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Research article

Oil prices and the natural gas liquids markets

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Abstract: This paper investigates the impact of oil market structural shocks on the prices of natural gas liquids (NGLs), including ethane, propane, normal butane, isobutane, and natural gasoline, over the period from January 1985 to April 2020. To identify the structural demand and supply shocks in the crude oil market, we use a vector autoregression model and assume that the innovations to the real price of crude oil are predetermined with respect to the local NGLs markets. Our results show that, in the long run, more than 55% of the variation in the real price of NGLs is explained by the structural shocks in the global crude oil market. We also find that, unlike oil supply shocks, demand-side shocks have permanent and persistent impacts on NGLs' real prices and should be of main concern to investors aiming to develop gas wells and NGLs producing technologies.

Keywords: oil price shocks; structural VAR; natural gas liquids

JEL Codes: C32, Q4

1. Introduction

Our objective in this paper is to investigate whether natural gas liquids (NGLs) prices in the United States react to crude oil price shocks and whether the responses depends on the source of the shock in the crude oil market. As Oglend et al. (2015) put it, "much focus in the literature has been directed towards the relationship between oil and natural gas markets. Less attention has been paid to other important petroleum products, and their relationship with oil and natural gas markets." In their investigation of whether the shale gas expansion has affected the relationship between liquified petroleum gases and oil prices, they use a generalized cointegrated vector autoregressive model for crude oil, natural gas, and liquified petroleum gases (as measured by propane and butane), and find that the strong relationship between natural gas and liquified petroleum gases with crude oil prior to the U.S. shale gas expansion has weakened in recent years. They also argue that the relationship between oil and natural gas prices depends not only on direct interfuel substitution, but also on the state of the liquids markets. For example, an increase in liquids prices due to higher oil prices, might lead to increased natural gas production and thus to lower natural gas prices.

In a more recent paper, Jadidzadeh and Serletis (2017) estimate the structural Vector AutoRegressive (VAR) 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, they treat the price of crude oil as endogenous and disentangle the causes underlying oil price shocks. In particular, they 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). They use monthly data, over the period from 1976:1 to 2012:12, and find 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.

In this paper, in the spirit of Oglend et al. (2015) and Jadidzadeh and Serletis (2017), we augment the global crude oil market model of Kilian (2009) to include the real prices of natural gas liquids (NGLs), and investigate the responses of each of ethane, propane, normal butane, isobutane, and natural gasoline to structural shocks in the crude oil market. We use monthly data, over the period from 1985:1 to 2020:4, and show that crude oil market fundamentals are an important determinant of NGLs prices. This time span includes time periods after the first incidence of the coronavirus pandemic when the oil industry experienced a dramatic fall in oil prices. In particular, we show that structural shocks in the crude oil market have made big contributions to the real price of NGLs, as they account for close to 55% of the long run variability of real NGLs prices. Moreover, we show that the responses of real NGLs prices vary depending on the cause of the oil price shock, with aggregate demand shocks and precautionary demand shocks accounting for most of the variation. Shocks in the NGLs markets (such as supply disruptions, weather conditions, deregulation, and major policy changes) account for about 45% of the long run variability of real NGLs prices.

The paper is organized as follows. Section 2 provides a brief discussion of the NGLs market. Section 3 discusses the data and provides some graphical representations. Sections 4 and 5 describe the empirical method and present the results. Section 6 concludes the paper.

