How Does the U.S. Natural Gas Market React to Demand and Supply Shocks in the Crude Oil Market?*

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Abstract

In this paper we use monthly data (over the period from January 1976 to December 2012) and a structural VAR model to disentangle demand and supply shocks in the global crude oil market and investigate their effects on the real price of natural gas in the United States. We identify the model by assuming that innovations to the real price of crude oil are predetermined with respect to the natural gas market and show that close to 45% of the variation in the real price of natural gas can be attributed to structural supply and demand shocks in the global crude oil market.

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Keywords: Oil price; Oil price shocks; Structural VAR.

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1 Introduction

We answer two questions in this paper. Do natural gas prices in the United States react to crude oil price shocks? Does the response depend on the source of the shock in the crude oil market? Economic theory suggests that crude oil prices and natural gas prices are linked through both demand and supply. With regards to demand, crude oil is not consumed directly, but is used as a factor of production in the refining industry in the production of gasoline, diesel, heating oil, and jet fuel. However, there are interactions between the crude oil market and the natural gas market, because natural gas competes with heating oil in the residential and commercial heating markets and is also used interchangeably with residual and distillate fuels in the industrial and electricity generation sectors. For example, Hartley *et al.* (2008) attribute the increased demand for natural gas to the installation of advanced combined cycle gas turbine power plants. With regards to supply, the relationship between the crude oil and natural gas markets is more complicated, because natural gas is found in two basic forms — associated natural gas and non-associated natural gas. The former is a coproduct of crude as it occurs in crude oil reservoirs whereas the latter is not in contact with crude oil. Although associated natural gas accounts for a small fraction of natural gas production in the United States, the liquefaction of natural gas makes possible the storage and delivery of natural gas from remote producing areas, with oil-indexed prices and long-term contracts, to large consuming areas. These factors including recent technological innovations in horizontal drilling and hydraulic fracturing have increased the production of shale gas suggest that crude oil and natural gas prices are related. For example, as can be seen in Figure 1, crude oil and natural gas prices in the United States (from the US Department of Energy) in general move together over time, but they decouple episodically in response to deregulation, technological change, and major policy changes.

Over the years, a large number of studies have sought to investigate whether the price of crude oil is an important determinant of the natural gas price. See, for example, Pindyck (2003), Serletis and Rangel-Ruiz (2004), Panagioditis and Rutledge (2004), and Brown and Yücel (2008), among others. Most of this literature employs time series models, specifically cointegration models and tests, to examine the long run equilibrium relationship between crude oil and natural gas prices. Among those, some studies such as Yücel and Guo (1994), Pindyck (2003), Brown and Yücel (2008), and Asche *et al.* (2006) show that the relationship between the oil price and the natural gas price is stable and asymmetric in a way that the oil price predominantly drives the natural gas price, but not the other way around. In contrast, other studies find that there is no relationship, or a very weak relationship between the two prices. For example Serletis and Rangel-Ruiz (2004) suggest that because of oil and gas deregulation in the United States, West Texas Intermediate (WTI) crude oil prices and Henry Hub natural gas prices do not have shared stochastic trends. Similarly, Bachmeier and Griffin (2006) conclude that, in the very long run, there is no relationship between the prices of primary energy goods, including crude oil and natural gas.

In this paper we build on Kilian (2009) and Kilian and Park (2009) and estimate the global crude oil market model of Kilian (2009), augmented with the real price of natural gas, in order to investigate the relationship between crude oil and natural gas prices. In doing so, we depart from the earlier literature that mostly treats the price of oil as exogenous and does not identify the causes underlying oil price shocks. We follow Kilian (2009) and Kilian and Park

(2009) and treat the price of crude oil as endogenous and disentangle the causes underlying oil price shocks. In particular, we model changes in the real price of crude oil as arising from three different sources: shocks to the global supply of crude oil, shocks to the global demand for all industrial commodities (including crude oil) that are driven by the global business cycle, and oil-market specific demand shocks (also referred to as precautionary demand shocks). We augment Kilian's (2009) structural Vector AutoRegressive (VAR) model to include the real price of natural gas, and investigate the response of the real price of natural gas to structural shocks in the crude oil market. More specifically, we incorporate the price of natural gas into Kilian's (2009) structural VAR model. Kilian (2009) shows how we can decompose the price of oil into structural shocks, and in this study we investigate the impact of those shocks on natural gas prices.

We show (using monthly data over the period from 1976:1 to 2012:12) that in the long run, an average of 45% of the variability of the real natural gas price in the United States can be attributed to structural shocks that drive the global crude oil market, suggesting that crude oil market fundamentals are an important determinant of natural gas prices. In particular, we show that oil supply shocks, shocks to the global demand for all industrial commodities that are driven by the global business cycle, and oil-market specific demand shocks (also referred to as precautionary demand shocks) have made big contributions to the real price of natural gas in the United States, as they account for about 45% of the long run variability of the real price of natural gas. We show that the responses of the real price of natural gas vary depending on the cause of the oil price shock, with aggregate demand shocks and precautionary demand shock accounting for most of the variation. We also show that shocks in the natural gas market (such as supply disruptions, weather conditions, deregulation, and major policy changes) account for about 55% of the long run variability of the real price of natural gas, thus causing episodic decoupling of the real price of natural gas from the real price of crude oil.

The paper is organized as follows. Section 2 discusses the data and provides some graphical representations. Sections 3 and 4 describe the empirical method and present the results. Section 5 addresses robustness issues, and the final section concludes the paper.

2 Data

We consider a structural VAR model based on monthly time series data for the United States, over the period from 1976:1 to 2012:12 (a total of 444 observations), for $\boldsymbol{z}_t = (\Delta prod_t, rea_t, rpo_t, rpg_t)'$, where $\Delta prod_t$ is the percent change in global crude oil production, rea_t is a measure of real economic activity, rpo_t is the real price of oil, and rpg_t is the real price of natural gas.

