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**Oil Price Shocks and Policy Uncertainty: New Evidence on the Effects
of US and non-US Oil Production***

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Abstract

Important interaction has been established for US economic policy uncertainty with a number of economic and financial variables including oil prices. This paper examines the dynamic effects of US and non-US oil production shocks on economic policy uncertainty using a structural VAR model. Such an examination is motivated by the substantial increases in US oil production in recent years with implications for US political and economic security. Positive innovations in US oil production are associated with decreases in US economic policy uncertainty. The economic forecast interquartile ranges about the US CPI and about federal/state/local government expenditures are particularly sensitive to innovations in US oil supply shocks. Shocks to US oil supply disruption causes rises in the CPI forecast uncertainty and accounts for 21% of the overall variation of the CPI forecaster disagreement. Dis-aggregation of oil production shocks into US and non-US oil production yield novel results. Oil supply shocks identified by US and non-US origins explain as much of the variation in economic policy uncertainty as structural shocks on the demand side of the oil market.

JEL codes: E44, G12, Q43

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Oil Production

1. Introduction

Baker et al. (2016) construct an index of economic policy uncertainty and show that it influences the business cycle and business investment. Research building on the contributions by Bloom (2009) and Baker et al. (2016) has established that economic policy uncertainty has significant implications for economic and financial activity.¹ Following the paper by Kilian (2009) connecting structural oil price shocks with the economy, Antonakakis et al. (2014) and Kang and Ratti (2013a, 2013b), among others, investigate the relationship between structural oil price shocks and economic policy uncertainty. They find that while oil price increases driven by real aggregate demand and oil-market specific demand shocks have long-term consequences for economic policy uncertainty, supply-side oil shocks do not greatly affect US economic policy uncertainty.² The latter result is in line with findings in the literature that supply-side oil shocks are relatively unimportant compared to demand-side oil price shocks for the macro economy by Hamilton (2009), Kilian (2009), Lippi and Nobili (2012), and Baumeister and Peersman (2013b).

In this study, we investigate the influence of US and non-US oil supply shocks on US economic policy uncertainty. Theoretically, a US oil supply shock directly influences US income,

¹ A considerable literature has developed examining the connection between indices of economic policy uncertainty and stock markets in various countries: Mensi et al. (2014) for BRICS; Arouri and Roubaud (2016) for the US and China; Li et al. (2016) for China and India; Dakhlaoui and Aloui (2016) for BRIC over time; Gao and Zhang (2016) for the UK; Wu et al. (2016) for a panel of nine countries; and Chang et al. (2015) for seven OECD countries. The implications of economic policy uncertainty for sectoral returns has also been examined: Lean and Nguyen (2014) for sustainable investment returns in Asia Pacific and North America; Antonakakis et al. (2016) for U.S. sustainable investments; Balcilar et al. (2016) for gold returns and volatility; Kang et al. (2017) global oil and gas companies. Bekiros et al. (2016) argue for a non-linear forecasting connection between economic policy uncertainty stock market return volatility. Liu and Zhang (2015) find that economic policy uncertainty has forecasting power in volatility prediction models for the stock market.

² Literature examining the relationship between economic policy uncertainty and oil price shocks includes the following. Aloui et al. (2016) adopt a copula method to study the effect of economic policy uncertainty on crude-oil returns. Bekiros et al. (2015) find that economic policy uncertainty provides information useful in predicting the change in oil prices. Arouri et al. (2014) find that increased economic policy uncertainty in major net oil importers has a negative effect on Gulf Cooperation Council stock markets.

whereas a non-US oil supply shock does not. This has implications for differential effects of US and non-US production shocks on economic policy uncertainty since the influence of oil shocks is thought to work through the demand for goods in the economy. Bernanke (2006) notes that energy prices affect aggregate activity primarily through effects on consumer spending and disposable income, an account supported by findings by Lee and Ni (2002) that oil price shocks influence activity at industry level through sector demand.³ Disaggregated oil supply variables may have different effects on US inflation and inflation expectations and forecasts about federal/state/local government expenditures, key components in economic policy uncertainty. Montoro (2012) and Natal (2012) argue that oil price shocks affect inflation and affect the monetary policy trade-off between inflation and output stabilization. Bernanke et al. (2004) argue that monetary policy influences the transmission of oil price shocks to the economy.

Our examination of the effects of the dis-aggregation of oil production shocks into US and non-US oil production shocks yield novel results. First, the recent literature attributes only moderate effect of supply shocks to economic policy uncertainty, while our results show relative large effect.⁴ Secondly, our results contribute to the literature of energy independency, supporting the view of Broadman and Hogan (1988), Anderson (1991) and Hall (1992), that an increase in energy independency has the potential to enhance not only economic growth but also has positive implications for economic policy and national security.

The investigation of the impacts of U.S. and non-U.S. oil supply shocks on U.S. economic policy uncertainty is particularly interesting given the unprecedented expansion in U.S.

³ Oil shocks are connected with government activity and policy in a number of additional ways. Barro's (1979) tax-smoothing and Becker and Mulligan's (1997) inefficient-tax models predict an adjustment of taxes and government expenditure in response to wealth shocks. For oil exporting countries, El Anshasy and Bradley (2012) find that higher oil prices raises the size of government and for the US, Gelb (1988) finds that oil price shocks cause a rise in federal government purchases. Pieschacón (2012) shows that fiscal policy can affect the influence of oil price shocks on economic activity.

⁴ Please see Antonakakis et al. (2014) and Kang and Ratti (2013a; 2013b).

oil production since 2009. As observed in Figure 1, US oil production trended downward from the mid-1980s to 2009 and then experienced a rapid expansion due to innovations and new technologies in the extraction of crude oil. These developments in US oil production have wide ranging implications that may differ from those associated with non-US oil production. Dahl and Duggan (1996) conduct a survey and find that US oil supply elasticity appears to be elastic. Kaufman et al. (2009) find that shocks to oil prices ripple down the US oil supply chain and inventory behaviors. Hayat and Narayan (2011) report that shocks to US oil supply disruptions account for about 35 percent of the variation of the growth of crude oil and petroleum products ending stocks. Medlock III (2012) notes that the US has more oil exporting potential driven, in part, by the recent shale gas and tight oil boom. In a recent paper Kang et al. (2016) shows that the disaggregation of world oil supply into US and non-US oil supply is an important factor in determining US real stock returns. The authors find that a positive US oil supply shock has a positive impact on US real stock returns, in contrast to the established finding that shocks to global oil production are relatively unimportant in influencing real stock returns.

Non-US oil production shows a different pattern of behavior from that of the US oil production over 1985-2015. The major fluctuations of non-US oil production are associated with the 1990-1991 Gulf War, 2003 Iraq War, 2008-2009 Global Financial Crisis, 2011 Arab Spring, and the 2014-2015 oil price down. Figure 1 shows that in these periods, the major historical event outbreaks are followed by an increase in the economic policy uncertainty index. Shapiro and Watson (1988) also note that major oil price changes in 1970s and 1980s were driven by exogenous political events in the Middle East. Utilizing the geopolitical events as a proxy of exogenous oil supply disruption, Hamilton (2003) confirms the relation between oil price fluctuations and GDP growth.

This study estimates a structural VAR model that recognizes the separate effects of US and non-US oil production shocks and of demand side influences on US economic policy uncertainty. Structural oil price shocks are found to explain 41% of the variation in economic policy uncertainty. Separation of oil production shocks into US and non-US oil production shocks is found to result in the conclusion that supply-side oil shocks are as important for economic policy uncertainty as are oil demand-side shocks, a modification of the view in the literature. At the 60 month forecast horizon over 1985 to 2015, US oil supply shocks and non-US oil supply shocks explain 20.7% of the variation in economic policy uncertainty and oil-market specific demand shocks and aggregate demand shocks explain 20.3% of the variation of economic policy uncertainty.

The response of economic policy uncertainty is positive and statistically significant to shocks to US oil supply disruption. Shocks to US oil supply disruption causes significant rises in the forecast interquartile ranges of the US CPI and accounts for 21% of the overall variation of the CPI forecaster disagreement. Innovations to US oil supply disruption are associated with 16% of the variation of the economic forecast interquartile ranges about federal/state/local government expenditures. It is also found that significantly increased US oil production for several months is associated with a positive shock to economic policy uncertainty.

The paper is organized as follows. Section 2 describes data sources and presents the structural VAR model. Section 3 discusses empirical results about the dynamics of oil price shocks and economic policy uncertainty. Section 4 concludes.

2. Data and Methodology

2.1. Data

We utilize monthly economic policy uncertainty and oil market data from January 1985 to December 2015. The oil supply proxy variables are given by the percent changes in non-US oil production ($\Delta prod_t^{nonUS}$) and in US oil production ($\Delta prod_t^{US}$) from the US Department of Energy. The global real economic activity proxy is the index of real economic activity (rea_t) constructed by Kilian (2009).⁵ The real price of oil (rpo_t) is US refiner acquisition cost of imported crude oil drawn from the US Department of Energy and deflated by the US CPI from the Bureau of Labor Statistics.