2. The NGLs market

As shown in Figure 1, non-associated natural gas, namely wet gas, is the raw natural gas extracted from gas wells, while associated-dissolved natural gas is the raw natural gas produced from oil wells. When the raw natural gas is produced, the majority of hydrocarbon gas liquids (HGL) are separated from the gas stream at either a gas processing plant or a refinery depending on the source of natural gas. HGLs that are extracted at the gas processing plants are delivered to other facilities, namely fractionators, to apply additional separation to meet certain commercial specifications. The end-products are natural gas liquids (NGLs) — ethane (abbreviated as C2), propane (C3), normal butane (NC4), isobutane (IC4), and natural gasoline (C5). They are stored in a liquid state for shipping and consumption and used in petrochemical plants as feedstocks, motor gasoline components, space heating, and other fuel use. The petrochemical industry is a major consumer of NGLs. For example, ethane is the main foundation of olefins such as ethylene, and natural gasoline is mainly used as a motor fuel component. The remaining gas, namely dry gas or methane (C1), is delivered to residential, commercial, and industrial consumers by pipelines. However, HGLs that are extracted at the oil refineries are usually converted to olefins such as ethylene, propylene, normal butylene, and isobutylene to make resins, plastics, and adhesives. Natural gas plants do not produce olefins — see Wamsley (2000) and the HGLs page by the U.S. Energy Information Administration for more detail. In this paper, we only focus on the NGLs and investigate the impact of oil price shocks on them. Although the market size of NGLs is relatively small compared to oil and refined products, the market is growing rapidly in the United States. Since the evolution of the U.S. unconventional oil in 2006, total field production of NGLs increased from just over 1.7 million barrels per day (MMBPD) in 2006 to nearly 5.4 MMBPD in 2021. According to the Energy Information Administration, in 2020, total HGLs use accounted for about 18% of total U.S. petroleum consumption.