Regarding the percent change in global crude oil production, $\Delta prod_t$, we use the oil production data from the U.S. Department of Energy to compute the log differences of world crude oil production in millions of barrels pumped per day (and averaged by month). We use Kilian's (2009) detrended real freight rate index to measure the component of real economic activity (rea_t) that drives demand for industrial commodities in global markets. As noted by Kilian (2009), this index is constructed from dry cargo single voyage ocean freight rates and is deflated by the U.S. Consumer Price Index (CPI) to express it in real terms. The real freight rate index is linearly detrended to remove long-term trends and thus represent the global business cycle. See Kilian (2009) for more details regarding the construction of this measure of global real economic activity.[1] Finally, we divide the U.S. composite refiners' acquisition cost of crude oil (RAC), as compiled by the U.S. Department of Energy, by the U.S. CPI to obtain the real price of crude oil, rpo_t, and we divide the U.S. natural gas wellhead price, as compiled by the U.S. Department of Energy, by the U.S. CPI to obtain the real price of natural gas, rpg_t.

The fact that global oil production enters the VAR model in percent changes, $\Delta prod_t$, and the measure of real economic activity, rea_t, is expressed as percent deviations from trend, suggests that we should be using the first differences of the natural logs of the real crude oil and natural gas prices in order to have consistent variables in the VAR system of equations. We note that the logged real crude oil and natural gas prices are not very informative regarding their unit root properties, although they should be stationary if each of the nominal crude oil and natural gas price cointegrates with the U.S. consumer price index. In this regard, as Lütkepohl and Netšunajev (2014) point out, overdifferencing may be more harmful than including a unit root series in levels, and to be on the safe side, we follow Kilian (2009), Kilian and Park (2009), and Lütkepohl and Netšunajev (2014) and use the log levels of the real crude oil and natural gas prices.[2]

Figure 2 shows the historical evolution of our series (the percent change in global crude oil production, $\Delta prod_t$, real economic activity, rea_t, log real oil price, rpo_t, and log real natural gas price, rpg_t) over the sample period.

3 The Structural VAR Model

The structural VAR representation is based on Kilian (2009) and Kilian and Park (2009) and is

$$\boldsymbol{B}\boldsymbol{z}_t = \gamma + \sum_{i=1}^{p} \boldsymbol{\Gamma}_i \boldsymbol{z}_{t-i} + \boldsymbol{\varepsilon}_t \tag{1}$$

where γ is a parameter vector, $\boldsymbol{B}$ and $\boldsymbol{\Gamma}_i$ denote the contemporaneous and lagged coefficient matrices, respectively, and $\boldsymbol{\varepsilon}_t$ is a vector of serially and mutually uncorrelated structural innovations, $\boldsymbol{\varepsilon}_t = \left(\varepsilon_t^{\Delta prod}, \varepsilon_t^{rea}, \varepsilon_t^{rpo}, \varepsilon_t^{rpg}\right)'$.

[1] Whether the detrended freight rate index is an adequate reflection of the overall economic climate is an issue beyond the scope of this paper.

[2] In this regard, as Kilian and Murphy (2014, p. 457) put it (in the context of their paper), the level specification "has the advantage that the impulse response estimates are asymptotically valid not only under the maintained assumption of a stationary real price of oil, but robust to departures from that assumption, whereas incorrectly differencing the real price of oil would cause these estimates to be inconsistent. The potential cost of not imposing unit roots in estimation is a loss of asymptotic efficiency, which would be reflected in wider error bands. Since the impulse response estimates presented below are reasonably precisely estimated, this is not a concern in this study. It should be noted, however, that historical decompositions for the real price of oil rely on the assumption of covariance stationarity and would not be valid in the presence of unit roots."

Assuming that $\boldsymbol{B}^{-1}$ exists, the reduced-form representation of equation (1) is

$$\boldsymbol{z}_t = \alpha + \sum_{i=1}^{p} \boldsymbol{A}_i \boldsymbol{z}_{t-i} + \boldsymbol{e}_t \tag{2}$$

where $\alpha = \boldsymbol{B}^{-1}\gamma$, $\boldsymbol{A}_i = \boldsymbol{B}^{-1}\boldsymbol{\Gamma}_i$, and the reduced form innovations, $\boldsymbol{e}_t$, are linear combinations of the structural shocks, $\boldsymbol{\varepsilon}_t$, $\boldsymbol{e}_t = \boldsymbol{B}^{-1}\boldsymbol{\varepsilon}_t$. We estimate the reduced-form (2) and recover the structural shocks, $\boldsymbol{\varepsilon}_t$, by imposing zero (exclusion) restrictions on the elements of $\boldsymbol{B}$. Then we use the structural moving average representation of the model to infer the impulse responses.

Since the natural gas market is assumed to be regional and segmented while the price of crude oil is determined in global markets, we follow Kilian and Park (2009) and impose a block-recursive structure on the contemporaneous relationship between the reduced-form VAR innovations and the underlying structural disturbances. In particular, we assume that $\boldsymbol{B}^{-1}$ has a recursive structure such that the reduced-form innovations, $\boldsymbol{e}_t$, can be decomposed according to $\boldsymbol{e}_t = \boldsymbol{B}^{-1}\boldsymbol{\varepsilon}_t$, as follows

$$\boldsymbol{e}_t \equiv \begin{pmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{rpo} \\ e_t^{rpg} \end{pmatrix} = \begin{pmatrix} b_{11} & 0 & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{oil\ \sup ply\ shock} \\ \varepsilon_t^{aggregate\ demand\ shock} \\ \varepsilon_t^{oil\ specific-demand\ shock} \\ \varepsilon_t^{other\ shocks\ to\ natural\ gas\ price} \end{pmatrix}. \tag{3}$$

We can think of our model (3) as being composed of two blocks, with the first block, consisting of the first three equations, describing the global crude oil market and the second block, consisting of only the last equation, describing the natural gas market.

As in Kilian (2009) and Kilian and Park (2009), we attribute fluctuations in the real price of oil to three structural shocks: shocks to the global supply of crude oil, referred to as "oil supply shocks," shocks to the global demand for all industrial commodities (including crude oil) that are driven by the global business cycle, referred to as "aggregate demand shocks," and an oil-market specific demand shock, referred to as "oil-specific demand shock" or "precautionary demand shock," designed to capture shifts in precautionary demand for crude oil in response to increased uncertainty about future oil supply shortfalls — see also Alquist and Kilian (2009) for more details. The structural shock in the second block is not a true structural shock, but an innovation to natural gas prices not driven by global crude oil demand or supply shocks.