The policy-related economic uncertainty index (pu_t) is developed by Baker et al. (2016).⁶ The index is a weighted average of four underlying uncertainty components: broad news-based policy uncertainty that quantifies the newspaper coverage of the policy-related economic uncertainty, tax legislation expiration uncertainty that reflects the number of federal tax code provisions set to expire in the future years, and the economic forecast interquartile ranges about US CPI and about federal/state/local government expenditures. Newspaper coverage reflects search results for articles containing terms related to economic policy uncertainty. The number of federal tax code provisions set to terminate measures the level of uncertainty regarding the course the federal tax code will take in the future. Forecaster disagreement over federal and state/local government purchases measures uncertainty about future fiscal policy. Forecast disagreement over future inflation is a representation of uncertainty about future monetary policy. Baker et al.'s (2016) economic uncertainty index gauges economic policy uncertainty about public views and economic policy making.

We conduct Augmented Dicky-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests for the stationarity of the oil and policy uncertainty

⁵ The data are available at Kilian's webpage: <http://www-personal.umich.edu/~lkilian/paperlinks.html>.

⁶ The data can be found at <http://www.policyuncertainty.com/>.

variables.⁷ The test results in Panel A of Table 1 show that oil supply and demand variables contain a unit root at the 10% significant level, whereas the ADF and PP tests for the policy uncertainty reject the hypothesis containing a unit root at the 1% significant level. In this paper we utilize the global real economic activity index and the real price of crude oil in levels rather than the first-differences to preserve the low-frequency covariation in the oil market data. Given the impulse response functions are reasonably precisely estimated in the VAR model, the potential cost of level specification would only be reflected in wider error bands (see Sims et al. (1990) and Kilian and Murphy (2014)).

In Panels B, C, D and E of Table 1, we follow Hansen (1997, 2000) to present test results for the constancy of parameters in the oil-policy uncertainty dynamic VAR models. The asymptotic p-values of the Supremum (Sup), Exponential average (Exp) and Average (Ave) Lagrangian Multiplier tests fail to reject the parameter stability of the relation between an oil supply/demand variable and the economic policy uncertainty. The set of tests is for structural change of unknown timing in the regression models. To further assess the extent and nature of parameter instability issues of the forecasting, a rolling sample analysis is followed in Section 3.5.

2.2. Methodology

This study considers a structural VAR model of order p to extract the separate supply and demand-side sources underlying oil price changes and their relation to the policy-related economic uncertainty in the following:

⁷ In the literature, the traditional tests for the stationarity include the work by Dickey and Fuller (1979), Elliot et al. (1996), Kwiatkowski et al. (1992), Ng and Perron (2001), Phillips and Perron (1988). The Phillips-Perron test has the same power properties as the ADF test. Because both tests lack power it is possible that the failure to reject the null in one case is simply a type II error. Employing two tests with the same power and size properties will not enhance the properties of either and it could be argued that the ADF Generalised Least Squares test might be more powerful. However, failure to reject the null in this one variable is not decisive for the model. Other tests such as ERS, KPSS and NP are then suggested in the investigation.

$$A_0 y_t = c_0 + \sum_{i=1}^p A_i y_{t-i} + \varepsilon_t, \quad (1)$$

where $y_t = (\Delta prod_t^{nonUS}, \Delta prod_t^{US}, rea_t, rpo_t, pu_t)$ is a 5×1 vector of endogenous variables, A_0 denotes the 5×5 contemporaneous coefficient matrix, c_0 represents a 5×1 vector of constant terms, A_i refers to the 5×5 autoregressive coefficient matrices, and ε_t stands for a 5×1 vector of serially and mutually uncorrelated structural disturbances.

We follow the setup in Kilian (2009) to assume that A_0^{-1} has a recursive structure such that the reduced-form VAR error term e_t can be decomposed by $e_t = A_0^{-1} \varepsilon_t$. The identifying restrictions on A_0^{-1} postulate a lower-triangle coefficient matrix in the structural VAR model. Kilian (2009) argues that oil production does not respond to contemporaneous changes in oil demand within a given month because of the high adjustment cost of changing oil production. Fluctuation in the real price of oil will not affect global economic activity within a given month due to the sluggishness of aggregate economic reaction. The US economic policy uncertainty ordered after oil price shocks is motivated by Lee and Ni (2002), Kilian and Park (2009), and Kilian and Vega (2011), who argue that oil prices are predetermined with respect to U.S. macroeconomic aggregates within a given month. While US economic policy uncertainty is allowed however to respond to oil supply and demand shocks on impact, shocks to the policy uncertainty are assumed to affect the global oil market only with a delay of at least one month. Kang et al. (2016) argue that non-US oil production does not respond to US oil supply shock within a given month. The US has been an oil importing country whose oil production averages about 11.3% of the global oil production over January 1985 to December 2015. We assume that

shocks to the US oil supply affect the non-US oil production only with a delay of at least one month.

3. Empirical Result

3.1. Responses to One-Standard Deviation Structural Shocks

In this subsection we present the responses of all endogenous variables in Equation (1) to one-standard deviation structural innovations. We utilize the estimates of the reduced-form VAR model that is consistently estimated by the least-squares method to construct the structural VAR representation of the model. Figure 2 shows the point estimates of the impulse response functions in the forecasting horizon 24 months to a structural shock together with one- and two-standard error bands constructed using a recursive-design wild bootstrap with 2,000 replications.

The impulse responses of US economic policy uncertainty to one-standard deviation structural shock are presented in the last row in Figure 2. An unexpected non-US oil supply disruption on economic policy uncertainty are mostly negative and statistically insignificant, although there is a statistically significantly negative effect on the economic policy uncertainty at the 11th month. In contrast, the responses of the policy uncertainty to an unexpected US oil supply disruption are positive in general and statistically significant in five of the first six months. The implication is that a positive innovation in US oil supply significantly reduces economic policy uncertainty, whereas a positive innovation in non-US oil supply qualitative does not. An unanticipated real aggregate demand shock causes a statistically significantly negative effect on the policy uncertainty in the window between the 3rd and the 7th month. The responses of the policy uncertainty to an oil-market specific demand shock, however, are marginally statistically significantly positive in the 5th month and in the window between the 9th and the 17th month.

The first column of Figure 2 illustrates the responses of an endogenous variable to non-US oil supply shocks. An unexpected non-US oil supply shock causes a sharp decline in the non-US oil production upon impact. The declined effect exhibits a partial reversal within the first year and shows persistence afterwards. This shock causes a cumulative rise in the US oil production from the 1st to the 24th month. The results are consistent with the view by Kilian (2009) that oil supply contractions in non-US region tend to trigger production in US. In contrast, the first diagram of the second column of Figure 2 shows that unexpected US oil supply shocks have a statistically nonsignificant effect on the non-US oil production. It provides supporting evidence on the identifying restrictions based on Kang et al. (2016) who argue that non-US oil production does not respond to US oil supply shock within a given month. The intuition is that the non-US oil production on average is about eight times of the US oil production over January 1985 to December 2015. It requires a large decline in the US oil supply for the non-US oil production reaction.

The third column of Figure 2 shows that an unanticipated real aggregate economic expansion causes positive effects on the non-US oil production, whereas this shock has statistically significantly negative effects on the US oil production at the 11th month. The fourth column of Figure 2 shows that an unexpected oil-market specific demand shock causes statistically significant negative effects on the non-US oil production after the 18th month. In contrast, this shock causes statistically significantly positive effects on the US oil production after the 15th month. The US economic policy shock does not show significant effect on the non-US oil production, whereas this shock causes a statistically significantly positive effect on the US oil production upon impact, then exhibiting a reversal of that rise within the first three months. In the fifth column, US oil production responds positively to a positive shock to

economic policy uncertainty and the effect is statistically significant for the first four months. Non-US oil production does not respond significantly to shocks to US economic policy uncertainty.

In summary, the response of US economic policy uncertainty is different to dissimilar oil supply and demand shocks. The response of economic policy uncertainty is negative to the shocks of non-US oil supply disruption and aggregate demand expansion, and is statistically significantly and positive to the shocks of US oil supply disruption and oil-market specific demand. The response of US oil production is different from that of non-US oil production to the structural oil price shocks. The responses of US oil production are statistically significantly positive to non-US oil supply disruption, negative to real aggregate demand shock, positive to oil-market specific demand innovation, and positive to the economic policy uncertainty shock. The responses of non-US oil production, however, are statistically significantly positive to real aggregate demand shock and negative to oil-market specific demand innovation. These results confirm that in analyzing the influence of oil prices on the policy uncertainty it is essential to identify the underlying source of the oil price shocks.

