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The Asymmetric Effects of Oil Price Shocks on the Chinese Stock Market: Evidence from a Quantile Impulse Response Perspective

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Abstract: This paper uses a quantile impulse response approach to investigate the impact of oil price shocks on Chinese stock returns. This process allows us to uncover asymmetric effects of oil price shocks on stock market returns by taking into account the different quantiles of oil price shocks. Our results show that the responses of Chinese stock market returns to oil price shocks differ greatly, depending on whether the oil and stock market is in a bust or boom state and whether the shock is driven by demand or supply. The impacts of oil price shocks on Chinese stock returns present asymmetric features. In particular during a bust phase, oil supply and demand shocks significantly depress stock market returns, while during a boom period, the aggregate demand shock enhances stock market returns. These results suggest some important implications for investors and decision makers.

Keywords: Chinese stock market; oil price shock; asymmetric effects; quantile impulse response; quantile vector autoregression

1. Introduction

Crude oil has been the focus of greater attention than other commodities. It plays a significant role in the economy and the financial market. Many economists have noticed the impacts of crude oil price on the economy [1–5]. As a barometer of the economy, the stock market's reaction is a reasonable and useful measure to reflect the impact of oil price shocks on the economy [6]. Abundant literature has investigated the link between oil price and stock markets and concludes that oil price shocks have substantial effects on stock markets [7–21].

Particularly, China has become the largest oil importer and consumer [22]. Table 1 shows that the crude oil imports of China increased rapidly from 126.8 million tons in 2005 to 335.5 million tons in 2015. And oil imports accounted for 60.6% of the country's total oil consumption in 2015. China is a giant player in the global oil market. In addition, the Chinese stock market has been the second largest in terms of both trading volume and capitalization. Therefore, a lot of literature has focused on the link between oil prices and the Chinese stock market [23–30]. These studies however, do not elaborate various complexities in the link between oil price and stock prices. For instance, stock markets may react differently to oil price shocks during bullish and bearish times. The effects of oil price shocks may be nonlinear or may be asymmetrical in negative and positive oil price shocks. Therefore, the effects of oil price shocks may be heterogeneous and varying depending on market conditions and the types of the oil price shocks. It is worth examining the effect of oil price shocks on the Chinese stock market simultaneously under the control of the oil and stock market conditions.

Table 1. World's oil productions, China's crude oil imports and China's oil import dependence during the 2005–2015 period.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
WOP	3938	3964	3951	3987	3887	3979	4012	4119	4127	4229	4362
COI	126.8	145.1	163.1	178.8	203.6	239.3	253.7	271.0	281.9	308.3	335.5
OID	42.9	47	47.2	49.8	51.3	54.8	56.1	56.4	57	59.6	60.6

Note: WOP denotes the world oil production (in million tons), COI denotes the Chinese oil imports (in million tons) and OID denotes the oil import dependence (in percentage) [31,32].

In this paper, this issue will be addressed by using a quantile impulse response function which can be calculated via a quantile vector autoregression frame. This method was first proposed by Cecchetti and Li [33] and has been used to explore the asymmetric and nonlinear effects between financial and economic variables [34,35]. Lee and Kim [36] argue that the quantile impulse response function is widely applicable and is beneficial in that it captures the dynamic responses that the conventional impulse response does not explain. Moreover, the impulse responses in multiple quantiles can be deemed a scenario analysis that is a forecast of a variable under a scenario of a specific economic shock. Therefore, we use a quantile impulse response approach to investigate the impact of oil price shocks on stock market returns during different oil market states, with particular interest in extreme stock market circumstances (i.e., bearish and bullish markets).

We will investigate the responses of Chinese stock market returns to oil price shocks in terms of several aspects. First, each variable in the quantile VAR (Vector Autoregression) model can be defined to be at some specific state of the business for the analysis, i.e., the quantiles may differ across equations. In order to analyse the asymmetric shock effects, we propose relating conditional quantiles of the change rate of supply and demand in the oil market to business states [34]. In the oil market, the lower negative change rate of global oil production, global real economic activity and the real oil price (at lower quantiles of the change rate distribution) can be attributed to business busts, whereas their higher positive change rates (at upper quantiles of the change rate distribution) can be attributed to a boom business state. This means that during a business bust phase, the supply and demand in the oil market should decrease while during a business boom phase, the supply and demand will increase. This assumption is reasonable. For example in a boom state, on one hand oil producers may adjust their oil production to increase the oil supply. On the other hand, a high demand for oil would drive up the price of oil. Therefore lower quantiles correspond to a bust oil market state, while upper quantiles correspond to a boom oil market state. Additionally, the lower quantiles of stock market return distributions correspond to a bearish market and its upper quantiles correspond to a bullish market.

Second, following Kilian and Park [12], oil price shocks are broken down into three different components: supply shocks, aggregate demand shocks and specific demand shocks. Then we investigate their effects on the Chinese stock market. Applying a quantile impulse response analysis, we study the direction, magnitude and duration of effects of oil price shocks on the Chinese stock market during different oil market conditions. Our empirical evidence indicates that the reaction of the Chinese stock market to oil price shocks depends on oil market conditions and the underlying forces of oil price shocks. Specifically during a bust phase, oil supply and demand shocks significantly depress stock market returns, while during a boom phase, only aggregate demand shock is positive, persistent and statistically significant. Additionally, we find that the different stock market circumstances (i.e., bearish and bullish markets) have different responses to oil price shocks.

Third, we examine the impact of oil price uncertainty on the Chinese stock market. Some literatures have investigated the relationship between oil price and the Chinese stock market. However, few studies examine the effects of oil price uncertainty on the Chinese stock market. In this paper, we use a quantile impulse response analysis to investigate the shock effects of oil price uncertainty. Our results indicate that in a bearish market, oil supply and demand uncertainties

have positive shock effects on Chinese stock market returns, while in a bullish market, oil supply and demand uncertainties show negative shocks effects.

The rest of this paper is organized as follows. Section 2 briefly reviews the literature. The methodology is presented in Section 3. Section 4 describes the data and their descriptive statistics. Section 5 provides empirical results and Section 6 concludes.

2. Literature Review

Numerous literatures have illustrated the effects of oil price shocks on stock market, for example, with a standard cash flows/dividends valuation model, Jones and Gautam [7] investigate the effects of oil price shocks on the stock markets in four developed countries US, Canada, Japan and England. Their empirical results show the important effects of the change in the oil price on the four countries' stock markets. Huang et al. [37] support causality effects from oil futures prices to stock prices. Sadorsdy [8] shows the significant role of oil price shocks and volatility in explaining the real stock returns in the US and a negative effect of oil price volatility on stock prices. Papapetrou [38] provides evidence that oil prices goes a long way in explaining stock price movements in the Greek stock market and shows the suppressing effects of positive oil price shocks on real stock market returns. Park and Ratti [11] comprehensively analysed the impact of oil price shocks on the stock markets of the United States and 13 European countries. The effect of oil price shocks on oil-importing countries is negative, however the effects on oil-exporting countries are positive.