The identification scheme is consistent with a global crude oil market characterized by a vertical short-run supply curve and a downward sloping short-run demand curve. In particular, the block-recursive structure implies that crude oil supply does not simultaneously react to oil demand shocks. For example, the three exclusion restrictions in the first row of $\boldsymbol{B}^{-1}$ ($b_{12} = b_{13} = b_{14} = 0$) imply that real economic activity, the real price of crude oil, and the real price of natural gas do not have a contemporaneous effects on oil supply, but only affect it with a lag. This assumption is consistent with the notion that only exogenous events, such as conflicts in the Middle east, affect oil production. The restrictions $b_{23} = b_{24} = 0$ imply that oil-specific demand shocks and other shocks to the natural gas price do not have a contemporaneous effect on the global business cycle, but affect it only with a lag. The third equation of the first block implies that the real price of oil changes instantaneously in response to unanticipated oil supply shocks (that shift the vertical supply curve), as well as to both aggregate demand shocks and oil-specific demand shocks (that shift the demand curve), but that the real price of oil does not contemporaneously react to the real natural gas price (so that $b_{34} = 0$). Finally, the nonzero elements in the last row of the $\boldsymbol{B}^{-1}$ matrix imply that global crude oil production, global real activity, and the real price of oil are treated as predetermined with respect to the natural gas price, meaning that all three oil supply and oil demand shocks have contemporaneous effects on the real natural gas price.

4 Structural VAR Estimates

As suggested by Kilian (2009), we assume $p = 24$ in (2) to account for the low frequency co-movement between the real price of oil and global economic activity, and estimate the reduced form VAR (with a total of 388 parameters) by the least squares method.[3] We then use the resulting estimates to construct the structural VAR representation of the model and calculate impulse response functions to one-standard deviation shocks, together with one- and two- standard error bands, based on the recursive-design wild bootstrap of Gonçalves and Kilian (2004). Our main objective is to investigate the effects of structural shocks in the crude oil market on natural gas prices in the United States.

In the upper panel of Figure 3 we review the responses of the real price of crude oil to each of the three structural shocks in the crude oil market — the oil supply shock, the aggregate demand shock, and the oil-specific demand shock. Point estimates are indicated by solid lines and one-standard error and two-standard error bands are indicated by dashed and dotted lines, respectively. As in Kilian (2009) and Kilian and Park (2009), we normalize the oil supply shock to represent a negative (one-standard deviation) shock and normalize the aggregate demand and oil-market specific demand shocks to represent positive shocks, so that all three shocks would tend to generate an increase in the real price of crude oil. As can be seen in Figure 3, the three structural shocks in the crude oil market have very different effects on the real price of crude oil (in the upper panel) and the real price of natural gas (in the lower panel). For example, an unexpected decline in the supply of crude oil has a transitory positive effect within the first year on the real price of oil while it has a sustained positive effect on the real price of natural gas after one year, based on one-standard error bands (these shocks have insignificant effect on both prices based on two-standard error bands); an unexpected increase in global demand causes an immediate and sustained increase in the real price of both crude oil and natural gas, although the response of the real price of natural gas is episodically insignificant in some months based on two-standard error bands; whereas an unexpected increase in the precautionary demand for oil causes immediate and sustained increases in both prices.

The forecast-error-variance decompositions in Tables 1 and 2 quantify the effects of the structural shocks on the real price of crude oil and the real price of natural gas, respectively. Although in the short-run the effects of the three structural shocks in the crude oil market on real natural gas prices are negligible (for example, the combined explanatory power of

[3] It is to be noted that model selection criteria such as the Akaike information criterion (AIC) favour a smaller VAR order (in our case $p = 3$), as also noted by Lütkepohl and Netšunajev (2014). Given, however, that the number of observations is sufficiently large, we follow Kilian (2009) and set $p = 24$.

these shocks on impact is less than 1% of the variation of the real crude oil and natural gas prices), the explanatory power increases as the forecast horizon increases. In the long run, the oil supply shock, the aggregate demand shock, and the oil-market specific demand shock together account for about 92% of the variability in the real price of crude oil and for about 45% of the variability in the real price of natural gas. This suggests that structural shocks in the global crude oil market are an important fundamental for the natural gas market in the United States, with the largest contributor being the aggregate demand shocks (accounting for more than 16% of the long-run variation in the real natural gas price), followed by precautionary demand shocks (accounting for about 16%), and oil supply shocks (accounting for about 13%). The rest of the variation in natural gas prices (accounting for about 55%) is attributed to natural gas market-specific shocks or generally other shocks.

The impulse responses reported in Figure 3 show the timing and magnitude of the responses of the real price of crude oil and the real price of natural gas to one-time structural shocks in the crude oil market. In Figure 4 we report (in the same fashion as in Figure 3) the cumulative impulse responses of the real price of crude oil and the real price of natural gas to each of the three supply and demand shocks in the crude oil market. Figure 4 shows that the cumulative impulse responses of the real natural gas price depend on the underlying cause of the increase in the real price of crude oil. This first graph on the lower panel of Figure 4 shows that shocks to the supply of crude oil have no impact on the real price of natural gas (the estimated impulse response function is never statistically distinguishable from zero). The graph in the middle shows that an unexpected increase in the demand for industrial commodities produces an immediate, positive and significant increase in the natural gas price based on one-standard error bands. Finally, the response of the real price of natural gas to a shock in the precautionary demand for crude oil is positive and statistically significant according to the one-standard error bands.

In Figures 5 and 6 we present the historical decomposition of the cumulative contribution of each of the structural shocks on the real price of crude oil and the real price of natural gas, respectively. Figure 5 suggests that oil supply shocks (in the first graph) have made small contributions to the real price of crude oil whereas aggregate demand shocks (in the graph in the middle) and oil-market specific demand shocks (in the third graph) have made the biggest contributions. Moreover, consistent with Kilian (2009) and Kilian and Park (2009), we find that although the aggregate demand shocks caused long swings in the real price of crude oil, the oil-market specific demand shock is mainly responsible for the sharp increases and decreases in the real price of crude oil. As Kilian (2009, p. 1062) puts it, "this fact is consistent with the view that precautionary demand shocks may reflect rapid shifts in the market's assessment of the uncertainty about future oil supply shortfalls."