3.2. Historical Decomposition of Economic Policy Uncertainty to the Structural Shock

The historical decomposition of the effect of the structural oil price shocks reported in Figure 3 provides us with the information on how the structural shocks have contributed to the economic policy uncertainty over time. The first panel shows that the historical effect of non-US oil supply shocks on the US economic policy uncertainty is comparatively small. US oil supply shocks in the second panel, however, cause a long swing in the economic policy uncertainty over 1990 - 2010. The cumulative contributions of real aggregate demand and oil-market specific demand shocks to the policy uncertainty are relatively large. While shocks to global aggregate

demand cause a long swing in the policy uncertainty over 1990 - 2015, innovations in the oil-market specific demand are responsible for fairly sharply defined increases and decreases in the US economic policy uncertainty in the 1990 - 1991 Gulf War, before the 2003 Iraq War, and during the 2008-2009 Global Financial Crisis in particular. The historical decomposition of fluctuations in the US economic policy uncertainty indicates that the policy uncertainty shocks historically have been driven mainly by a combination of US oil supply shocks and oil demand side shocks, instead of the non-US oil supply shocks.

3.3. Variance Decomposition of the US Economic Policy Uncertainty

The variance decomposition in Panel A of Table 2 quantifies how important the structural shocks have been on average for the US economic policy uncertainty. In the first few months the effects of the structural shocks in the crude oil market on the policy uncertainty are negligible. Over time the explanatory power of the structural oil price shocks increases. After 60 months 41% of the variation in the US economic policy uncertainty is accounted for by the innovations of the supply and demand oil shocks. The contributions of US oil supply shocks and oil-market specific demand shocks explain 12.9% and 12.3% of the overall variation of the policy uncertainty, respectively. When oil supply shocks are differentiated by US and non-US origins, shocks on the supply side of the oil market explain as much of the variation in economic policy uncertainty as do structural shocks on the demand side of the oil market.

Panel B of Table 2 presents a summary of the variance decomposition of all the structural shocks at the forecast horizon 60 months. The table shows that the spillover between the crude oil market and the US economic policy uncertainty is comparatively large. The spillover index is 0.389 and is highly statistically significant with a t-value 10.72.

3.4. The Transmission Channel of Oil Price Shocks to the US Policy Uncertainty

The index of economic policy uncertainty is a weighted average of four underlying components: 1/2 weight for broad news-based policy uncertainty, and 1/6 weight each for government purchase forecast interquartile range, CPI forecaster disagreement, and the tax code expiration uncertainty respectively. We utilize the four uncertainty components to investigate the transmission channel of how oil supply and demand side shocks affect US policy-related economic uncertainty. The analysis is conducted by estimating four analogous structural VAR models with each component ordered last instead of the overall economic policy uncertainty in Equation (1).

Figure 4 reports the point estimates of the impulse response functions of the components of economic policy uncertainty over 24 months forecasting horizon of structural shock with one- and two-standard error bands (constructed using a recursive-design wild bootstrap with 2,000 replications). We will focus on the impacts of negative innovations in US oil production reported in the second column of Figure 4. An unexpected shock to US oil supply disruption causes a statistically significant positive impact on news-based policy uncertainty in the first 2 months. This effect then dissipates over time. An innovation to US oil supply disruption raises the forecast interquartile ranges about federal/state/local government expenditures with significant effects over the 10th through 14th months. An unexpected shock to US oil supply disruption causes rises in the forecast interquartile ranges for the CPI (CPI forecaster disagreement), with statistically significant results out over 4 to 7 months and out over 13 to 16 months. Effects of innovation to US oil supply interruption on the number of federal tax code provisions set to expire are negative and are not statistically significant.

The contributions of structural shocks to variation in the components of economic policy uncertainty are reported in Table 3. The last column in Table 3 implies that the structural oil

price shocks collectively explain 35%, 53%, 49% and 42% of the variation in news-based, expenditure dispersion, CPI disagreement and tax expiration uncertainties after 60 months, respectively. These numbers contrast with the 41% of the variation in economic policy uncertainty overall explained by structural oil price shocks (from Table 2).

In Table 3, shocks to US oil supply account for 21% and of the variation of the CPI forecaster disagreement at the 60-month horizon. In contrast, shocks to non-US oil supply contribute only 1.6% to the explanation for variation in the CPI forecaster disagreement. Innovations to US oil supply are associated with 16% and of the variation of expenditure dispersion uncertainty at the 60-month horizon. Shocks to US oil supply explain 6.2% and 6.4% of variations in news-based and tax expiration uncertainties. Shocks to US oil production affect economic policy uncertainty mainly through impacts on the economic forecast interquartile ranges about US CPI and about federal/state/local government expenditures.

3.5. Rolling Sample Analysis

In this subsection, we examine the time-varying effects of the structural oil supply and demand shocks on the US policy-related economy uncertainty. Hamilton (2013) argues that the global oil market has a major change since the early 1970s. Baumeister and Peersman (2013a, 2013b) show that the volatility of global oil production has trended downwards over the last thirty-five years. As observed in Figure 1, the study is particularly motivated by the period after 2009 in that period US oil production experiences an unprecedented expansion due to innovations and new technologies in the extraction of crude oil. We estimate the structural VAR model using 193-month rolling samples in order to assess the extent and nature of spillover variation starting in January 2001. The rolling sample analysis uses the first sample over

1985:01-200:12, the second sample over 1985:02-2001:01, etc., with each subsequent sample adding one new month and dropping the first month of the data in the preceding sample.

We present the spillover index introduced by Diebold and Yilmaz (2009; 2014) in Figure 5, showing a summary of the contributions of shocks to a variable to the forecast error variances of that variable and other endogenous variables in the VAR model. The result in Figure 5 is in line with the finding by Antonakakis et al. (2014) that the spillovers increase considerably during the Global Financial Crisis of 2008 – 2009. Spillovers of oil prices and policy uncertainty in the period of 2006-2007 increase dramatically following the Hurricane Katrina in 2005 and there are substantial upticks in the spillover index at the time of the Arab Spring in 2011. Spillovers between oil market shocks and economic policy uncertainty fell during 2012 and 2013 and remained in a lower range over 2014 and 2015 level as the oil price turns down.

The dynamic contributions of the individual structural oil shocks to economic policy uncertainty are shown in Figure 6. In July 2008 the dynamic contribution of shocks to US oil production in the long run reaches the peak height of 36% of the overall variation in US policy-related economy uncertainty. This contribution of shocks to US oil production economic policy uncertainty displays a decreasing trend after 2010.

The dynamic contribution of non-US oil production shocks to the overall variation of economic policy uncertainty in Figure 6 rises in association with major global oil supply disruptions due to the 1990-1991 Gulf War, 2003 Iraq War, 2008-2009 Global Financial Crisis, and 2011 Arab Spring. Following a long rise of real activity over 2001-2004 and a significant drop of the real activity over 2005-2006, the dynamic contribution of shocks to aggregate demand reaches its highest point in 2005:10. During the 2008-2009 Global Financial Crisis and 2011 Arab Spring, the contribution of oil-market specific demand shocks is sharply increased in

the overall variation of economic policy uncertainty. These results confirm that Oil price shocks and economic policy uncertainty are interrelated. The direct effects of oil shocks on the real activity are amplified by endogenous policy uncertainty responses.

3.6. Asymmetric response of policy uncertainty to oil price shocks

This subsection investigates the effect of oil shocks on the degree of asymmetry in the response of economic policy uncertainty to the oil price increases and decreases. The asymmetric responses of real activity to changes in crude oil prices have been heavily studied in the literature (e.g., Radchenko (2005) for real gasoline prices, Huang et al. (2006) for changes in industrial production and real stock returns, and Kilian and Vigfusson (2011) for unemployment, gasoline consumption and real GDP).

We follow Kilian and Vigfusson (2011) and consider a simple bivariate VAR model for the test of the asymmetric responses:

$$\begin{aligned} o_t &= a_{10} + \sum_{i=1}^p a_{11,i} o_{t-i} + \sum_{i=1}^p a_{12,i} pu_{t-i} + \varepsilon_{1,t}, \\ pu_t &= a_{20} + \sum_{i=0}^p a_{21,i} o_{t-i} + \sum_{i=1}^p a_{22,i} pu_{t-i} + \sum_{i=0}^p g_{21,i} o_{t-i}^+ + \varepsilon_{2,t}. \end{aligned} \quad (2)$$

In the nonlinear VAR model (2), pu_t denotes the economic policy uncertainty, o_t represents the growth rate of non-US oil production, US oil production, real price of oil, or the real aggregate demand, and $o_t^+ = \max(o_t, 0)$ is defined as the increase of o_t . The dynamic responses to unanticipated positive and negative oil price changes are calculated based on the estimates of the regression coefficients.