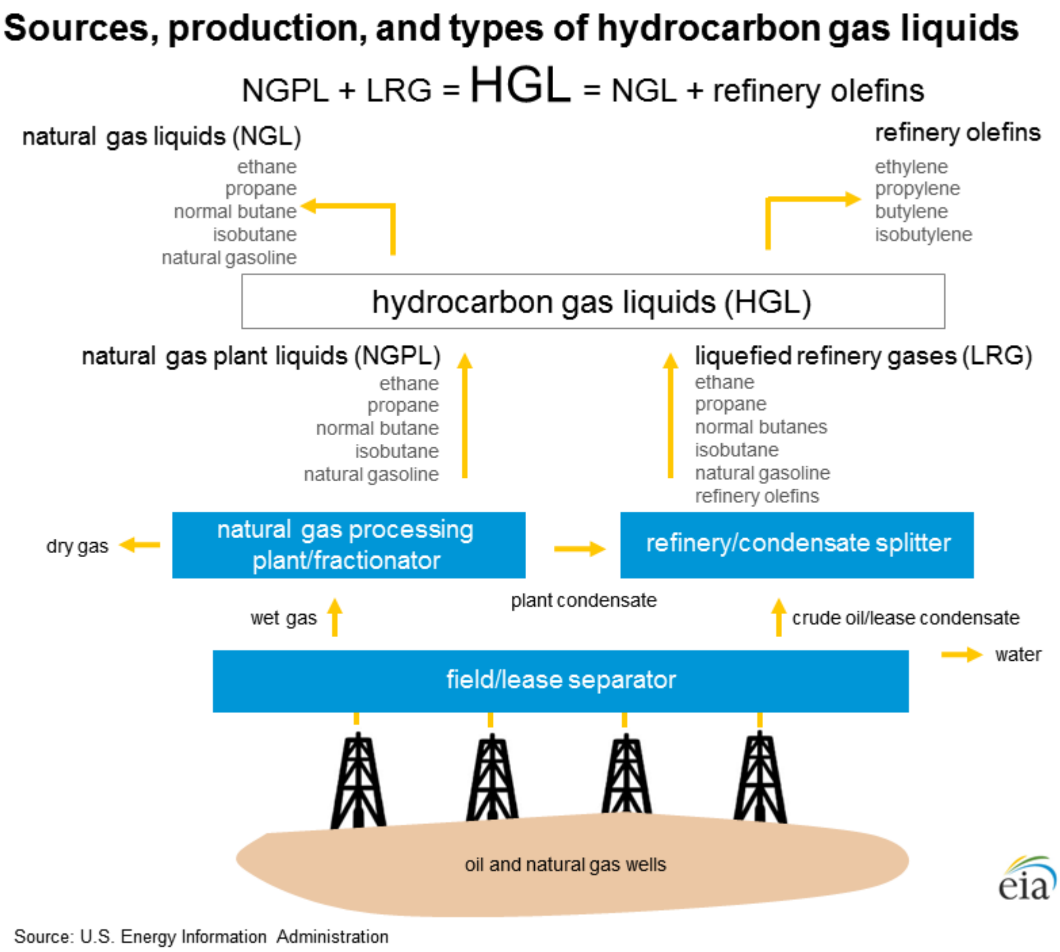

Figure 1. Taxonomy of hydrocarbon gas liquids (HGL).

In the presence of prolonged periods of low natural gas prices and technologies that extract these valuable liquefiable hydrocarbons from raw natural gas, the production of NGLs is a key source of income for gas producers. Therefore, NGLs value eventually impacts overall gas revenue and consequently the stock returns of the oil and gas companies that own the wells and deliver extracted raw natural gas for processing. In addition, as Miles (2014) and Boersma et al. (2015) discuss, the development of NGLs may lead to upstream, midstream, and downstream investment — such as development in gas reserves (upstream), an increase in the capacity of natural gas processing plants and fractionation (midstream), and the development of petrochemical plants (downstream). As highlighted by Kang et al. (2017) and Diaz et al. (2016) oil market shocks and corresponding uncertainties have major implications on oil and gas industry investment. Further, it should be noted that investment in NGLs helps to reduce environmental pollutants as greenhouse gas emissions released by natural gas-based products are lower than oil- or coal-based products.

The price of NGLs is determined locally at major trading hubs in three major regional markets including the North American, the European, and the East Asian market. We hypothesize that the global oil market shocks have a significant impact on NGLs prices. We propose three channels underlying the relationship between oil prices and NGLs prices. First, although the largest share of NGLs production originates from natural gas processing plants and fractionators, a considerable amount is produced from the crude oil at the refineries. For example, in 2020, gas plants produced 84% of propane in the United States, and the remaining 14% come from the refineries. So, we expect propane prices to be highly correlated with crude oil prices. Second, NGLs such as natural gasoline and normal butane are blendstock for producing finished gasoline or petrochemical feedstocks. So, the prices of natural gasoline and normal butane are highly linked to gasoline which is mainly come from crude oil. Third, there are many gas hubs at the European and East Asian markets where gas prices are formed using oil indexation mechanisms (compared to the gas-on-gas completion mechanism that gas prices are formed by the interplay of supply and demand of natural gas) — see Rui et al. (2020) for more details. So, we expect that any change in oil prices would change the price of natural gas and consequently those of NGLs. Therefore, changes in the crude oil market influence the prices of NGLs either directly or indirectly.

In this paper, we investigate how different sources of oil price changes, including 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), might impact the prices of NGLs. Following recent papers by Kassouri et al. (2021) and Kassouri and Altintas (2021), we hypothesize that heterogeneous oil price shocks have different effects on the prices and consumption of NGLs, and consequently have different implications on upstream, midstream, and downstream investments.

3. Data

We use monthly data from 1985:1 to 2020:4, a total of 424 observations, for the United States. The structural vector autoregression (VAR) is employed to model multivariate time series of $z_t = (\Delta prod_t, rea_t, rpo_t, rpngl_t)'$, where $\Delta prod_t$ is the global crude oil production in percent change, rea_t is a measure of global real economic activity, rpo_t is the real price of oil, and $rpngl_t$ is the real price of a NGL product, either ethane, propane, normal butane, isobutane or natural gasoline.