Finally, the historical decomposition of fluctuations in the real price of natural gas in Figure 6 suggests that historically the real price of natural gas has been driven by a combination of structural shocks in the crude oil market (mainly, real economic activity and precautionary demand shocks) and natural gas market specific shocks. In fact, the real price of natural gas and the real price of crude oil move together if the source of fluctuations is one of the structural shocks in the crude oil market — an oil supply shock, an aggregate demand shock, or an oil-specific demand shock. The real price of natural gas may decouple from the real price of crude oil (as shown in Figure 1) when there are changes in the fundamental influences of the natural gas price, such as, for example, weather conditions, seasonal effects, supply disruptions, storage activity, and imports of liquefied natural gas. In this regard, Brown and Yücel (2008), Ramberg and Parsons (2012), and Nick and Thoenes (2014), in their investigations of the aggregate oil price impact on natural gas prices, show that natural gas prices are anchored in a long-term relationship with oil prices, with the latter explaining a range of 15% to 40% of the variation in natural gas prices, and that the short-run dynamics of natural gas prices are driven by a variety of transitory and other exogenous factors, including weather, seasonality, storage, supply disruptions, and coal prices.

In fact, the recent fluctuations in the real price of natural gas (see Figure 1) were mostly driven by other shocks in the natural gas market. For example, the supply disruptions in the European natural gas markets due to the "Arab Spring" and the civil war in Libya in the spring of 2011, the Russian-Ukrainian gas transit dispute in January 2009, and the suspension of Russian gas exports in February 2012, as well as the development of shale gas production after 2009 in the United States are all captured by the other shocks to the real price of natural gas in the fourth graph of Figure 6.

5 Robustness

The long sample period used in this paper raises the question of structural stability of the estimated structural VAR, suggesting an empirical analysis based on sub-samples. For example, the role of crude oil in the electricity sector, where it competes with natural gas, has changed significantly over time. Also, the recent institutional and technological revolution in natural gas production in the United States has led to a decoupling of natural gas prices from crude oil prices, as can be seen in Figure 1 which shows a negative correlation between oil prices and natural gas prices in recent years. In this regard, it should be mentioned that in the United States natural gas is traded in spot and futures markets like other commodities; thus natural gas prices at the wellhead are determined by demand and supply conditions. This contrasts sharply with Europe, where natural gas prices are linked under long-term contracts to oil prices — see Makholm (2015). In addition, due to burner tip competition between natural gas and oil products, and the general similarity of their production technologies, natural gas and crude oil prices have been historically closely related — see Serletis and Rangel-Ruiz (2004), De Bock and Gijón (2011), and Asche *et al.* (2012) for analyses of the relationship between oil and gas prices over time.

As discussed by Wang *et al.* (2014), in terms of our sample, we can divide the evolution of natural gas development in the United States into two periods, before 2000 and after 2000, both tied to fluctuations in the price of oil. In the early 1970s, the U.S. economy was hit by an oil crisis, as a result of the oil embargo stemming from the Arab-Israeli war of 1973, that led to a quadrupling of the oil price. Also, in the late 1970s the overthrowing of the Shah of Iran led to a doubling of the price of oil. These two oil crises propelled the U.S. government to invest in research and development and also to support alternative sources of energy, including unconventional natural gas. As a result, the output of shale gas in the United States increased more than seven-fold between 1979 and 2000. The period since 2000 is refereed to as the 'industrial-scale period' in natural gas production — see Wang *et al.* (2014). The prospect of falling conventional gas production led to the development of advanced drilling techniques, such as, for example, horizontal drilling and hydraulic fracturing, that significantly increased the productivity of shale gas wells. Also, the increase in oil and gas prices in the 2000s made shale gas production economically more attractive. As a result, shale gas production in the United States increased 12-fold from 2000 to 2010.

In order to investigate the robustness of our results, in what follows we split the sample in 2000 and calculate the forecast-error-variance decompositions, impulse responses, and cumulative responses for the periods before and after 2000.

5.1 Before 2000

For the period from 1976:1 to 1999:1 (with 288 monthly observations), because the number of observations is not sufficiently large, we estimate the structural VAR with three lags ($p = 3$ in (2)) as suggested by the AIC, thus estimating a total of 52 parameters. The forecast-error-variance decompositions reported in Table 3 show that in the short-run the effects of oil market shocks on the real price of natural gas are negligible, but in the long run they account for about 69% of the variation in the real price of natural gas. This is a much stronger effect than in the case of the full sample (see Table 2).

According to the impulse responses and the cumulative impulse responses shown in Figure 7, only oil-specific demand shocks have significant effects on the real price of natural gas in the period before 2000, in contrast to the evidence based on the full sample (see Figures 3 and 4) over which aggregate demand shocks also have significant effects on the real price of natural gas. Thus, our results based on the forecast-error-variance decomposition analysis and the impulse responses and the cumulative impulse responses, indicate that for the period before 2000 oil prices were a significant determinant of the real price of natural gas.

5.2 After 2000

For the period from 2000:1 to 2012:12 (with 156 monthly observations), we estimate the structural VAR with two lags ($p = 2$ in (2)) as suggested by the AIC, estimating a total of 36 parameters. The forecast-error-variance decompositions in Table 4, reported in the same fashion as those in Tables 2 and 3, show that in the short-run the effects of oil market shocks on the real price of natural gas are negligible, but in the long run, oil market shocks explain about 52% of the fluctuations in the real natural gas price, compared to 45% and 69% for the full sample (see Table 2) and the sub-sample before 2000 (see Table 3), respectively.

The impulse responses and the cumulative impulse responses in Figure 8, show that only aggregate demand shocks (that is, shocks to the global demand for all industrial commodities that are driven by the global business cycle) have a significant effect on the real natural gas price in the period after 2000. This is consistent with some of the recent literature that indicates that there has been decoupling of crude oil and natural gas prices — see, for example, Ramberg and Parsons (2012).

6 Conclusion

We have used the global crude oil market model of Kilian (2009) to disentangle the causes underlying crude oil price shocks and investigate the response of natural gas prices in the

United States to changes in the price of crude oil. In doing so, we focus on specific oil market shocks, instead of an aggregate oil price impact. Our results, based on an identified structural VAR and monthly data over the period from 1976:1 to 2012:12, show that the response of the real price of natural gas may differ greatly depending on the underlying cause of the oil price shock. We show that close to 45% of the variation in the real price of natural gas can be attributed to structural supply and aggregate demand shocks in the global crude oil market. We also show that shocks in the natural gas market account for about 55% of the long run variability of the real price of natural gas, thus causing episodic decoupling of the real price of natural gas from the real price of crude oil.