Figure 7 shows asymmetric responses $I_{pu}(h, \sigma)$ and $-I_{pu}(h, -\sigma)$ of the economic policy uncertainty to one standard deviation oil price shocks. For example, for oil production changes, the response $I_{pu}(h, \sigma)$ is to an increase in oil production and $-I_{pu}(h, -\sigma)$ is the negative of the response to a decrease in oil production. The difference between the two responses is relatively

larger to non-US oil supply shocks than that to other shocks. The corresponding tests of the symmetry, reported in Panel 1 of Table 4 based on 20,000 simulation of model (2), also present a higher statistically significant level of the asymmetric responses to the non-US oil supply shocks. On reading Table 4, in Panel 4, the null hypothesis of symmetry of CPI dispersion response to positive and negative US oil supply changes cannot be rejected at 0, 1 and 3 months (p values of 0.175, 0.394, 0.452), but is rejected at 5% level at 6 month horizon and at 1% level for 12 and 24 month horizons.

Figure 8 illustrates the asymmetric responses of policy uncertainty components to one standard deviation oil supply shocks. The responses of policy uncertainty components are relatively stronger to the decrease in oil production than that to the increase in oil production in general. The difference between the negative and positive responses of expenditure dispersion is relatively larger in the fourth diagram of Figure 8 and highly statistically significant in the third column of Panel 3 in Table 4 to the US oil supply shocks. The difference between the negative and positive responses of taxation expiration uncertainty is relatively larger but statistically nonsignificant within a year to the non-US oil supply shocks. For the policy uncertainty components, the symmetric responses of News, Expenditure and Taxation (CPI) uncertainty are more likely to be rejected for shocks to positive and negative to US (non-US) oil supply shocks.

Finally, we change the order of the first variable non-US oil production and the second variable US oil production in the structural VAR model. The results (not reported here) show that the fraction of forecast error variance decomposition of policy uncertainty and the pattern of its responses upon four oil price shocks is very similar to that reported in Table 2 and Figure 2.

4. Conclusion

This study utilizes a structural VAR model to estimate the effects of US and non-US oil production shocks and of demand side influences on US economic policy uncertainty. After 60 months, structural oil price shocks explain 41% of the variation in economic policy uncertainty overall, and 53% and 49% of the variation in expenditure dispersion and CPI disagreement uncertainties, respectively. Oil supply shocks identified by US and non-US origins explain as much of the variation in economic policy uncertainty as structural shocks on the demand side of the oil market. At the 60 month forecast horizon over 1985 to 2015, US oil supply shocks (oil-market specific demand shocks) explain 12.9% (12.3%) of the variation of the economic policy uncertainty, and non-US oil supply shocks (aggregate demand shocks) explain 7.8% (8.0%) of the variation of economic policy uncertainty. The separation of oil production shocks into US and non-US oil production shocks modifies the view in much of the literature that supply-side oil shocks have little consequence for economic policy uncertainty.

We find that economic policy uncertainty responds differently to US oil production shocks and non-US oil production shocks. The response of economic policy uncertainty is positive and statistically significant to shocks to US oil supply disruption and negative and not statistically significant to shocks to non-US oil supply disruption. The economic forecast interquartile ranges about the US CPI and about federal/state/local government expenditures are particularly sensitive to innovations in US oil supply shocks. Shocks to US oil supply disruption causes significant rises in the CPI forecast uncertainty and accounts for 21% of the overall variation of the CPI forecaster disagreement. Innovations to US oil supply disruption are associated with 16% of the variation of expenditure dispersion uncertainty at the 60-month horizon.

The finding in this paper suggests that enhance domestic oil production in the US has consequences for political and economic security since positive shocks to US oil production are associated with lower US economic policy uncertainty. In addition, significantly increased US oil production for several months is associated with a shock to increased economic policy uncertainty. Shocks to US oil production affect economic policy uncertainty mainly through impacts on the economic forecast interquartile ranges about US CPI and about federal/state/local government expenditures. The results suggest that in analyzing the influence of structural oil market shocks on economic policy uncertainty it is important to differentiate between oil supply shocks originating inside and outside of the US.

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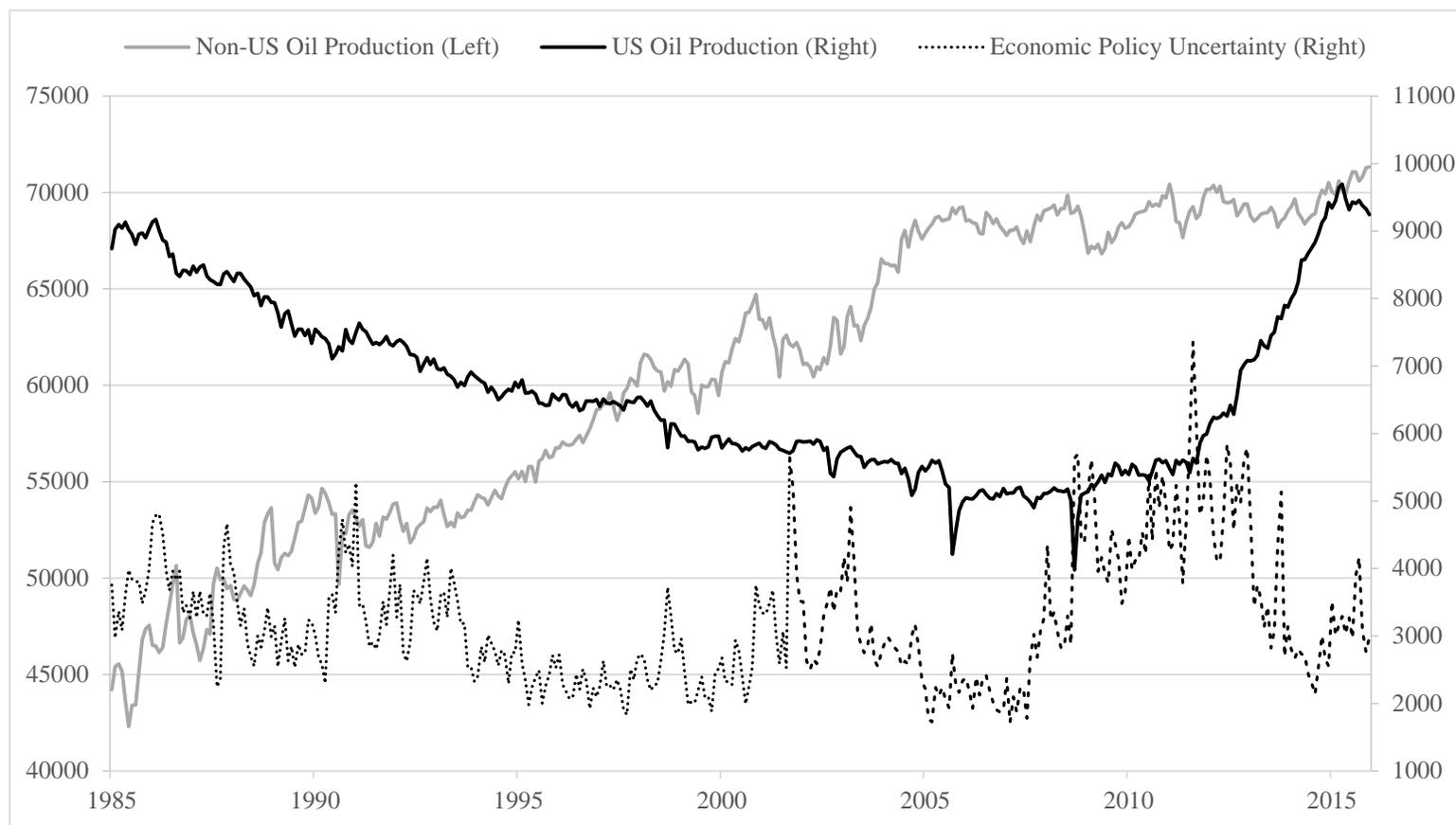
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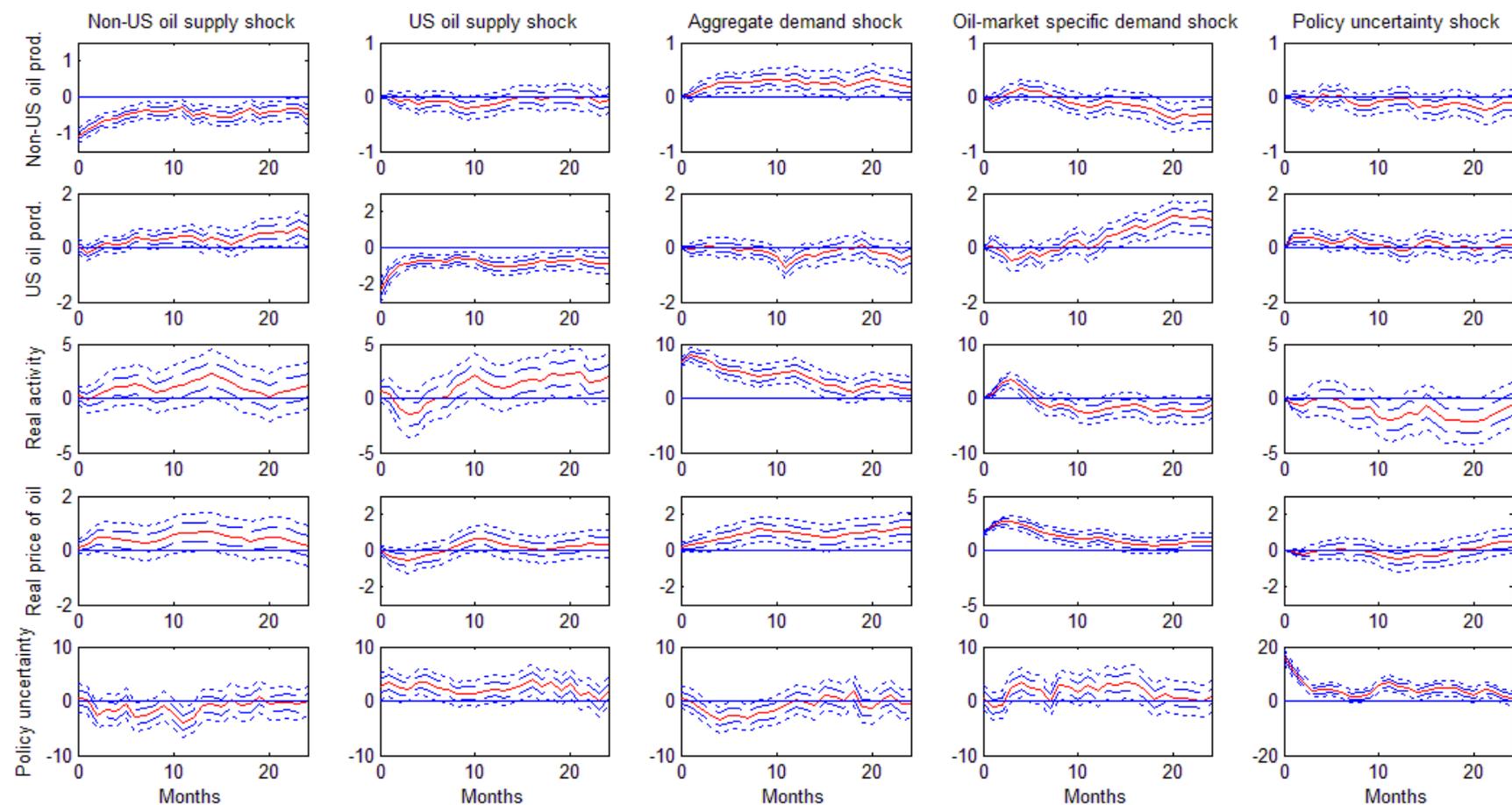
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Figure 1. US and Non-US oil production, economic policy uncertainty, 1985:01 – 2015:12