The world oil production data is available in diffrent publications of the Monthly Energy Review, the U.S. Department of Energy. We compute the log differences of world crude oil production for $\Delta prod_t$. Regarding rea_t, we use the detrended real freight rate index of Kilian's (2009) which is available in his personal webpage. This index measures the component of global real economic activity that drives demand for industrial commodities in global markets. The global real economic activity index

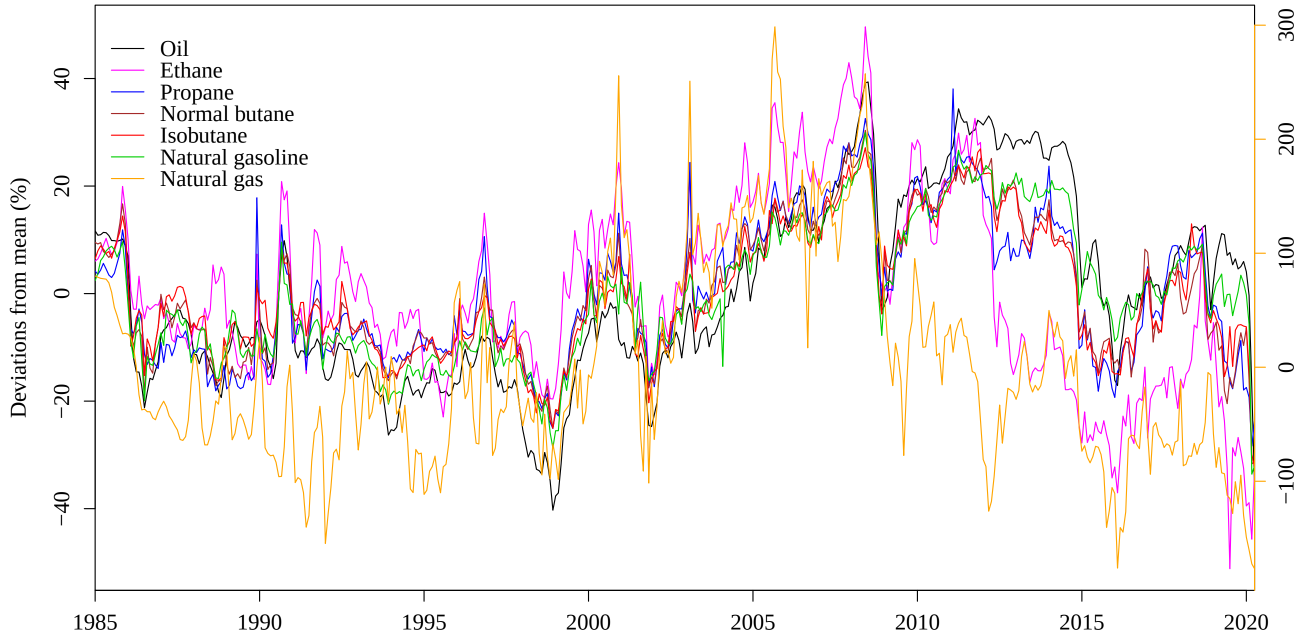

Figure 2. Real crude oil, natural gas liquids (NGLs) and natural gas prices, 1985:M1−2020:M4.
Note: The natural gas price is shown on the y_2 axis and the other prices are on the y_1 axis.

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; whether the detrended freight rate index is an adequate reflection of the overall economic climate is an issue beyond the scope of this paper. See Kilian (2009) for more details regarding the construction of this measure of global real economic activity. For the crude oil price, we use the U.S. composite refiners' acquisition cost of crude oil (RAC), as compiled by the U.S. Department of Energy. As for the NGL prices, we use the North American spot purity ethane price, the North American spot LPG propane price, and the normal butane, isobutane, and natural gasoline prices (all in dollars per gallon), as compiled by Bloomberg. We divide each price by the U.S. CPI to obtain the corresponding real price. Figure 2 shows the historical evolution of the crude oil, natural gas, and the five NGL prices over the sample period. Tables 1 and 2 report the contemporaneous correlations among the series in logged levels and growth rates, respectively. Figure 3 shows the logged nominal price (on the y_1 axis) and its growth rate (on the y_2 axis) for each of the crude oil and the five NGL.

Table 1. Contemporaneous correlations between logged nominal prices, 1985:M1−2020:M4.