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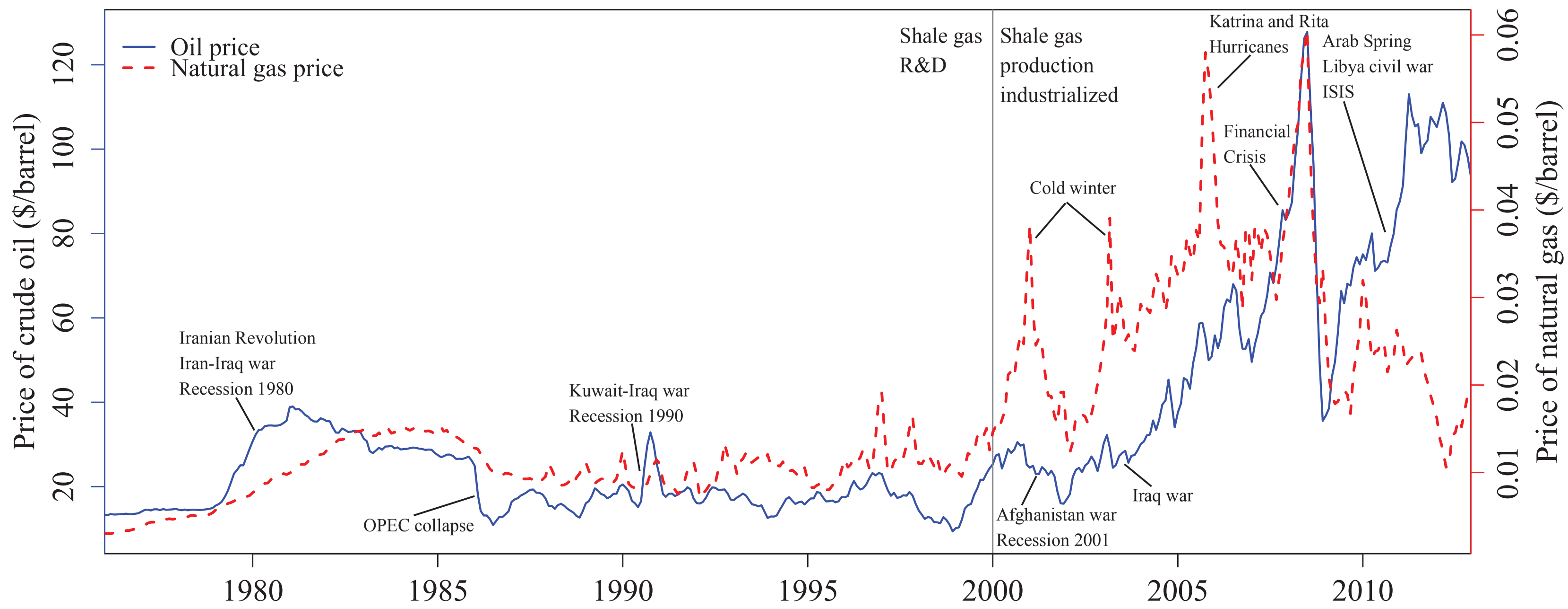