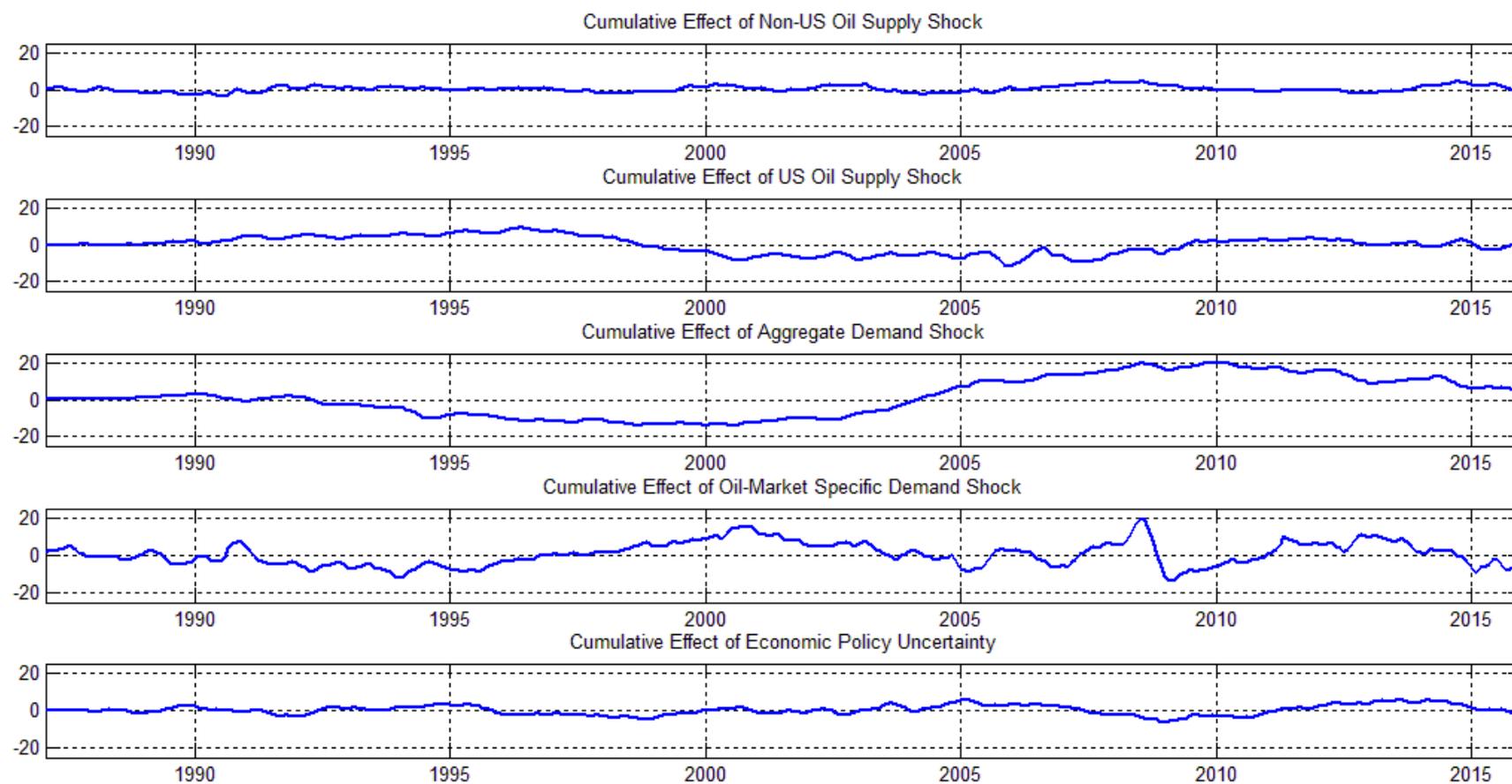
Notes: the figure shows monthly data of world Non-US oil production, US oil production, and economic policy uncertainty index between 1985:01-2015:12. The economic policy uncertainty index is multiplied by 30 for the exposition purpose.

Figure 2. Responses to one-standard deviation structural shock



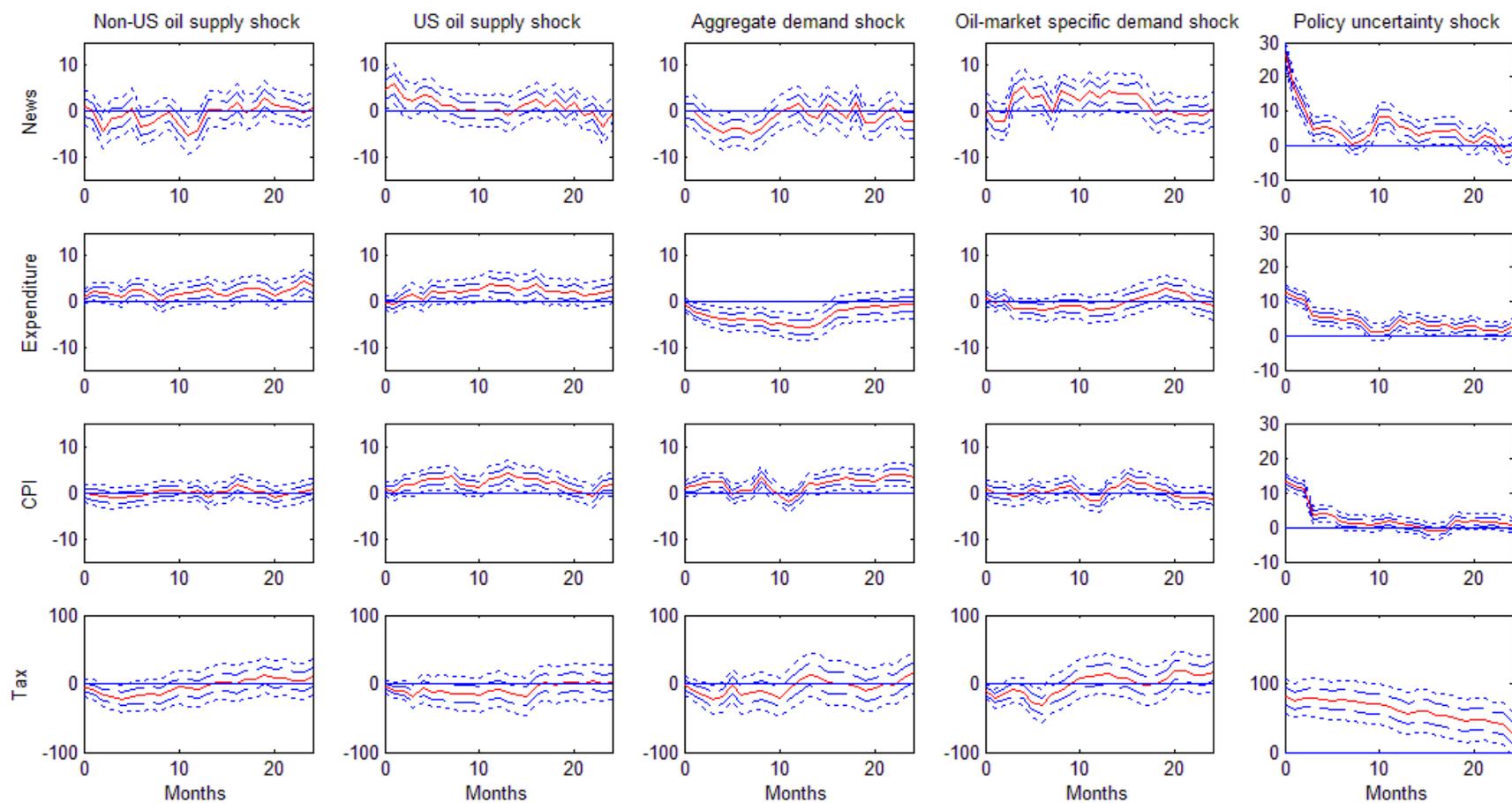
Notes: Point estimates, with one- and two-standard error bands, derived from the structural VAR model described in the text. The confidence intervals were constructed using a recursive-design wild bootstrap. The impulse responses of a variable indicated on the left hand side to shocks indicated along the top of the figure appear in each row. Thus, for example, the impulse responses of US economic policy uncertainty to one-standard deviation structural shock are presented in the last row in Figure 2.

