robustness of the main results by using different international oil prices, including the West Texas Intermediate (WTI) oil price and the Brent oil price. First, we study the time-varying responses of China's inflation to these two types of price shocks. Although there are differences in the response strengths, no significant differences are found in the response directions and tendencies of these prices. In addition, we use variance decomposition to quantify the contributions of structural shocks. The results for the different oil prices are shown in Table 4. Compared with the U.S. refiners' acquisition cost for imported crude oil, we find that although the contributions of the four types of oil price shocks change slightly, the ranking of the contributions does not change. The increase in oil price driven by oil-specific demand shocks has the most important impacts on China's IMPI and PPI, while China's CPI is mainly affected by domestic demand shocks. Moreover, the pass-through effects of oil price shocks on China's inflation gradually weaken along the price chain from the import stage to the consumption stage. Thus, using international oil prices does not affect the nature of the empirical results.

3.6.2 Alternative measure of global economic activity

We further check the robustness of the main results using an alternative measure of global economic activity. In addition to Kilian's index, the Baltic Dry Index (BDI) is used as an indicator of global economic activity (Kilian, 2009; Tan et al., 2015); it is therefore necessary to determine whether the main results are stable using this alternative measure. We find that the directions and trends of the time-varying responses of Chinese inflation to the four types of oil price shocks are similar for both the BDI and KI, with only a slight difference in the response strength. We also investigate the robustness of the variance decomposition results using the BDI. The results in

Table 4 show that the contribution of global demand shocks to China's inflation at each stage increases significantly because the BDI index is more reflective of the activity of the commodity market than the economic index is. However, the ranking of the contributions of the four types of oil price shocks does not change, and the pass-through effects of oil price shocks on China's inflation gradually weaken along the price chain. Therefore, the empirical results in this paper are highly stable.

3.6.3 Alternative lag criterion

Naturally, using different values for the optimal lag length will impact the empirical results. In the empirical results presented above, we determine the optimal lag lengths for the AIC, HQ and FPE. For the robustness check, we adjust the optimal lag length to 6, which is suggested for the LR, and run the TVP-SVAR-SV model again. First, we study the time-varying responses of China's inflation to the structural shocks. Although the response strengths are greater than those shown in Figs. 3-6 when the alternative optimal lag length is used, the directions and trends of the time-varying impulse responses have no significant differences. The results of the variance decomposition using the adjusted lag length are also presented in Table 4. We find that the contributions of the four types of oil price shocks are slightly greater, while the main influencing factor of China's inflation at each stage does not change, and the pass-through effects of oil price shocks on China's inflation gradually weaken along the price chain. Thus, we conclude that our main results are robust after adjusting the optimal lag length.

Table 4. Variance decomposition results of the robustness check(%).

	Period	1	3	12	1	3	12	1	3	12
			IMPI			PPI			CPI	
WTI oil price	Oil supply shock	0.13	0.13	0.12	0.06	0.22	0.41	0.31	0.63	0.63
	Global demand shock	0.14	2.32	1.72	0.86	1.24	1.11	0.20	0.29	0.32
	Domestic demand shock	0.02	0.22	0.07	0.94	1.01	0.57	10.26	10.14	9.97
	Oil-specific demand shock	0.83	13.75	21.44	0.82	12.55	19.09	2.76	3.26	3.63
	Aggregate	1.12	16.42	23.35	2.68	15.02	21.18	13.53	14.32	14.55
Brent oil price	Oil supply shock	0.02	0.18	0.42	0.19	0.41	0.82	0.30	0.65	0.65
	Global demand shock	0.12	2.28	1.58	0.55	0.98	0.89	0.24	0.30	0.32
	Domestic demand shock	0.04	0.22	0.09	0.57	0.85	0.60	9.99	9.86	9.68
	Oil-specific demand shock	1.73	14.28	21.39	1.70	15.67	21.12	2.26	3.09	3.48
	Aggregate	1.91	16.96	23.48	3.01	17.91	23.43	12.79	13.90	14.13
BDI	Oil supply shock	0.09	0.13	0.25	0.10	0.27	0.60	0.32	0.68	0.67
	Global demand shock	0.33	3.94	5.47	0.80	2.43	4.04	0.26	0.67	0.74
	Domestic demand shock	0.04	0.20	0.07	0.91	0.92	0.42	10.29	10.10	9.95
	Oil-specific demand shock	0.95	12.04	17.70	0.75	11.99	16.67	1.95	2.27	2.61
	Aggregate	1.41	16.31	23.49	2.56	15.61	21.73	12.82	13.72	13.97
SVAR(6)	Oil supply shock	0.44	0.41	0.19	0.11	0.10	0.61	0.15	0.17	0.92