Figure 1. Crude oil and natural gas prices, 1976:1−2012:12

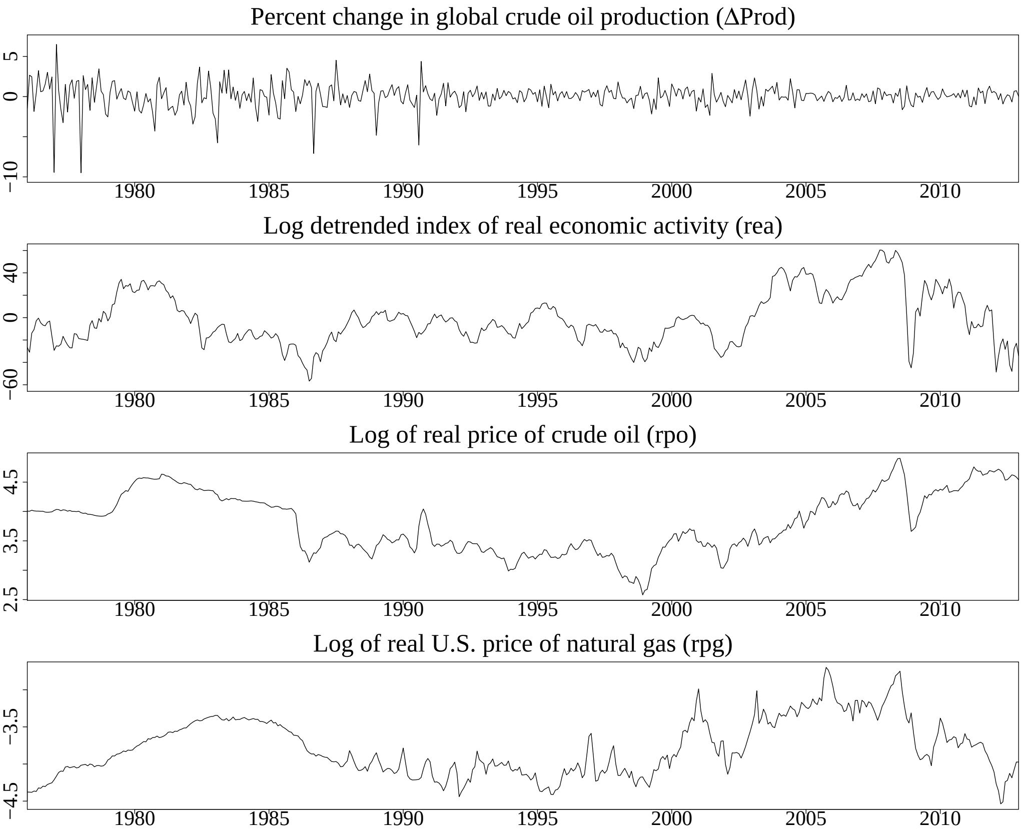

Figure 2. Historical evolution of the series, 1976:1−2012:12

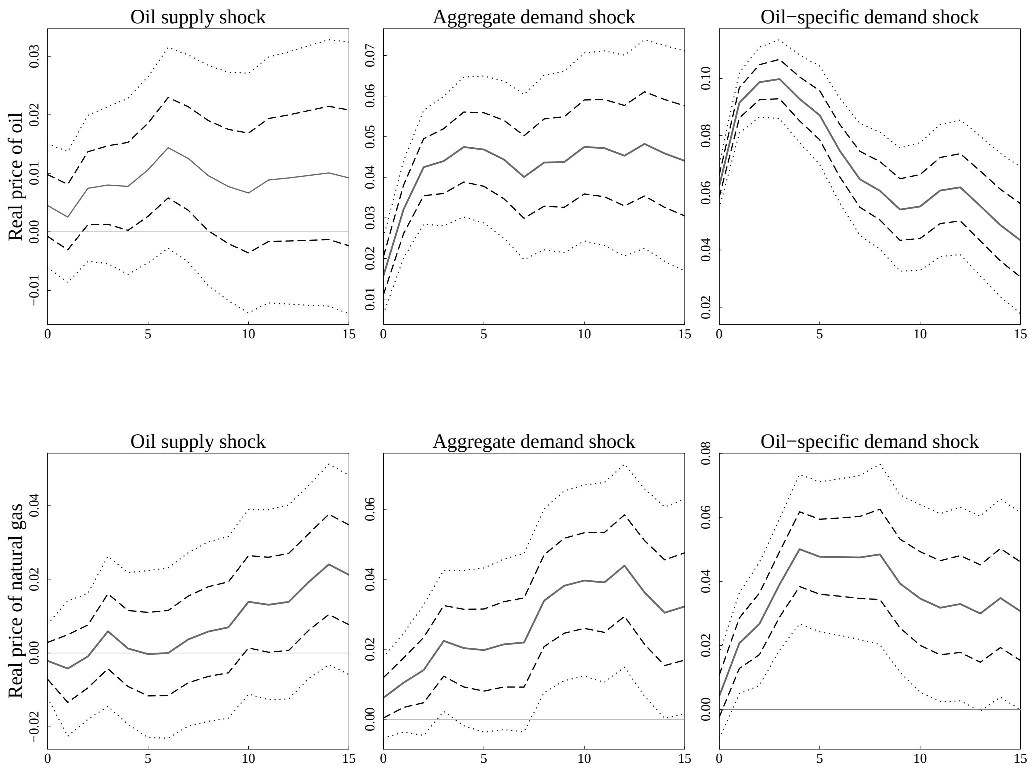

Figure 3. Responses of the real price of crude oil (upper panel) and the real price of natural gas (lower panel) to one-standard deviation structural shocks: Point estimates with one- and two-standard error bands.

Table 1. Percent contribution of supply and demand shocks in the crude oil market to the overall variability of the real crude oil price.

	Shock			
Horizon	Oil supply	Aggregate demand	Oil-specific demand	Other
1	0.49	5.99	93.53	0.00
2	0.20	9.42	90.38	0.00
3	0.33	12.25	87.42	0.01
15	1.12	25.08	72.67	1.14
∞	2.58	50.29	39.57	7.56

Note: Based on variance decomposition of the structural VAR model (1).

Table 2. Percent contribution of supply and demand shocks in the crude oil market to the overall variability of the real natural gas price.

	Shock			
Horizon	Oil supply	Aggregate demand	Oil-specific demand	Other
1	0.06	0.50	0.24	99.20
2	0.13	0.85	2.58	96.44
3	0.10	1.41	4.78	93.71
15	1.89	14.22	24.29	59.60
∞	13.13	16.07	15.84	54.96

Note: Based on variance decomposition of the structural VAR model (1).

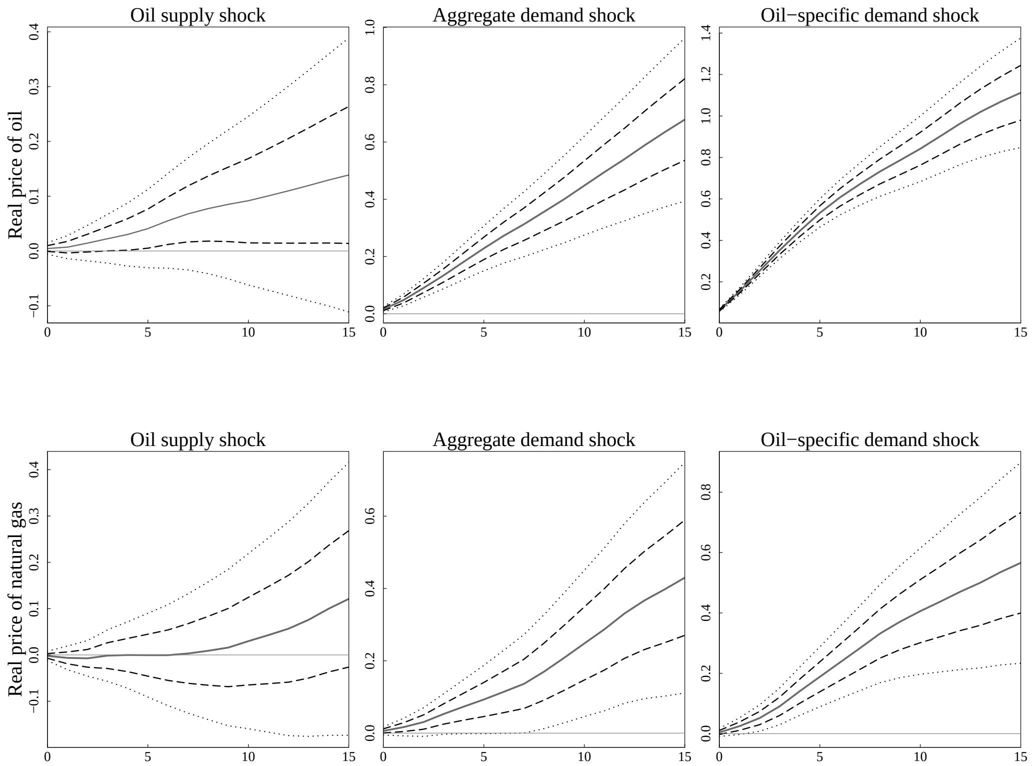

Figure 4. Cumulative responses of the real price of crude oil (upper panel) and the real price of natural gas (lower panel) to one-standard deviation structural shocks: Point estimates with one- and two-standard error bands.