	Ethane	Propane	Normal butane	Isobutane	Natural gasoline	Crude oil	Natural gas
Ethane	1						
Propane	0.84	1					
Normal butane	0.81	0.98	1				
Isobutane	0.79	0.97	0.99	1			
Natural gasoline	0.72	0.95	0.96	0.97	1		
Crude oil	0.67	0.92	0.94	0.96	0.98	1	
Natural gas	0.82	0.83	0.79	0.77	0.74	0.70	1

Table 2. Contemporaneous correlations between differenced logged nominal prices, 1985:M1−2020:M4.

	Ethane	Propane	Normal butane	Isobutane	Natural gasoline	Crude oil	Natural gas
Ethane	1						
Propane	0.65	1					
Normal butane	0.57	0.78	1				
Isobutane	0.53	0.67	0.78	1			
Natural gasoline	0.48	0.59	0.63	0.59	1		
Crude oil	0.37	0.38	0.42	0.46	0.54	1	
Natural gas	0.35	0.30	0.24	0.21	0.16	0.14	1

In our system of VAR equations, we adapt the demeaned forms (deviation from the mean) of the natural logs of the real price of oil (rpo_t) and NGLs ($rpngl_t$) to be consistent with the other variables (i.e. $\Delta prod_t$ and rea_t). Then, all variables are expressed in percent changes. Regarding the stationarity of the logged real crude oil and NGLs prices, although the tests show no evidence of rejecting the unit root hypothesis, they should be stationary if these prices cointegrate with the U.S. consumer price index. However, as Lütkepohl and Netšunajev (2014) and Kilian and Murphy (2014) point out, over differencing may be more harmful than including a unit root series in levels. Therefore, to be on the safe side, we follow Kilian (2009) and employ the log levels of the real crude oil and NGLs prices.

4. The structural VAR model

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

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

where $\boldsymbol{\gamma}$ 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, $\boldsymbol{\varepsilon}_t = \left(\varepsilon_t^{\Delta prod}, \varepsilon_t^{rea}, \varepsilon_t^{rpo}, \varepsilon_t^{rpngl}\right)'$.