To capture the specific relationships between the oil price and stock market returns, Kilian [5] adopts a structural VAR to decompose the oil price shocks into oil supply shocks, aggregate demand shocks and oil-specific demand shocks. Following the procedure of Kilian [5], many studies have examined the impact of oil supply and demand shocks on the stock market. Kilian and Park [12] show the different responses of aggregate US real stock market to different types of oil shocks. Specifically, oil supply shocks have no significant impact on stock market. Apergis and Miller [39] investigate the effects of structural oil price shocks on eight developed countries' stock markets (Australia, Canada, France, Germany, Italy, Japan, the United Kingdom and the United States). They find little evidence that oil market shocks have a significant impact on those stock markets. Basher et al. [17] investigate the dynamic relationship between oil shocks and emerging stock markets. They show that the positive oil supply shocks decrease the oil prices while the positive oil demand shocks create an increase the oil price. Moreover, oil prices react positively to positive shocks of the emerging stock markets. Wang et al. [40] study the effects of three structural shocks on the stock market in nine oil-importing countries and seven oil-exporting countries. Their empirical results suggest that the effect of oil price shocks on the stock market of a country depends on the net position of that country and the type of oil price shocks.

Recently, many economists have studied the effect of oil price shocks on the Chinese stock market. For example, Cong et al. [23] adopted the VAR approach to explore this topic and found no effect of oil price shocks on the Chinese stock market, except in the manufacturing sector and some oil companies. Employing an ARJI(-ht)-EGARCH model, Zhang and Chen [41] found that the Chinese stock market correlated only with expected volatilities in global oil prices and global oil prices have only minor positive effects on the Chinese stock market. Fang and You [42] evaluated the effects of oil supply and demand shocks on the Chinese stock market with a structural VAR approach. They drew the conclusion that it presented a significant negative effect on oil-specific demand shocks but no statistically significant effects on global demand oil shocks. Based on the extreme value theory, Chen and Lv [28] show a positive extremal dependence between oil prices and the Chinese stock market. It is noteworthy that Fang and You [42] seemed to look at different types of oil shocks but not look at the effects of different quantiles, whereas Chen and Lv [28] suggested that the extremes of the distribution of the oil market and stock market are dependent; however, they do not look at different types of oil shock.

In a previous paper [43], we applied a quantile regression technique to investigate the linkage between oil price and Chinese stock market returns. Our results showed that the effects of crude oil price shocks on industry stock market returns presented significant heterogeneous across the stock return distribution. However, we did not identify the trigger forces of oil price shocks in the previous paper. In addition, relative to the quanitle regression method the quantile impulse response method can systematically analyse the shock effects under different stock and oil market states (boom or bust). Therefore, we further analyse the impact of oil price shocks on the Chinese stock market in the present paper.

Focusing on understanding how large positive or negative oil price shocks impact different stock market return quantiles, Sim and Zhou [44] proposed a novel quantile-on-quantile approach to examine the quantile dependence relationship between oil prices and United States stock returns. In this paper, the lower oil price shock quantiles are regarded as large and negative oil price shocks, while the upper oil price shock quantiles are seen as large and positive oil price shocks. They find that the relationship between oil prices on US equities is asymmetric. Along these lines, Reboredo and Ugolini [45] use a copula-quantile method to capture quantile dependence between oil price shocks and stock market returns in three developed economies and five BRICS countries. They examine how quantile and interquantile oil price movements impact different stock return quantiles and find asymmetric effects of oil price shocks on stock market returns. However, both studies analyse the asymmetric effects of oil price shocks on stock market returns in two-dimensional systems, so we cannot extend their methods to higher-dimensional situations. The present methodology has the advantage in that it can easily accommodate higher-dimensional models.

Our research sought to explore the impact of oil supply and demand shocks on Chinese stock market returns during different oil market phases. To the best of our knowledge, no paper has yet thoroughly investigated this topic. Furthermore, we adopt the quantile impulse response analysis based on a quantile structural VAR model because it offers a structural multiple equation framework i.e., it is vital to model the interaction effects of a system of variables.

3. Methodology

Our interest is using the quantile impulse response to uncover the dynamic responses of Chinese stock market returns to oil market structural shocks in the different phases of the business. In order to calculate quantile impulse responses, we use a quantile structural vector autoregression technique which employs a quantile regression method to estimate a structural vector auto-regressions model. In this section, we first briefly introduce the quantile regression method, then present the reduced form of the quantile structural VAR and identify the structural shocks to conduct quantile impulse response analysis.

3.1. Quantile Regression

Quantile regression can be seen as a flexible generalization of standard regression equations [46]. Compared with the least-square method, it has two major advantages. The first is that quantile regression estimations can be robust to non-Gaussian or heavy-tailed data, and the second is that the quantile regression model allows practitioners to provide more easily interpretable regression estimates $\tau \in (0, 1)$. The quantile regression model explains the $\tau - th$ quantile of y_t, given the values of a vector of explanatory variables x_t as

$$Q_\tau(y_t | x_t) = x_t \beta(\tau) \tag{1}$$

where $Q_\tau(y_t) = F^{-1}(\tau)$, $F(y_t)$ is the probability distribution function of the random variable y_t. The notation $\beta(\tau)$ highlights that there is a potentially different parameter vector at each respective

quantile τ of the distribution. The unknown parameter vector $\beta(\tau)$ can be estimated for any quantile $\tau \in (0,1)$ by minimizing the following expression with respect to $\beta(\tau)$:

$$\hat{\beta}(\tau) = \underset{\beta(\tau)}{argmin} \sum_{t=1}^{T} (\tau - 1_{\{y_t < x_t \beta(\tau)\}}) |y_t - x_t \beta(\tau)| \tag{2}$$

where $1_{\{y_t < x_t \beta(\tau)\}}$ is the usual indicator function. The solution to the quantile regression model is obtained using the programming algorithm suggested by Koenker and D'Orey [47]. The resulting estimate $\hat{\beta}(\tau)$ can capture the extent to which the $\tau - th$ quantile of the conditional distribution of y_t changes if x_t changes by one unit. In this way, one can characterize the impact of changes in the x_t variables on the whole conditional distribution of y_t, measured at any of its quantiles that are of interest to the researcher.

3.2. The Reduced-Form Quantile Structural VAR

From the point of view of program implementation, we first present the reduced form of quantile structural VAR. The structural model is then recovered in a second step by decomposing the covariance matrix of the error term. In this paper, the reduced form quantile VAR is given as

$$y_t = c(\tau) + \sum_{i=1}^{p} B_i(\tau) y_{t-i} + e_t(\tau), \quad for \quad t = 1, ..., T \tag{3}$$

where

$$y_t = \begin{pmatrix} \Delta prod_t \\ \Delta rea_t \\ \Delta rpo_t \\ \Delta rps_t \end{pmatrix}, \ c(\tau) = \begin{pmatrix} c_1(\tau_1) \\ c_2(\tau_2) \\ c_3(\tau_3) \\ c_4(\tau_4) \end{pmatrix}, \ e_t(\tau) = \begin{pmatrix} e_t^{\Delta prod}(\tau_1) \\ e_t^{\Delta rea}(\tau_2) \\ e_t^{\Delta rpo}(\tau_3) \\ e_t^{\Delta rps}(\tau_4) \end{pmatrix},$$

$$B_i(\tau) = \begin{pmatrix} \beta_{i,11}(\tau_1) & \beta_{i,12}(\tau_1) & \beta_{i,13}(\tau_1) & \beta_{i,14}(\tau_1) \\ \beta_{i,21}(\tau_2) & \beta_{i,22}(\tau_2) & \beta_{i,23}(\tau_2) & \beta_{i,24}(\tau_2) \\ \beta_{i,31}(\tau_3) & \beta_{i,32}(\tau_3) & \beta_{i,33}(\tau_3) & \beta_{i,34}(\tau_3) \\ \beta_{i,41}(\tau_4) & \beta_{i,42}(\tau_4) & \beta_{i,43}(\tau_4) & \beta_{i,44}(\tau_4) \end{pmatrix}.$$

Here, y_t is a 4 vector of endogenous variables in which $\Delta prod$ denotes the percentage change in global crude oil production, Δrea denotes the percentage change in global real economic activity, Δrpo denotes percentage change in the real price of oil, and Δrps denotes the percentage change in real stock price index. $c(\tau)$ is a 4 vector of intercepts at quantiles $\tau = (\tau_1, \tau_2, \tau_3, \tau_4)'$, $B_i(\tau)$ for $i = 1, ..., p$ denotes the matrix of lagged coefficients at quantiles $\tau = (\tau_1, \tau_2, \tau_3, \tau_4)'$, and $e_t(\tau)$ is a vector of error terms.