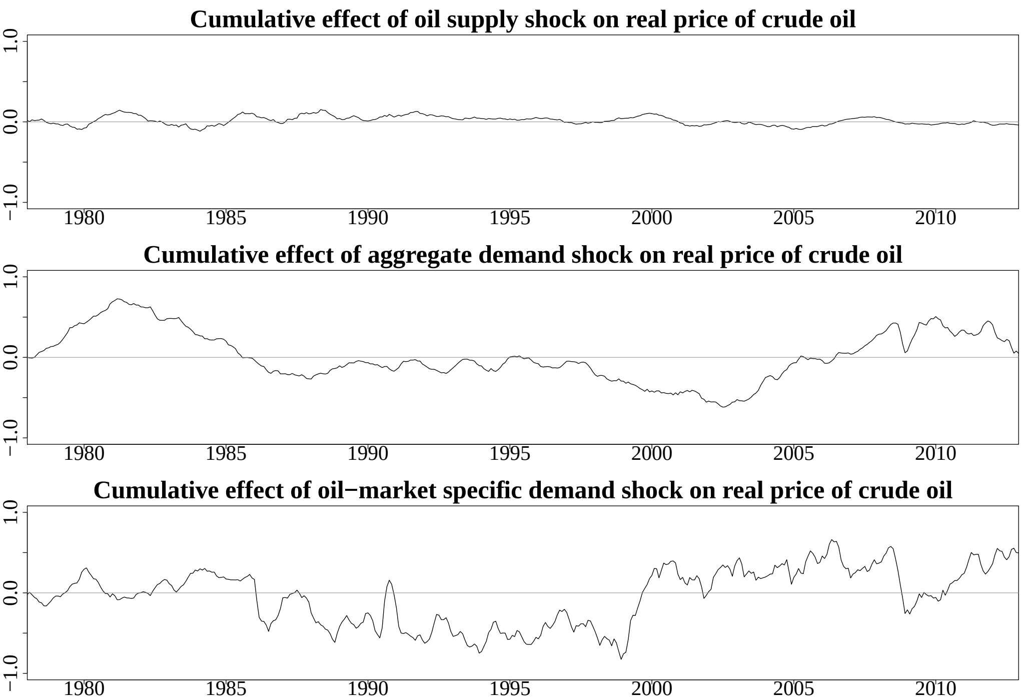

Figure 5. Historical decomposition of the real price of crude oil.

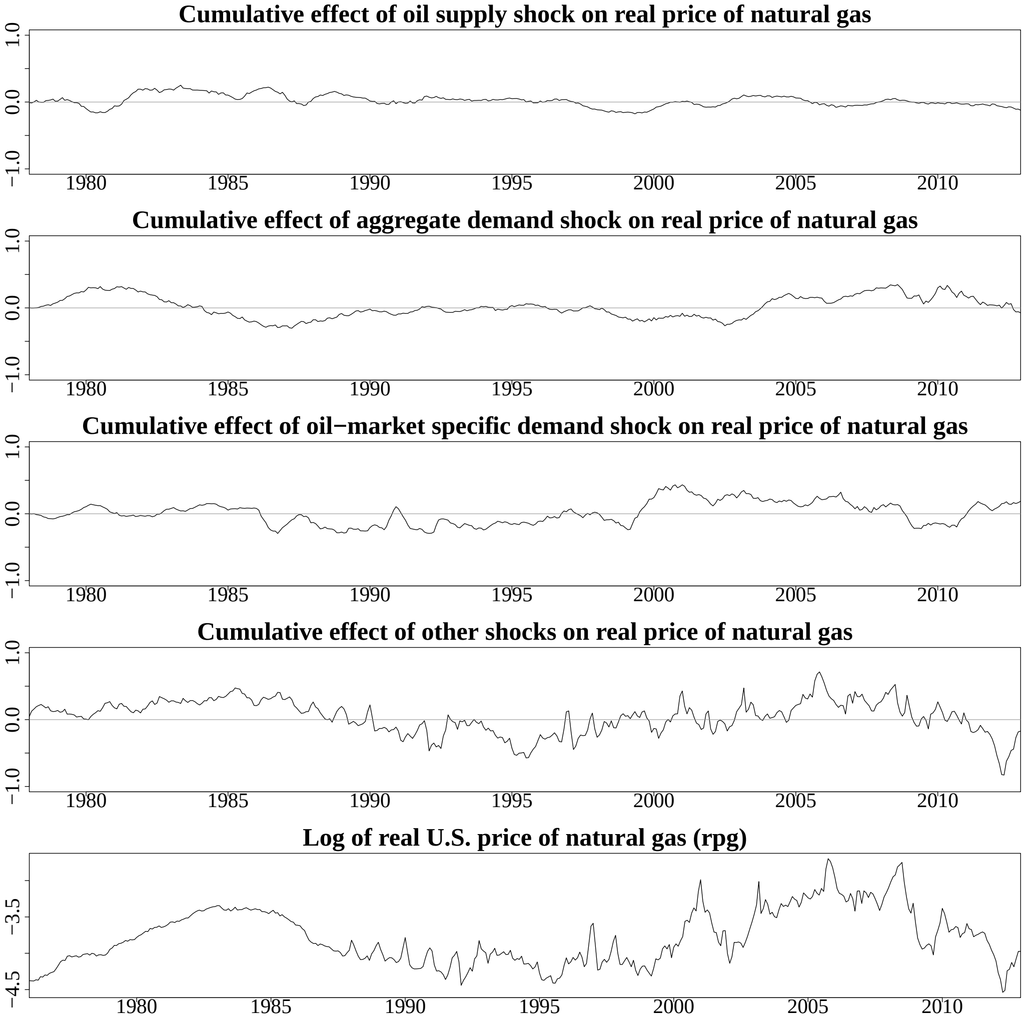

Figure 6. Historical decomposition of the real price of natural gas.

Table 3. Percent contribution of supply and demand shocks in the crude oil market to the overall variability of the real natural gas price, 1976:1–1999:12.