Figure 3. Historical decomposition of economic policy uncertainty



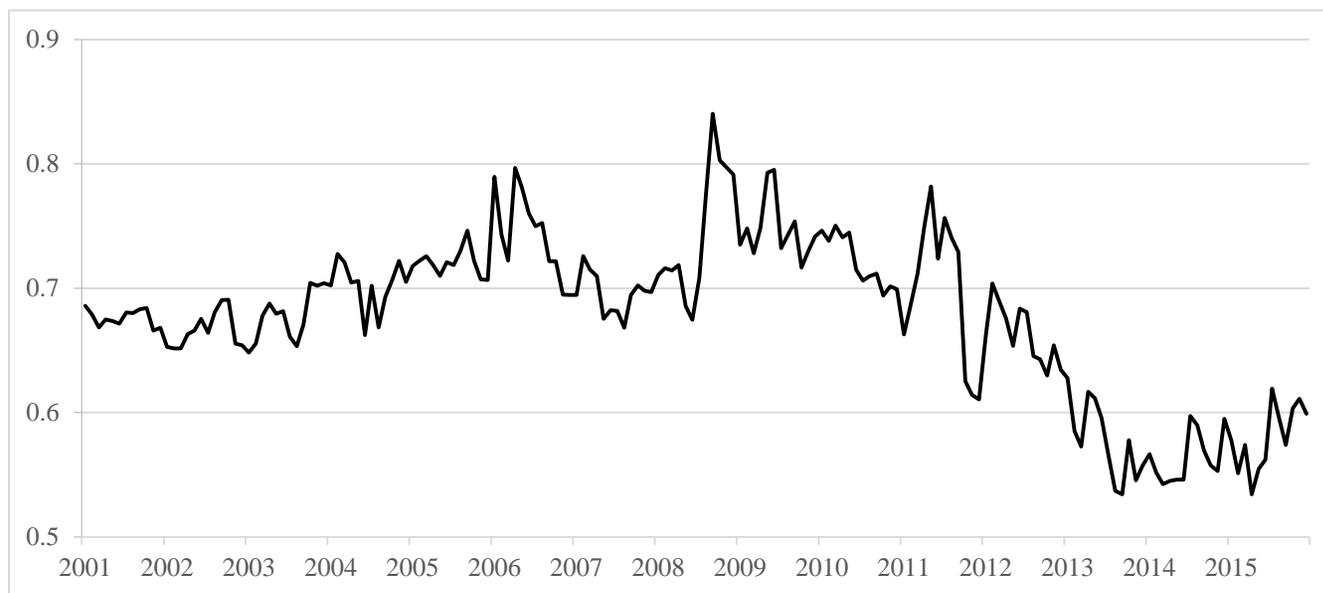
Notes: Estimates derived from the structural VAR model described in the text, averaged to annual frequency.

Figure 4. Responses of economic policy uncertainty components to one-standard deviation structural shock



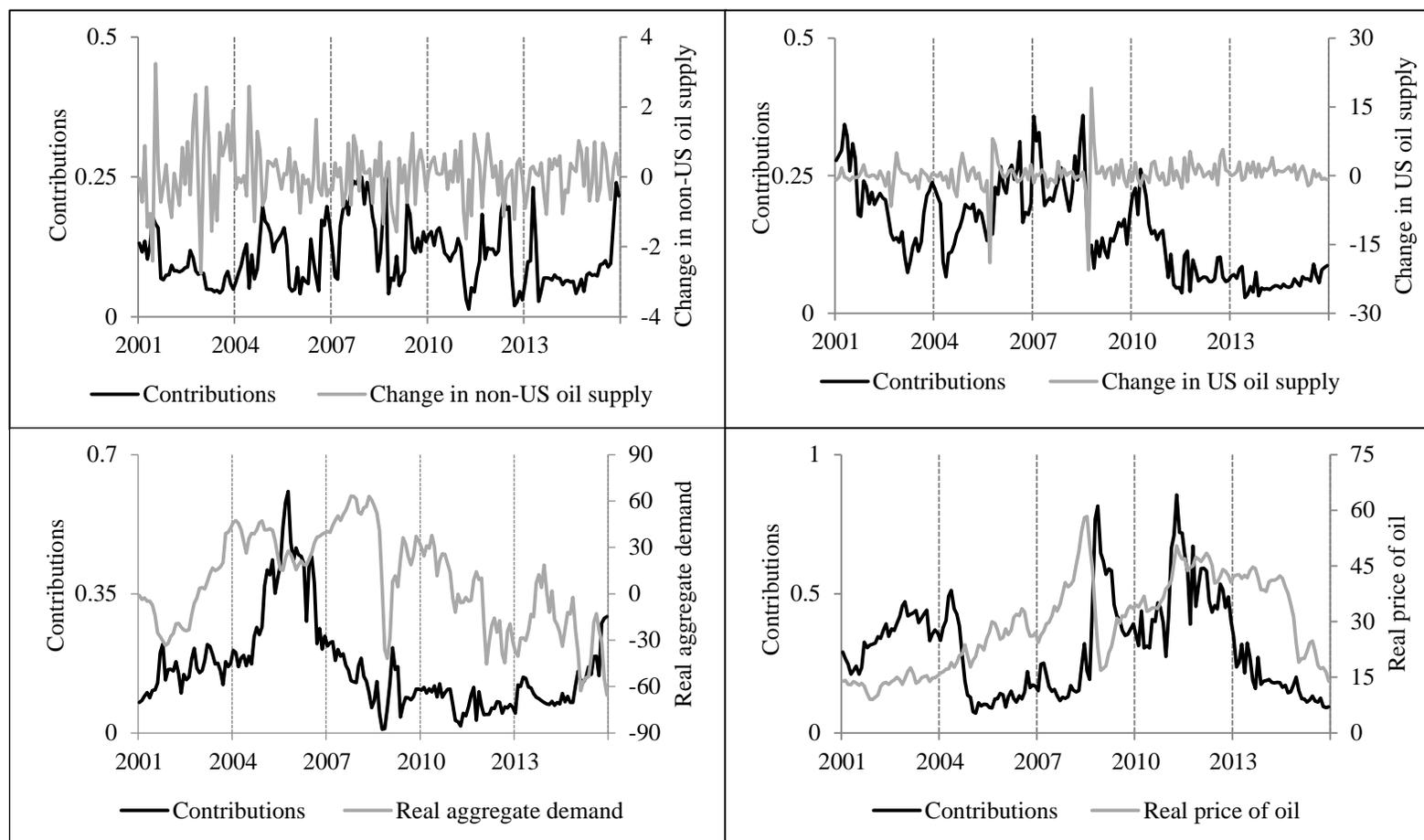
Notes: Point estimates, with one- and two-standard error bands, derived from the structural VAR model described in the text. The confidence intervals were constructed using a recursive-design wild bootstrap.