The quantile VAR model emphasizes the important fact that the parameters in each equation may pertain to different quantiles of the conditional distribution of the respective left-hand side variable. This model is attractive because it allows us to use the estimated model to answer a variety of interesting empirical questions. For instance, there is a boom oil market in which the oil supply, the real economic activity and oil price are in the 90th percentile of the data ($\tau_1 = 0.9$, $\tau_2 = 0.9$, $\tau_3 = 0.9$), whereas in a bearish stock market, stock returns are in the 10th percentile of the distribution ($\tau_4 = 0.1$).

To obtain the estimated coefficient matrices $\hat{B}_i(\tau)$ and $\hat{c}(\tau)$, we assume that the errors $e_t(\tau)$ satisfy the population quantile restrictions $Q_\tau(e_t(\tau)|y_{t-1}, ..., y_{t-p}) = 0$. These restrictions imply that the population responses of the y at quantiles $\tau = (\tau_1, \tau_2, \tau_3, \tau_4)'$ are characterized by

$$Q_\tau(y_t|y_{t-1}, ..., y_{t-p}) = c(\tau) + \sum_{i=1}^{p} B_i(\tau) y_{t-i} \tag{4}$$

Since each equation of (4) has the same right-hand side, the model can be estimated on an equation-by-equation basis for each vector τ using quantile regression [33].

3.3. The Quantile Impulse Response

In order to identify the structural shocks of the global oil market, we give these error terms e_t as a structure restriction, which specifies the contemporaneous relationship between the reduced-form disturbances and the underlying structural disturbances. By modifying the procedure of Kilian and Park [12], we decompose the structural shocks as follows:

$$
e_t = \begin{pmatrix} e_t^{\Delta prod} \\ e_t^{\Delta rea} \\ e_t^{\Delta rpo} \\ e_t^{\Delta rps} \end{pmatrix} = \begin{pmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{Oil\ supply\ shock} \\ \varepsilon_t^{Aggregate\ demand\ shock} \\ \varepsilon_t^{Oil-specific\ shock} \\ \varepsilon_t^{Stock-specific\ shock} \end{pmatrix}
\tag{5}
$$

where ε_t represents a white noise process in which the covariance matrix is an identity matrix. The identifying restrictions underlying Equation (5) have their own nature and origin. First, because oil production is capital-intensive and time-consuming, therefore the oil supply shock cannot trigger changes of aggregate demand and crude oil price in the short term. Second, although the response of global economy activity to oil-specific demand shock is lagging behind, it can still react immediately to oil supply shock. In addition, in the short term, stock price shock cannot influence world economic activity. Third, the expected shortfall in oil supply and global economic activity can create changes in precautionary demand [12]. The oil-specific shock responses to oil supply and aggregate demand shocks. Finally, many other factors such as changes in interest rates and exchange rates can trigger stock-specific shock [17,48].

According to the above structural shocks identified, we orthogonalize the covariance matrix of the residuals using a Cholesky decomposition and calculate the associated quantile-specific impulse response function. The 95% confidence interval of the impulse response function is obtained using the 'bootstrapping' approach. The 95% confidence bounds are provided to judge the statistical significance of the impulse response functions. Using the impulse response function, we are able to implement impulse response analysis in our compelling quantile levels and plot the impact of a one-unit increase in the one variable's innovation at date t on another variable at date $t + s$. Therefore, we can find the response of the interesting variable's change when shocks occur in other variables under various quantiles.

4. Data and Summary Statistics

The data applied in this paper is monthly and spans the period from October 2001 to December 2015. We selected October 2001 as the start date because the State Council of China further deregulated the domestic oil-pricing mechanism until October 2001. In order to identify oil market supply and demand shocks on the Chinese stock market, global oil production, global real economic activity index, the world oil price and stock price index are collected. The global oil production data measured in thousands of barrels per day are sourced from the US Energy Information Administration. The global real economic activity index is likely to capture shifts in the demand for industrial global business markets and is available to download from Lutz Kilian's homepage. Moreover, Kilian [5] has fully explained the rationale of using this index to measure the global demand for oil. The world real oil price in dollars per barrel is measured using the US refiner acquisition cost of crude oil and then deflated by US Consumer Price Index (CPI). It is worth noting that we abandoned the country-specific oil price and instead used the world oil price because the world oil price could better capture the impact of oil price shock on stock markets than country-specific prices, which reflected the offsetting movements in exchange rates [11]. The world oil price may affect the Chinese stock market through

different channels. On one hand, because China is net oil-importer, therefore, a dramatic increase in the world oil price may lead to lower consumption demand and higher production costs, all of which would constrain the economic development and ultimately decreasing stock market returns. On the other hand, the global economic cycles will influence the China's real economy and financial market. Therefore, a fluctuation of the world oil price will affect China's exports and real economy and the Chinese stock market will reflect the world oil price trends. As a proxy for the Chinese stock market, Shanghai Composite index is collected from CSMAR. The Shanghai composite index is a stock market index of all stock (A shares and B shares) traded on the Shanghai stock exchange. It reflects the changes in stock prices traded on the Shanghai stock exchange. The nominal price index is converted to the real price index using Chinese CPI. These CPI data are available from the OECD.