	Shock			
Horizon	Oil supply	Aggregate demand	Oil-specific demand	Other
1	0.01	0.13	0.24	99.62
2	0.04	0.17	2.31	97.48
3	0.04	0.13	6.95	92.88
15	0.59	0.87	36.83	61.71
∞	1.28	4.10	63.27	31.35

Note: Based on variance decomposition of the structural VAR model (1).

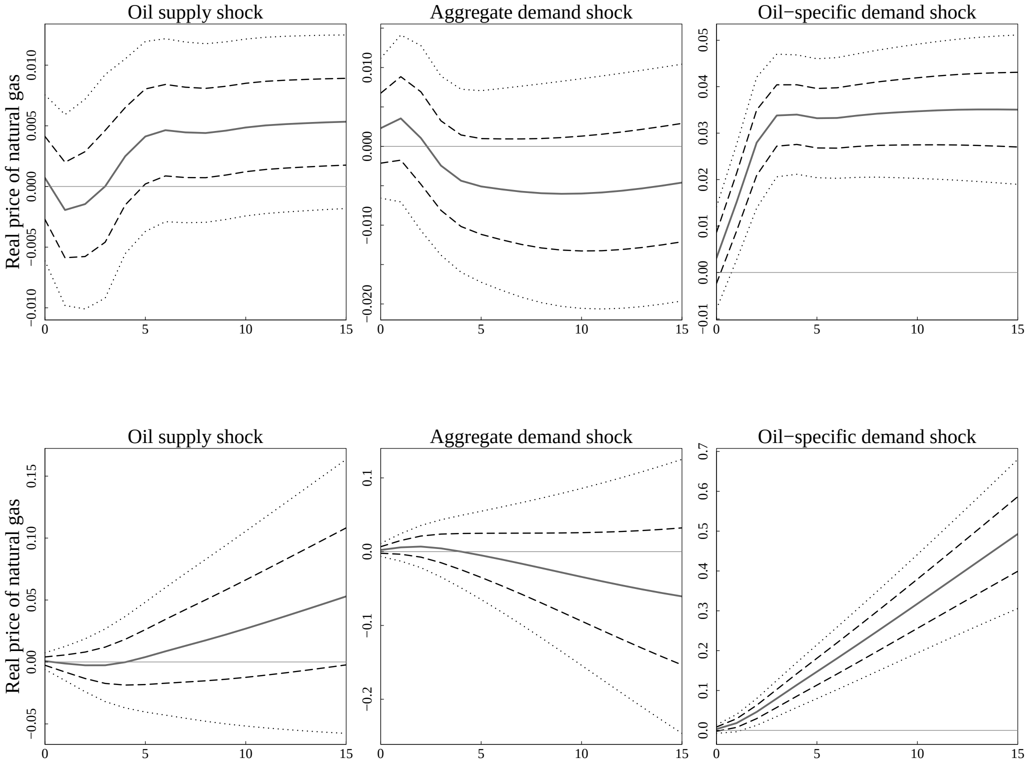

Figure 7. Responses (upper panel) and cumulative responses (lower panel) of the real price of natural gas to one-standard deviation structural shocks: Point estimates with one– and two–standard error bands, 1976:1–1999:12.

Table 4. Percent contribution of supply and demand shocks in the crude oil market to the overall variability of the real natural gas price, 2000:1–2012:12.

	Shock			
Horizon	Oil supply	Aggregate demand	Oil-specific demand	Other
1	0.11	0.38	0.10	99.41
2	0.86	1.06	0.05	98.03
3	0.71	3.37	0.04	95.88
15	1.17	34.51	1.55	62.77
∞	3.12	24.23	24.51	48.13

Note: Based on variance decomposition of the structural VAR model (1).

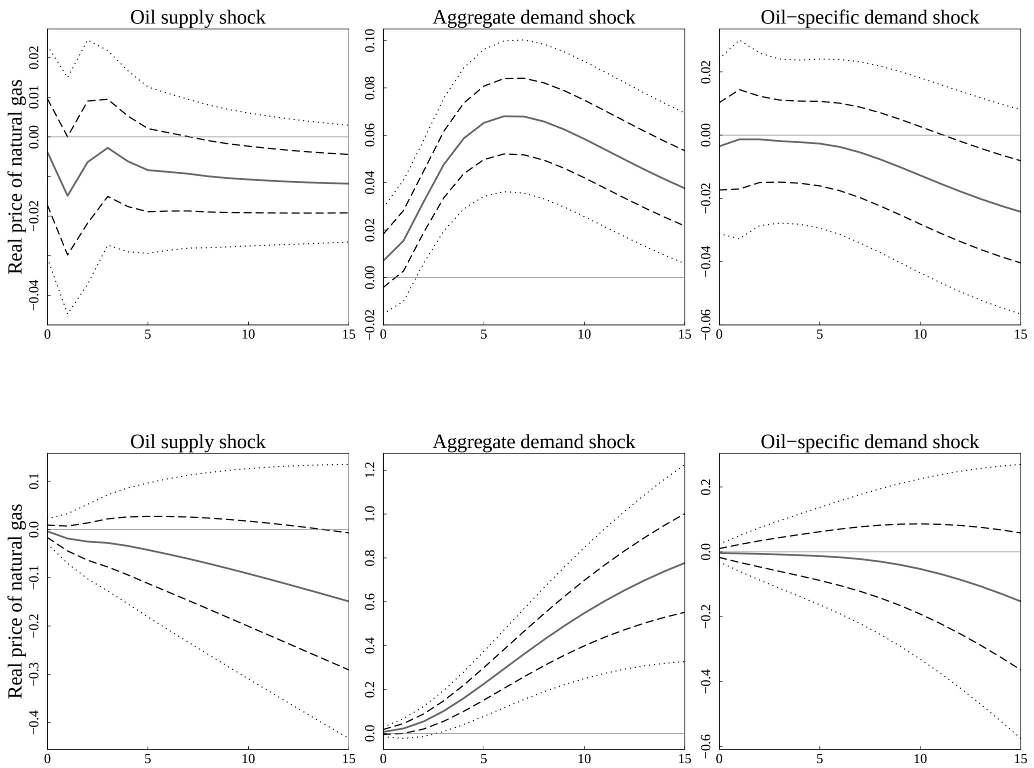

Figure 8. Responses (upper panel) and cumulative responses (lower panel) of the real price of natural gas to one-standard deviation structural shocks: Point estimates with one– and two–standard error bands, 2000:1–2012:12.