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

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

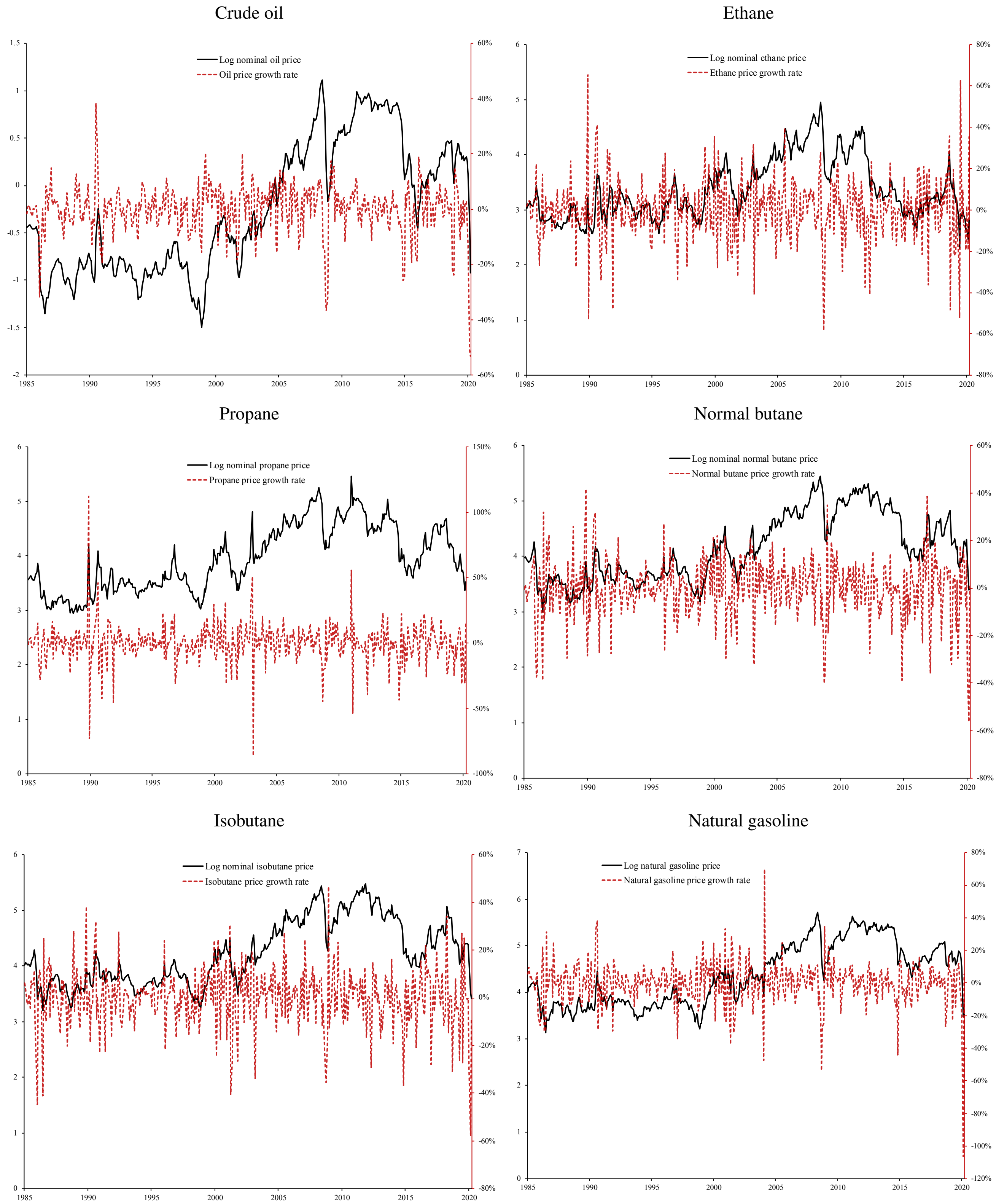

Figure 3. Logged nominal crude oil and NGLs prices (all in $/gallon), 1985:M2−2020:M4.

where $\boldsymbol{\alpha} = \boldsymbol{B}^{-1}\boldsymbol{\gamma}$, $\boldsymbol{A}_i = \boldsymbol{B}^{-1}\boldsymbol{\Gamma}_i$, 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 first estimate the reduced form VAR in (2), and then impose zero (exclusion) restrictions on matrix $\boldsymbol{B}$ to recover the structural shocks. We finally compute the impulse response functions to trace the impact of the structural shocks on the NGLs prices.

As discussed in Section 2, the NGL markets are regional and segmented while the crude oil markets are global. This means that shocks in the NGL markets do not impact the price of crude oil simultaneously. Therefore, similar to Kilian and Park (2009), we impose a block-recursive structure on the contemporaneous relationship between the underlying structural disturbances and the reduced-form VAR innovations. 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

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

We can think of (3) as being composed of two blocks: the first block comprises the first three equations and describes the oil market while the second block only consists of the fourth equation and specifies the NGL market.

As in Kilian (2009) and Jadidzadeh and Serletis (2017), the fluctuations in the real price of oil are attributed to three structural shocks: (1) shocks to the global supply of crude oil entitled as “oil supply shocks,” (2) shocks to the global demand for all industrial commodities (including crude oil) that are driven by the global business cycle, entitled as “aggregate demand shocks,” and (3) oil-market specific demand shock, entitled 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. It should be noted, however, that the structural shock in the second block is not a true structural shock. It is an innovation to the NGL price which is not driven by the shocks that are specific to the global crude oil market.