　　Figure 1 plots the real oil prices, as well as Shanghai composite index prices. Observe that the real oil prices and stock prices appear in an inconsistent variation trend, sometimes moving together but frequently moving in opposite directions, which verifies the fact that various complexities exist in the relationship between oil prices and stock prices. According to Figure 1, we can intuitively identify the periods of boom and bust of oil and stock markets. For the world oil market, the most remarkable surge in the price of oil since 1979 occurred between mid-2003 and mid-2008, in which the oil price surge was not caused by oil supply disruptions but by a series of increases in the crude oil demand associated with an unexpected expansion of the global economy and driven by strong additional demand for oil from emerging Asia in particular. From June 2008 to February 2009, the world oil price presented a sharp drop which was caused by the financial crisis of 2008. In 2009, the collapse of the global financial system was not imminent, the demand for oil recovered to levels prevailing in 2007 and the price of oil stabilized near 100 US dollars per barrel between 2010 early 2014. Between June 2014 and January 2015 the world oil price appeared a sharply decline. After a slight and transitory rise, since July 2015 the world oil price continued to fall. For the Chinese stock market, it underwent a bull market four times in the sample periods. The Shanghai composite index increased from 1080.94 in June 2005 to 5954.77 in October 2007, which was triggered by the reform of shareholder structure and the RMB appreciation. From November 2008 to July 2009, the four trillion investments of the central government and the ten industrial revitalization planning antagonized the stock price surge. Due to the influences of the second round of quantitative easing monetary policy, the Chinese stock market appeared in a transitory bull market from July to November 2010. Between July 2014 and June 2015, a series of reform programs and policy guidance of the Chinese government triggered an increase in the Shanghai composite index from 2201.56 to 4277.22.
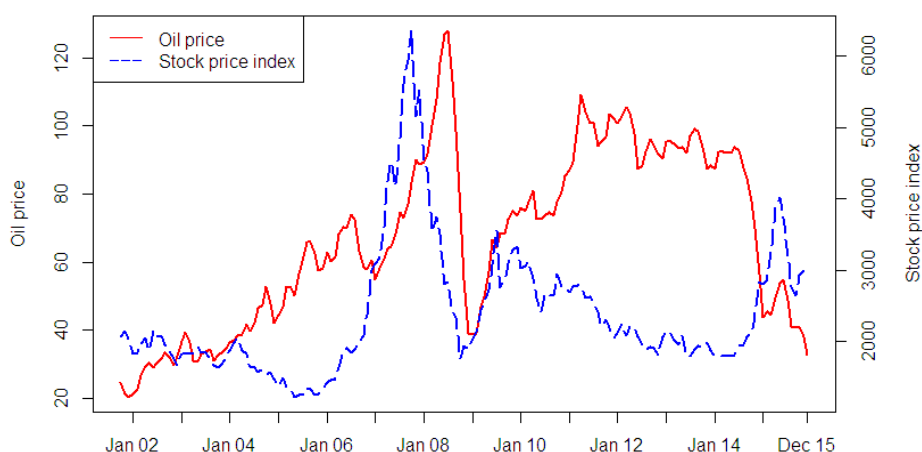

Figure 1. Dynamics of the real oil price and Shanghai composite index from October 2001 to December 2015.

In order to check if the fundamental oil supply and demand shocks influence Chinese stock market, we try to incorporate changes of crude oil production, economic activity and crude oil price into the shocks mentioned above. Thus, these variables showed the first changes in obtaining their real change rate.

Table 2 presents descriptive summary statistics for this study. Maximum and minimum values demonstrate change of crude oil production is far less than the variability of global economy activity and oil price change, which indicates that crude oil supply presents a stable increase however, global economic activity and oil-specific demand is increasing drastically. Thus, we conclude that shocks on crude oil demand have a large impact on the fluctuations of the crude oil price. Different from other variables, the mean of the global real economic activity is negative. However, all of the variables show negative skewness and excess kurtosis. The Shapiro-Wilk test results show that the normality of the change rate of oil market shocks and real stock returns are strongly rejected, which further validates the rationality of using the quantile regression method to estimate the VAR model.

Table 2. Summary statistics of oil and stock markets.

Variables	$\Delta prod$	Δrea	Δrpo	Δrps
Min	−2.4254	−40.8204	−33.7239	−27.9749
Max	2.3601	36.2818	17.5295	22.8623
Median	0.0967	0.6412	1.2439	0.5883
Mean	0.1005	0.1651	0.1596	0.1884
Std. dev	0.7415	9.2117	8.2394	8.2547
Skewness	−0.443	−0.6207	−1.2566	−0.4209
Kurtosis	3.6462	6.9927	5.7796	4.0909
Shapiro−Wilk test	0.9904 (0.3122)	0.9658 (0.0003)	0.9199 (0.0000)	0.9760 (0.0048)

Note: The *p*-values of Shapiro-Wilk test statistics are reported in parentheses.

Granger and Newbold [49] noted that a VAR model that contains non-stationary variables may suffer from a spurious regression problem and the results may not be reliable. Accordingly, we pretest our variables for stationarity data using the Augmented Dickey Fuller (ADF) test. The results of unit root tests are shown in Table 3, in which each variable in the structure VAR model is stationary.

Table 3. ADF unit root tests for the VAR model.

Variables	None	With Intercept	With Trend and Intercept
$\Delta prod$	−11.6683 (0.0000)	−12.0333 (0.0000)	−11.9969 (0.0000)
Δrea	−9.5033 (0.0000)	−9.5682 (0.0000)	−9.5118 (0.0000)
Δrpo	−7.7154 (0.0000)	−7.6991 (0.0000)	−7.8854 (0.0000)
Δrps	−11.4368 (0.0000)	−11.4099 (0.0000)	−11.3815 (0.0000)

Note: The optimal lag length for the tests was determined using the Schwarz Information Criterion (SIC). The *p*-values are reported in parentheses.

5. Empirical Results

To improve our understanding of the heterogeneous impact of oil shocks on Chinese stock returns, we investigate not only the effects of oil price shocks on stock market returns but also the impact of oil price uncertainty on stock market returns. We use a quantile impulse response function to capture the asymmetric effects of oil market shocks on the Chinese stock market.

5.1. Impact of Oil Price Shocks on Stock Market Returns

Following Kilian and Park [12], we examine the reaction of the Chinese stock market to oil supply shock, aggregate demand shock and oil-specific shock. Moreover, by using a quantile structural VAR model to calculate the quantile impulse response function, we can capture the impacts of oil price

shocks under different oil and stock market states, which help us to obtain a more complete picture of the factors affecting stock market returns. In each quantile VAR model, the optimal order for the VAR (p) process is chosen by Akaike's information criterion.

5.1.1. Asymmetric Effects over Bust and Boom Market States

This section assumes that the oil market and stock market are driven by one business state. Thus, variables in this part of the analysis are estimated at the same conditional quantile, i.e., $\tau_1 = \tau_2 = \tau_3 = \tau_4$. For conciseness, we present the baseline results for just five quantiles $\tau = \{0.05, 0.1, 0.5, 0.9, 0.95\}$. These quantiles are just some typical quantiles of distribution and the general results are robust over different choices of other possible quantiles. When $\tau = 0.05$ and $\tau = 0.1$, we evaluate the shock effects of oil market on stock market returns for a business in a bust. If $\tau = 0.5$, we estimate the shock effects at the median of stock returns, which is close to its mean. When $\tau = 0.9$ and $\tau = 0.95$, the cyclical component of oil and the stock market is predicted to be booming. We present these quantiles to guarantee the readability and centre the focus on this topic.

Figure 2 shows the responses of the Chinese stock market to oil market structural shocks during different oil and stock market states. As shown in Panels A and B, at the average state of business, global oil supply shocks and demand shocks have no statistically significant effects on the Chinese stock market. This result is consistent with the previous empirical findings of Cong et al. [23], who found that oil price shocks did not show statistically significant impacts on the real returns of the Chinese stock market composite index. The following reasons may explain this phenomenon. Chinese financial market is supervised strictly and has a lack of transparency. Because the shares held by the state and legal entities are not allowed to be traded, Chinese stock returns only reflect the demand of the domestic investor. Therefore, as a result of the incomplete market, Chinese stock market returns do not have a significant response to the global demand of oil price shocks. The stock-specific shock however, has a significant, positive effect on Chinese stock market. This implies the positive effect of the deregulations.