Figure 5. The spillover plot of structural oil prices and economic policy uncertainty, 2001:1–2015:12



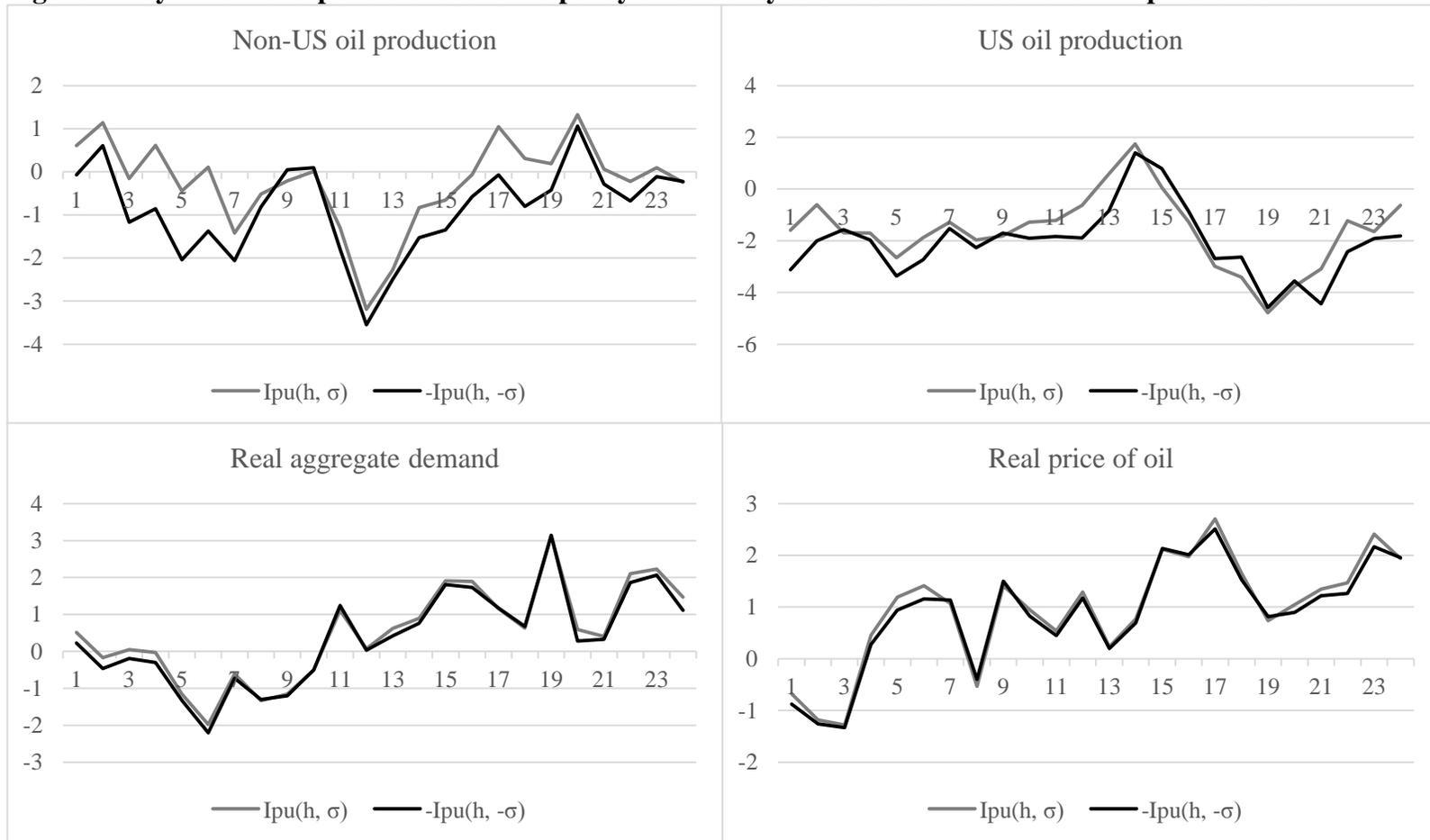
Notes: The spillover index is defined in the text as the sum of forecast error variance decomposition contributions from one variable structural shock to the other variables when the forecast horizon is 60 months, estimated using 193-month rolling windows.

Figure 6. Contributions to the variation of economic policy uncertainty from structural shocks, 2001:01-2015:12



Notes: Contributions to the variation of economic policy uncertainty from non-US oil supply, US oil supply, aggregate demand, and real price of oil, 2001:01-2015:12, described in the text and estimated using 193-month rolling windows.

Figure 7. Asymmetric responses of economic policy uncertainty to one-standard deviation oil price shocks



Notes: The figure shows the response of economic policy uncertainty to one standard deviation oil price shock.

Figure 8. Asymmetric responses of policy uncertainty components to one-standard deviation oil supply shocks
 Non-US oil supply shock US oil supply shock

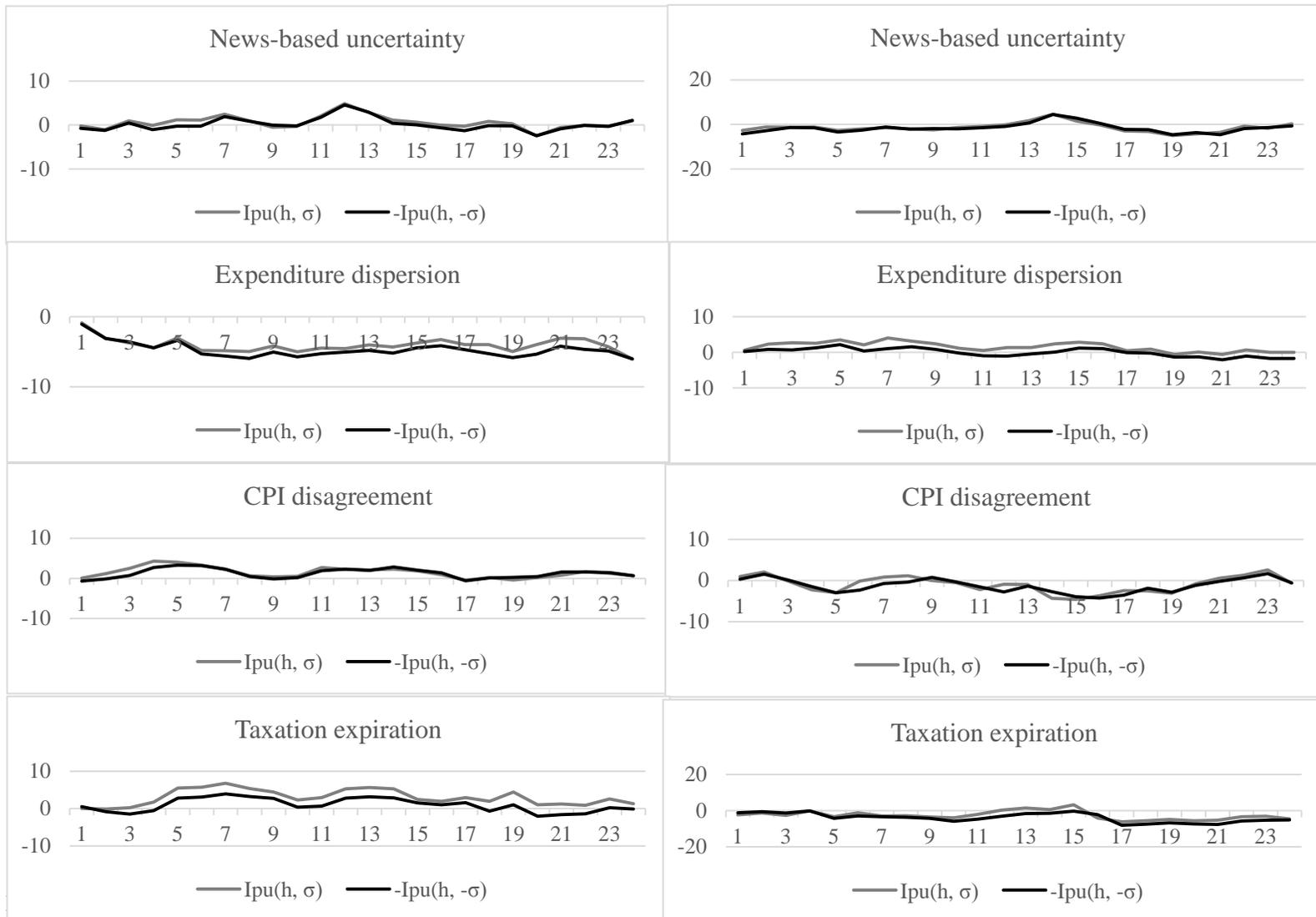


Table 1. Results of stationary test and structural change test

Panel A. Results of stationarity test										
Variables	ADF Test			PP Test			KPSS Test			
	Without trend		With trend	Without trend	With trend		Without trend		With trend	
prod ^{nonUS}	-2.013		-2.680	-1.629	-3.220	**	5.243	***	0.684	***
prod ^{US}	-0.784		1.509	-0.594	1.251		1.799	***	0.939	***
rea	-2.403	*	-2.174	-2.597	**		0.826	***	0.399	***
rpo	-1.682		-2.356	-2.085	-2.784		3.164	***	0.690	***
pu	-3.167	***	-3.257	-5.300	***		0.686	**	0.463	***