Global demand shock	0.10	2.23	2.42	0.37	0.79	2.50	0.63	1.45	3.34
Domestic demand shock	0.04	0.29	1.98	1.01	1.25	2.04	9.20	12.25	13.34
Oil-specific demand shock	3.24	19.10	27.51	2.09	17.83	25.90	1.99	2.17	4.29
Aggregate	3.82	22.03	32.10	3.58	19.97	31.05	11.97	16.04	21.89

4. Conclusions and policy implications

To understand the pass-through effects of oil price shocks on China's inflation at the stages of import, production and consumption, we use the IMPI, PPI and CPI to construct a price chain that reflects the intrinsic connections. In addition, we decompose the structural shocks of oil price fluctuations into four types: oil supply shocks, global demand shocks, domestic demand shocks and oil-specific demand shocks. We then construct the TVP-SVAR-SV model to comprehensively analyze the time-varying effects of the oil price shocks on China's inflation at each stage for the period 1999:1 to 2016:12. Based on the results, we can draw the following conclusions.

(1) The pass-through effects of oil supply shocks, global demand shocks, domestic demand shocks and oil-specific demand shocks on China's inflation are time-varying at each stage, and there are significant differences in the function direction, strength and duration at different time horizons and points in time. An increase in oil price driven by oil supply shocks has a negative effect on China's inflation in most cases, while the responses of China's inflation to increases in oil price driven by the other three types of oil demand shocks are mostly positive. Moreover, oil price mechanism reforms, financial crises and economic cycle fluctuations lead to significant changes in the pass-through effects of oil price shocks on China's inflation.

(2) The pass-through effects of oil price shocks on China's inflation are incomplete at each stage and decrease along the price chain, with import prices having the most significant impact, followed by producer prices and consumer prices. Of the four types of oil price shocks, the increase in oil price driven by oil-specific demand shocks is the most important cause of China's inflation at the import and production stages during the full sample period, while China's inflation at the consumption stage is mainly affected by domestic demand shocks. In addition, the international financial crisis caused a structural change in the impacts of oil price shocks on China's inflation. The inflationary effects of oil price shocks have been dramatically weaker since the international financial crisis than they were before the crisis.

In general, this paper addresses the temporal variations in the responses of China's inflation at the import, production and consumption stages to four types of oil price shocks. Based on the empirical results, we propose the following policy recommendations. Because different types of oil price shocks have different impacts on China's inflation, the government should take targeted measures based on the different sources of the oil price shocks. Policies aimed at stabilizing inflation should focus on the changes in demand shocks, especially domestic demand and oil-specific demand shocks. Specifically, under the new normal, China needs to stimulate consumption and expand domestic demand, thereby reducing the adverse effects of oil price fluctuations. From the perspective of oil-specific demand shocks, the Chinese government should develop an open crude oil futures market based on the introduction of crude oil futures as of March 26, 2018. Crude oil futures and related derivatives could be developed to reduce the adverse impacts of oil price shocks and provide a convenient risk hedging tool. In terms of formulating an anti-inflation policy, the Chinese government must consider how inflation differs at different stages of oil price shocks and adopt differentiated policies. Due to price controls and regulations on refined oil, the pass-through effects of oil price shocks decrease along the price chain; therefore, it is necessary to promote market-oriented energy pricing, reduce the perceived distortion and improve the smoothness of the price transmission mechanism. In addition, the pass-through effects of oil price shocks on China's inflation are time-varying, so policies should focus on the recent effects rather than past influences, and dynamic management control for different economic situations is required to address the oil price shocks that influence China's inflation.

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Highlights

- A TVP-SVAR-SV model is used to study the effects of oil price shocks on inflation.
- The pass-through effects of oil price shocks on China's inflation are time-varying.
- The effects of oil price shocks on China's inflation decrease along the price chain.
- There is a structural change before and after the international financial crisis.