Panels C and D in Figure 2 present the impact of the oil market structural shocks on Chinese stock market returns during a bust phase. The global oil supply shocks, aggregate demand shocks and oil-specific demand have negative statistically significant shock effects on Chinese stock market returns after period 3. China is a net oil-importing country. An increase in oil prices may lead to lower real consumption and higher production costs, all of which may constrain the economy and limit the number and types of investment opportunities available, ultimately decreasing stock market returns. Especially in a bust business phase, the negative shock effects are more significant. A plausible explanation is that the companies are more sensitive to the rising cost of production during a business bust. In addition, stock markets are more strongly correlated with various classes of assets when the stock markets are bearish [50]. Moreover, the negative response of stock market returns is persistent as Panel B shows, which implies that an increase in the oil price derived from oil supply or oil demand will cause the stock market returns to persistently decrease.

During a boom phase, as shown in Panels E and F in Figure 2, the aggregate demand shock has a positive statistically significant effect, which may seem surprising because as a net oil-importing country, the relationship between its stock market returns and oil price shocks should be negative. However, during an economic boom, crude oil price and stock price are increased simultaneously. Especially, in spite that a rise in oil price increases the production costs, the negative shock effects would be weakened by the special adjustment mechanism in domestic oil prices. On the other hand, positive demand shock should lead to higher oil prices but this could have two effects. First, an increase in a firm's costs depresses profits. However, a second effect, the higher sales for Chinese companies' products overseas, have a positive impact on profits and hence, firm value; thus, the cost impact could be outweighed by increased revenues. Therefore, we find a positive relationship between the increase in the oil price derived from aggregate demand and the Chinese stock market returns.
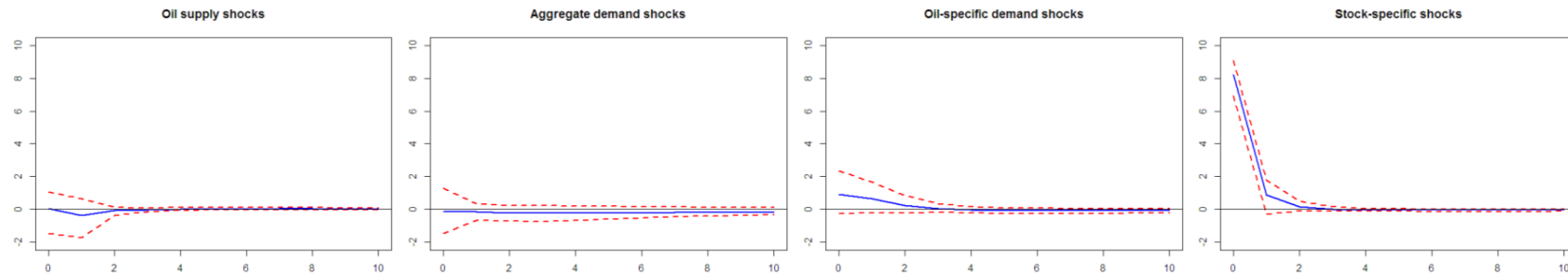
Panel **A**: During the general phase (OLS)
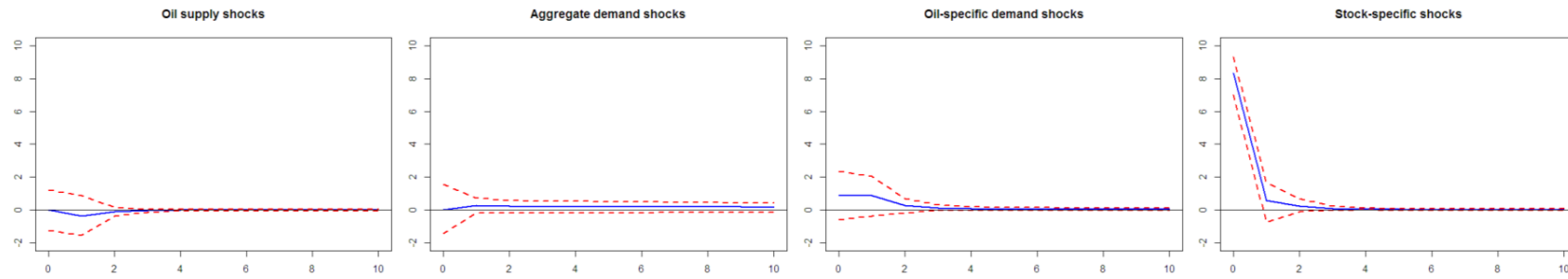
Panel **B**: During the general phase ($\tau = (0.5, 0.5, 0.5, 0.5)$)
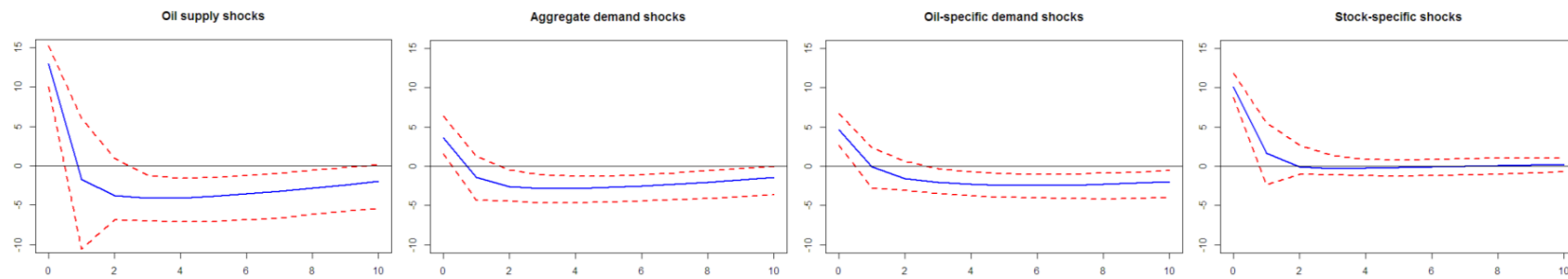
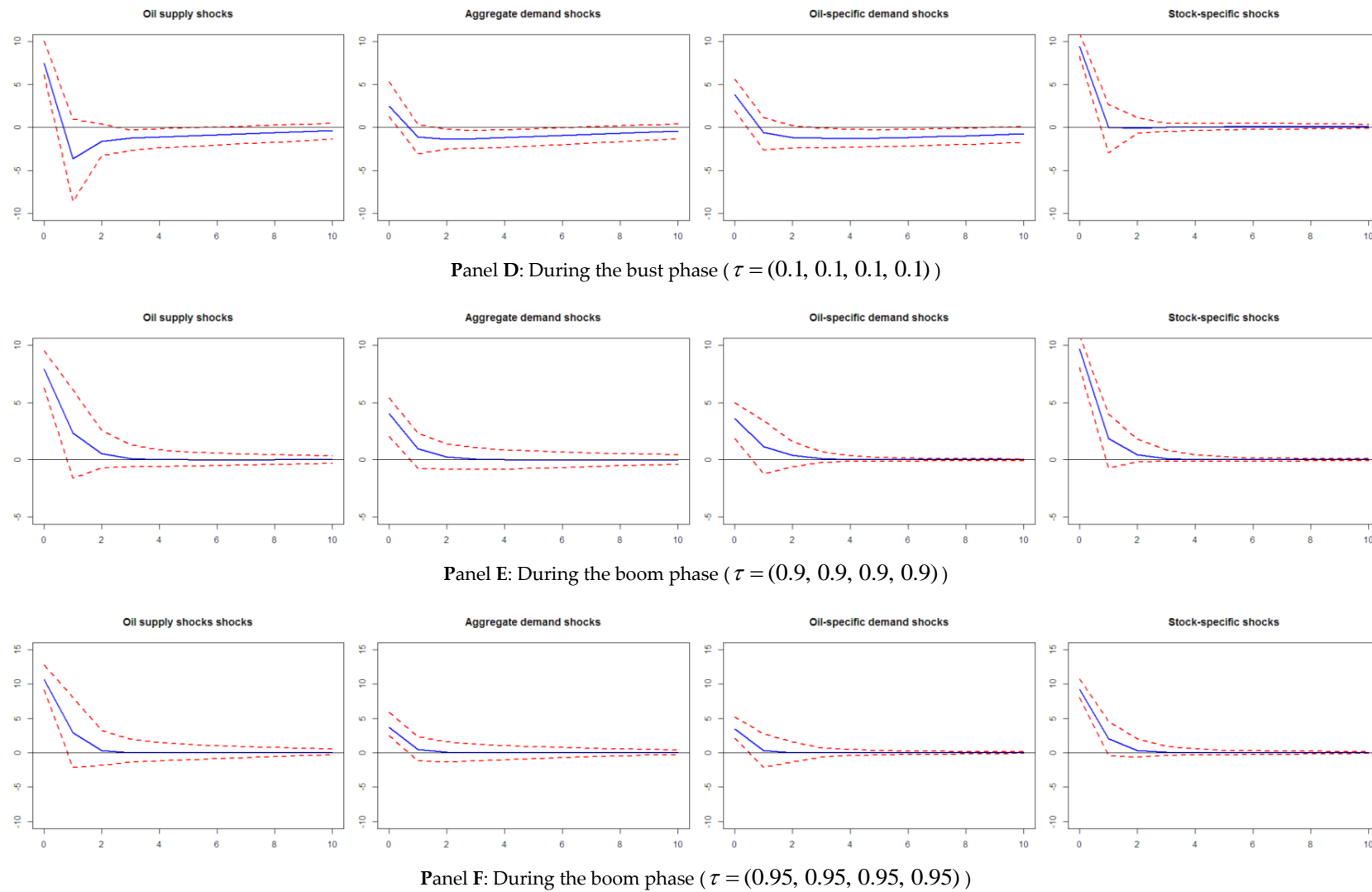**P**anel **C**: During the bust phase ($\tau = (0.05, 0.05, 0.05, 0.05)$)