Panel B. Results of structural change test between prod ^{nonUS} and pu					Panel C. Results of structural change test between prod ^{US} and pu				
Test statistic	P-value				Test statistic	P-value			
	Andrews	Bootstrap	Hetero-Corrected			Andrews	Bootstrap	Hetero-Corrected	
Sup LM	18.615	0.737	0.646	0.853	Sup LM	28.006	0.137	0.133	0.327
Exp LM	7.154	0.634	0.560	0.829	Exp LM	10.641	0.145	0.146	0.315
Ave LM	12.730	0.484	0.437	0.729	Ave LM	11.288	0.665	0.623	0.561

Panel D. Results of structural change test between rea and pu					Panel E. Results of structural change test between rpo and pu				
Test statistic	P-value				Test statistic	P-value			
	Andrews	Bootstrap	Hetero-Corrected			Andrews	Bootstrap	Hetero-Corrected	
Sup LM	26.358	0.202	0.186	0.372	Sup LM	21.793	0.487	0.439	0.690
Exp LM	8.560	0.387	0.345	0.489	Exp LM	8.003	0.479	0.438	0.677
Ave LM	11.266	0.668	0.567	0.578	Ave LM	11.353	0.657	0.581	0.670

Notes: In Panel A, the null hypotheses for ADF and PP are: the series has a unit root I(1), whereas the null hypothesis of the KPSS test is: the series is stationary I(0). *, **, and *** denote the significant level at 1%, 5%, and 10% level respectively. The prod is the natural logarithm of oil production, rea is real aggregate demand, rpo is the natural logarithm of real price of oil, ret is the real stock market return, and Δ is the first difference operator. In Panels B, C, and D, the critical value of test statistic is based on Hansen (1997, 2000), whereas the null hypothesis of the structural change test for the relation of policy uncertainty and an oil variable is the constancy of parameters in the equation when the policy uncertainty is the dependent variable in the bivariable VAR. Note that Sup, Exp and Ave, are acronyms for supremum, exponential average and average, respectively. These 3 LM-statistics are derived from the optimal arguments of Andrews (1993) and Andrews and Ploberger (1994).

Table 2. Forecast error variance decomposition (FEVD) of economic policy uncertainty, 1985:01-2015:12

Horizon	Non-US oil supply shock	US oil supply shock	Aggregate demand shock	Oil-market specific demand shock	Other shock
<i>Panel 1. FEVD of policy uncertainty</i>					
1	0.001 (0.06)	0.028 (0.87)	0.001 (0.12)	0.002 (0.12)	0.968 (24.51)
3	0.016 (0.65)	0.052 (1.06)	0.004 (0.28)	0.004 (0.24)	0.923 (16.43)
12	0.067 (1.15)	0.089 (1.40)	0.069 (1.37)	0.070 (1.32)	0.705 (8.02)
24	0.061 (1.09)	0.125 (1.54)	0.058 (1.35)	0.095 (1.40)	0.662 (6.61)
60	0.078 (1.37)	0.129 (1.68)	0.080 (1.37)	0.123 (1.80)	0.590 (6.04)

Panel 2. Spillover table when forecast horizon H=60

Contributions To	Contributions From				
	(1) Non-US oil supply shock	(2) US oil supply shock	(3) Aggregate demand shock	(4) Oil-market specific demand shock	(5) Other shock
(1)	0.790 (16.54)	0.042 (1.74)	0.048 (1.95)	0.052 (2.33)	0.067 (2.66)
(2)	0.055 (2.05)	0.705 (11.27)	0.081 (2.60)	0.102 (2.91)	0.057 (2.30)
(3)	0.039 (0.63)	0.091 (1.34)	0.621 (5.64)	0.175 (1.79)	0.074 (1.18)
(4)	0.043 (0.64)	0.156 (1.58)	0.417 (2.98)	0.351 (2.77)	0.033 (0.47)
(5)	0.078 (1.38)	0.129 (1.68)	0.080 (1.38)	0.123 (1.79)	0.590 (6.09)

Total Spillover Index: 0.389 (10.72)

Notes: The table shows percent contributions of demand and supply shocks in the crude oil market to the overall variability of economic policy uncertainty. The forecast error variance decomposition is based on the structural VAR model described in the text. The values in parentheses represent the absolute t-statistics when coefficients' standard errors were generated using a recursive-design wild bootstrap.

Table 3. Forecast error variance decomposition (FEVD) of economic policy uncertainty components, 1985:01-2015:12

Horizon	Non-US oil supply shock	US oil supply shock	Aggregate demand shock	Oil-market specific demand shock	Other shock
<i>Panel 1. FEVD of news-based policy uncertainty</i>					
1	0.001 (0.07)	0.030 (0.84)	0.000 (0.00)	0.000 (0.02)	0.969 (24.47)
12	0.048 (1.17)	0.055 (1.17)	0.066 (1.46)	0.074 (1.53)	0.757 (10.13)
60	0.068 (1.76)	0.062 (1.45)	0.089 (1.96)	0.128 (2.36)	0.652 (8.95)
<i>Panel 2. FEVD of expenditure dispersion</i>					
1	0.006 (0.45)	0.001 (0.11)	0.003 (0.29)	0.003 (0.27)	0.986 (40.26)
12	0.044 (0.93)	0.058 (0.94)	0.215 (2.32)	0.025 (0.66)	0.659 (6.51)
60	0.122 (1.68)	0.159 (1.84)	0.201 (2.18)	0.049 (0.77)	0.469 (4.86)
<i>Panel 3. FEVD of CPI disagreement</i>					
1	0.000 (0.01)	0.004 (0.34)	0.005 (0.37)	0.002 (0.16)	0.988 (38.54)
12	0.009 (0.31)	0.095 (1.43)	0.058 (1.46)	0.013 (0.47)	0.825 (10.70)
60	0.016 (0.53)	0.210 (2.80)	0.172 (2.71)	0.095 (1.90)	0.507 (6.17)
<i>Panel 4. FEVD of taxation expiration</i>					
1	0.007 (0.47)	0.003 (0.34)	0.001 (0.05)	0.015 (0.78)	0.973 (28.08)
12	0.034 (0.72)	0.025 (0.55)	0.034 (0.59)	0.042 (0.89)	0.866 (9.71)
60	0.058 (0.86)	0.064 (0.91)	0.220 (1.85)	0.074 (1.09)	0.584 (4.40)

Notes: The table shows percent contributions of demand and supply shocks in the crude oil market to the overall variability of economic policy uncertainty components. The forecast error variance decomposition is based on the structural VAR model described in the text. The values in parentheses represent the absolute t-statistics when coefficients' standard errors were generated using a recursive-design wild bootstrap.

Table 4. Testing the symmetry of policy uncertainty response $I_{pu}(h,\sigma)=-I_{pu}(h,-\sigma)$ for $h=0,1,2,\dots,H$, to oil price shocks

Horizon	Non-US oil production	US oil production	Real aggregate demand	Real price of oil
<i>Panel 1. Overall economic policy uncertainty</i>				
0	0.001	0.010	0.002	0.055
1	0.005	0.019	0.002	0.154
3	0.001	0.056	0.008	0.170
6	0.001	0.092	0.045	0.107
12	0.001	0.168	0.003	0.039
24	0.007	0.001	0.001	0.002
<i>Panel 2. News-based policy uncertainty</i>				
0	0.103	0.001	0.003	0.015
1	0.257	0.002	0.007	0.018
3	0.058	0.004	0.037	0.074
6	0.012	0.012	0.092	0.137
12	0.073	0.025	0.272	0.289
24	0.001	0.001	0.185	0.025
<i>Panel 3. Expenditure dispersion</i>				
0	0.305	0.297	0.632	0.018
1	0.485	0.001	0.877	0.058
3	0.564	0.001	0.221	0.004
6	0.512	0.001	0.425	0.005
12	0.542	0.001	0.503	0.071
24	0.056	0.001	0.528	0.001
<i>Panel 4. CPI disagreement</i>				
0	0.002	0.175	0.734	0.187
1	0.001	0.394	0.802	0.418
3	0.003	0.452	0.950	0.322
6	0.002	0.037	0.080	0.194
12	0.001	0.001	0.240	0.021
24	0.001	0.001	0.062	0.001
<i>Panel 5. Taxation expiration</i>				
0	0.424	0.082	0.033	0.680
1	0.263	0.183	0.068	0.001
3	0.342	0.352	0.095	0.001
6	0.612	0.195	0.011	0.001
12	0.653	0.317	0.001	0.001
24	0.001	0.001	0.001	0.001

Notes: The table shows the p-values of testing the symmetry of policy uncertainty response to oil supply- and demand-side one standard deviation shocks. The results are based on 20,000 simulations of the model.