Figure 2. *Cont.*

Panel D: During the bust phase ($\tau = (0.1, 0.1, 0.1, 0.1)$)

Panel E: During the boom phase ($\tau = (0.9, 0.9, 0.9, 0.9)$)

Panel F: During the boom phase ($\tau = (0.95, 0.95, 0.95, 0.95)$)

Figure 2. Impulse response of Chinese stock returns to structural shocks under different oil and stock market states for the full sample period.

5.1.2. Asymmetric Effects in Bearish and Bullish Stock Markets

In this section, we analyse the asymmetric effects of oil supply and demand shocks on bearish and bullish stock markets during different oil market states. For the business state, we use quantile $\tau = 0.2$ to represent an oil market bust and $\tau = 0.8$ to denote an oil market boom. Putting it differently, the vector τ is assumed to be $(0.2, 0.2, 0.2, \tau_4)'$ during the bust phase and $(0.8, 0.8, 0.8, \tau_4)'$ during the boom phase. τ_4 is then allowed to vary, to represent the various stock market states. For conciseness, we present the baseline results for the $\tau_4 = \{0.1, 0.9\}$ quantiles of the stock market return distribution. The $\tau_4 = 0.1$ represents a bearish market and $\tau_4 = 0.9$ denotes a bullish market.

Figure 3 depicts the responses to oil market shocks for an oil market in a bust period, in which Panel A illustrates the response when the stock market is in a good state (bullish market) and the Panel B shows the case when the stock market is in a bad state (bearish market). Thus, it can compare the effects of an oil market shock in situations when the stock market is at its best and its worst states. In a bearish market, the impacts of oil price shocks on stock market returns are similar to the situation where the oil and stock markets are driven by a bust oil market state, in which the shock effects of oil supply and demand on stock market returns have negative statistical significance. In a bullish market, the aggregate demand shock has a statistically significant positive effect. The speculative behavior of investors in the stock market provides a possible explanation for this phenomenon. Although the global economy is in a bust phase, the investors remain bullish on Chinese economic prospects. The increase in the oil price derived from aggregate demand shocks is seen by investors as a sign of the Chinese economy's recovery. As a result, they will buy shares in the Chinese stock market and push up the price of stock. These shock effects are key ingredients of the development and final burst of speculative bubbles.

Panel A in Figure 4 illustrates the responses of the bearish stock market to oil price shocks for an oil market in a boom period. There is no statistically significant effect of the response of Chinese stock market returns to oil supply shock, aggregate demand shock and oil-specific demand shock. However, as shown in Panel B in Figure 4, the increase in the oil price derived from the aggregate has positive and statistically significant shock effects on the Chinese stock market, which is similar to the condition in which the oil and stock markets are driven by a boom business state.

Furthermore, because our study period includes the recent 2007–2010 financial crisis and the financial crisis can have a significant impact on world oil and financial markets [51,52], it is opportune to examine the potential impact of the financial crisis on market interdependencies between real oil prices and stock prices. To do so, we divide our study period into two sub periods, referred to as a pre-crisis period (October 2001 to August 2008) and a post-crisis period (September 2008 to December 2015). September 2008 is chosen as the breakpoint because oil prices plunged 12% on 23 September 2008 and the financial crisis erupted on 15 September 2008 [53]. We use the quantile impulse response method to separately estimate the models for the two sub periods and find a significant increase in the effects of oil-specific demand shocks on stock prices over the post-crisis period when compared to the pre-crisis period. The result supports the previous studies' findings [30,54]. However, the pattern of oil price shocks on stock markets over the post-crisis period does not differ from the pre-crisis period and the whole sample period.
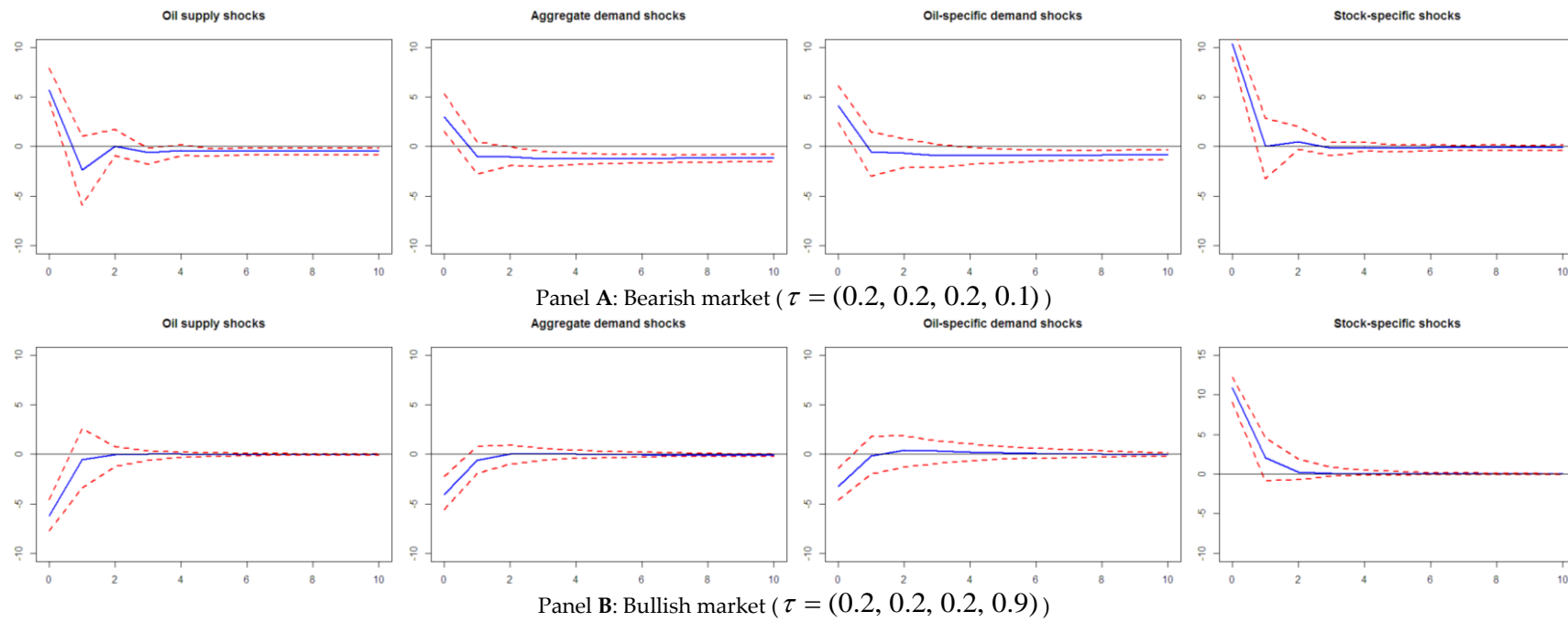
Figure 3. Impulse response of Chinese stock returns to structural shocks at bust oil market state for the full sample period.
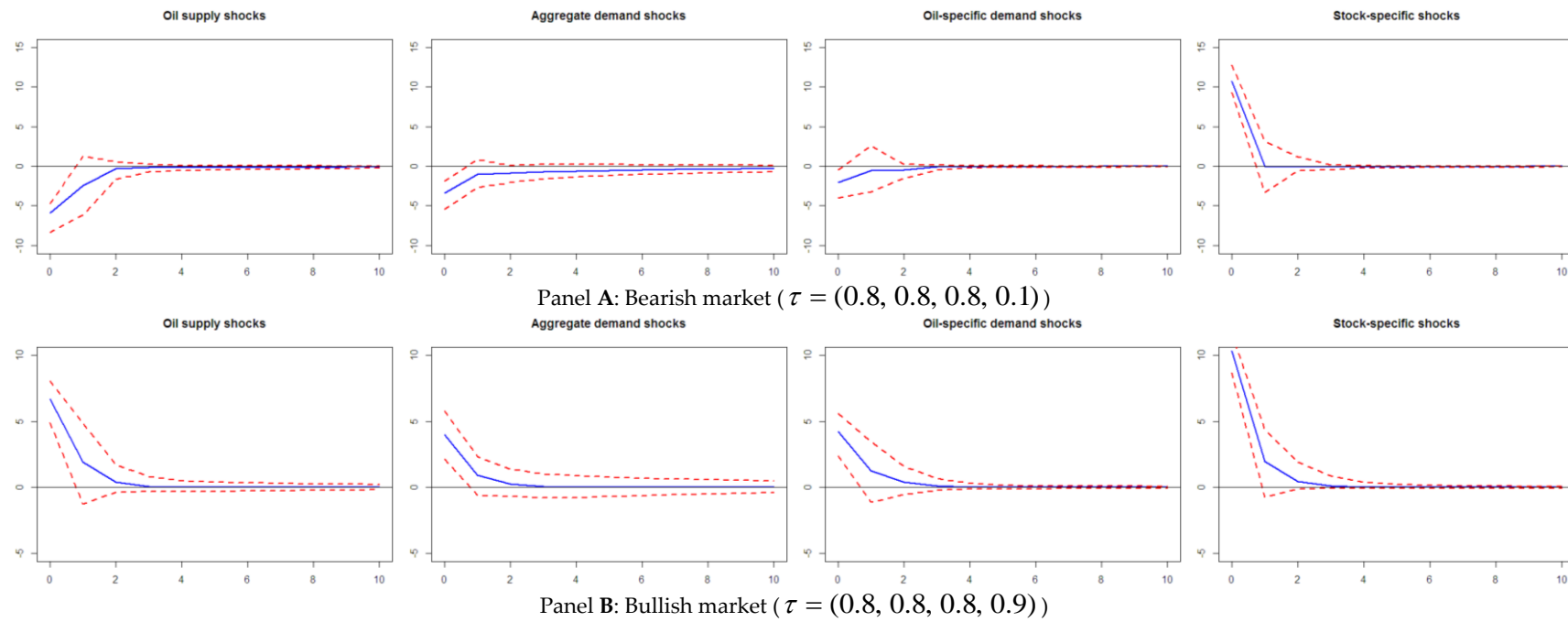
Figure 4. Impulse response of Chinese stock returns to structural shocks at boom oil market state for the full sample period.

5.2. Asymmetric Effects of Oil Price Uncertainty Shocks on Stock Market Returns

In this section, we explore the asymmetric effects of oil price uncertainty shocks on Chinese stock market returns. Because oil price fluctuations can lead to cyclical fluctuations in investments [55,56] it is essential to investigate the effects of oil price uncertainty shocks on stock market.

Following Wang et al. [40], we first decompose oil price shock into three different supply and demand shocks and then square these shocks to measure the three corresponding oil price uncertainty: oil supply uncertainty (opu), aggregate demand uncertainty (adu) and precautionary demand uncertainty (pdu). After quantifying the oil price uncertainties, the quantile structural VAR model is used to examine the impacts of the three uncertainties on the bearish and bullish stock market returns, where we replace the variable vector y_t by $y_t = (opu_t, adu_t, pdu_t, \Delta rps_t)$ in Equation (3). In the quantile structural VAR model, the quantile vector $\tau = (0.5, 0.5, 0.5, \tau_4)$, which means that we measure the three oil price uncertainties at the medians of their conditional distributions and evaluate the effects on stock market returns at various quantiles of its conditional distribution. In this way, we estimate if the effects of oil uncertainty shocks differ between relatively low or high stock market returns. Although the estimation can be performed at any quantile of stock market returns, in principle, we present the results for just three quantiles of stock returns, i.e., $\tau_4 = \{0.1, 0.5, 0.9\}$.

Figure 4 illustrates the effect of oil price volatility on Chinese stock market. Panel A shows the general stock market situation in which we can see that the three oil price uncertainties do not have statistically significant shock effects on Chinese stock market returns. They, however, still perform negative shock effects on Chinese stock market returns. A plausible explanation is that the business uncertainty depresses world economic development resulting in a bust oil market. As an oil-importing country, a decrease in the oil price would reduce production costs which in turn offset the negative impact which is included because of oil price uncertainty. On the other hand, the special adjustment mechanism in Chinese oil prices would weaken the negative effects of oil price uncertainty shocks on the stock market. Panels B and C in Figure 5 reveal the impact of oil price uncertainty on bearish and bullish stock markets, respectively. It is obvious that there are opposite shock effects in bearish and bullish stock markets. In a bearish market, the three oil price uncertainties have positive shock effects on stock market returns, which imply that oil price uncertainty will raise the price of the stock. On the contrary, in a bullish market, the impacts of oil price uncertainties are significantly negative in the month when the shock started, although it loses its significance as time elapses. We argue in light of the evidence, that this finding is sensible. In the stock market, stock prices are the present discounted value of the future net earnings of a firm, so both the current and the expected future impacts of an oil price uncertainty shock should be absorbed quickly into stock market prices and returns. In a bearish market, firms and consumers interpret the unexpected rises in oil price uncertainty as an improvement of the economic outcome. The oil price uncertainty may trigger higher volatility in the stock market, which provokes speculators to buy the shares and as a result, boost the price of stock. However, in a bullish market, oil price uncertainty will cause panic psychology among investors who worry about their assets being reduced. Consequently, they will sell their shares and consolidate the profits obtained from the bullish market. Therefore, we observe the opposite shock effects of oil price uncertainty during bearish and bullish stock markets.
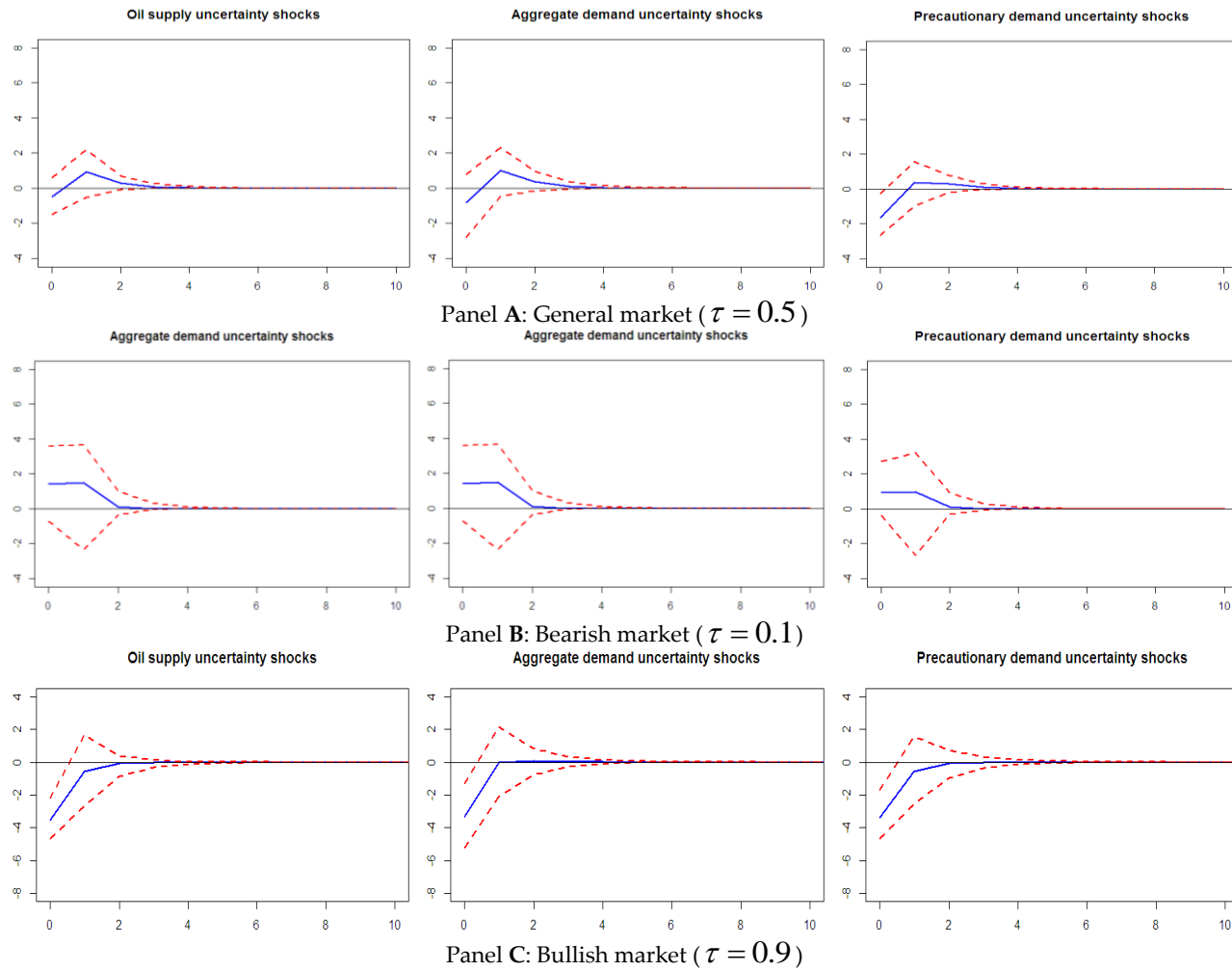
Panel **A**: General market ($\tau = 0.5$)

Panel **B**: Bearish market ($\tau = 0.1$)

Panel **C**: Bullish market ($\tau = 0.9$)

Figure 5. Impulse response of Chinese stock returns to oil price uncertainty shocks at different stock market states.

6. Conclusions

This paper sheds light on the asymmetric effects of global oil price shocks on the Chinese stock market. We argue that the conditional quantiles of oil price distribution may be related to the different oil market states. Building on this, we use a quantile impulse response approach to uncover the asymmetric effects of oil price shocks in various oil and stock market states.

The empirical results show that the impacts of oil price shocks on Chinese stock market returns depends on whether the oil and stock market state is in bust or boom, as well as whether the shock is caused by supply or demand. During a bust phase, the oil supply and demand shock effects have a negative, statistically significant effect on Chinese stock market returns, which is in line with theoretical considerations. This can be explained by the fact that China is a net oil-importing country, so the increase in the oil price will raise the production costs of companies and then depress the stock market returns. However during a boom period, only the aggregate demand has positive statistically significant shock effects on Chinese stock market returns. This is easy to explain. On one hand, the growth in global economic activity simultaneously stimulates the increase in crude oil and stock prices. On the other hand, the special adjustment mechanism in Chinese oil prices may greatly weaken the negative effects. Moreover, when the oil market is in a bust period, while the stock market is a bullish market, the aggregate demand shock shows positive significant effects on Chinese stock market returns. This may be argued to constitute empirical evidence for the phenomenon of speculative bubbles, as unexpected changes to oil prices leads to positive growth in the stock market.

In addition, we find that the impact of oil price uncertainty on the Chinese stock market could vary across the stock return distribution. In a bearish market, the impact of oil price uncertainty is positive, while in a bullish market, the impact of oil price uncertainty is negative. This indicates that in different stock markets, investors have different responses to the uncertainty of shocks.

Our results suggest several important implications. First, they show that the impact of oil price shocks on the Chinese stock market is heterogeneous, providing us with a scientific basis in which to make clear the dynamics of stock prices and helps to have a better understanding of some counterintuitive stock market behavior appearing in China. Second, our results uncover some stock market risks related to oil price shocks and this can offer valuable advice to investors and decision makers. Investors should hold oil stocks to diversify their investment portfolio and pay close attention to the asymmetric effects of oil price shocks on the stock market in order to consider long and short positions in a bearish and bullish stock market. The decision makers, during different oil and stock market states, should adopt diverse strategies to hedge the risk of oil price shocks, thereby lessening upheaval in the financial markets caused by a significant oil price shocks.

Author Contributions: Huiming Zhu designed the study and was involved in drafting the initial manuscript. Xianfang Su designed the main stages of the research, acquired and analysed the data, and drafted the initial manuscript. Yawei Guo and Yinghua Ren revised the manuscript critically for important content. All authors read and approved the final manuscript.

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