To uniquely solve for the structural parameters in (1) and indentify the model, we presume that, in the short run, the global oil market is represented by a vertical supply curve and a downward-sloping demand curve. This identification scheme is consistent with the block-recursive structure implying that oil demand shocks do not simultaneously impact crude oil supply. Therefore, we impose zero (exclusion) restrictions on the elements of $\boldsymbol{B}^{-1}$ so that $\boldsymbol{B}^{-1}$ or $\boldsymbol{B}$ is lower triangular. That is, the zero restrictions in the first row of $\boldsymbol{B}^{-1}$ ($b_{12} = b_{13} = b_{14} = 0$) implies that rea_t, rpo_t and $rpngl_t$ do not have contemporaneous effects on $\Delta prod_t$, but only affect it with a lag. The restrictions in the second row of $\boldsymbol{B}^{-1}$ ($b_{23} = b_{24} = 0$) imply that shocks to the oil-specific demand and the NGLs market do not have a contemporaneous effect on rea_t, but affect it only with a lag. The restriction in the third row of $\boldsymbol{B}^{-1}$ ($b_{34} = 0$) implies that rpo_t instantaneously reacts to unanticipated oil supply shocks (that shift the vertical supply curve), as well as to both demand shocks, including aggregate demand shocks and oil-specific demand shocks (that shift the demand curve), but that the rpo_t does not contemporaneously react to $rpngl_t$. Finally, no restriction is imposed on the last row of $\boldsymbol{B}^{-1}$ matrix. This implies that the variables in the first block (i.e. $\Delta prod_t$, rea_t and rpo_t) are treated as predetermined with respect to the real NGLs price ($rpngl_t$), meaning that the real NGLs price changes instantaneously in response to all three shocks in the crude oil market.

5. Structural VAR estimates

We follow Kilian (2009) and assume $p = 24$ in (2) and estimate the reduced form VAR by the least-squares method equation by equation. We then identify the structural parameters of the SVAR model, and finally recover the structural moving average representation of the model to calculate the impulse responses. The (cumulative) impulse response functions to one-standard deviation shocks, together with one- and two-standard error bands, are based on the recursive-design wild bootstrap of Gonçalves and Kilian (2004). It is to be noted that our main objective is to investigate the effects of structural shocks in the crude oil market on each of the NGLs' prices.

In Figures 4–8, we present the impulse responses (in panel A) and the cumulative impulse responses (in panel B) of the real price of crude oil (in the first row) and each of the NGL prices (in the second row) 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), 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 oil.

As can be seen in Figures 4–8, the three structural shocks in the crude oil market have very different effects on the real price of crude oil and the real NGL price. In general, the effect of each structural shock is very similar on the real price of oil and each of the NGL prices. Moreover, these shocks show similar effects across the NGL products. For example in the panel A of Figure 4, an unexpected decline in the supply of crude oil has a sustained positive effect on the real price of crude oil and ethane 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 ethane, although the response of the real price of ethane gets insignificant after 14 months based on the one-standard error bands; whereas an unexpected increase in the precautionary demand for oil causes immediate and sustained increases in both prices. The impulse responses on the other NGL prices — propane, normal butane, isobutane and natural gasoline — presented in Figures 5–8 are very similar to those of ethane.

The impulse responses reported in panel A of Figures 4–8 show the timing and magnitude of the responses of the real price of crude oil and the real NGL prices to one-time structural shocks in the crude oil market. In panel B we report (in the same fashion as in panel A) the cumulative impulse responses of the real price of crude oil and the real NGL price to each of the three supply and demand shocks in the crude oil market. For example, panel B of Figure 4 shows that the cumulative impulse responses of the real ethane price depend on the underlying cause of the increase in the real price of crude oil. The first graph on the lower row of panel B in Figure 4 shows that shocks to the supply of crude oil have no impact on the real price of ethane (the estimated impulse response function is not statistically distinguishable from zero after 15 months). 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 ethane price based on one- and two-standard error bands. Finally, the response of the real price of ethane to a shock in the precautionary demand for crude oil is positive and statistically significant according to the one- and two-standard error bands. The cumulative impulse responses for the other NGL prices are very similar to those for ethane.

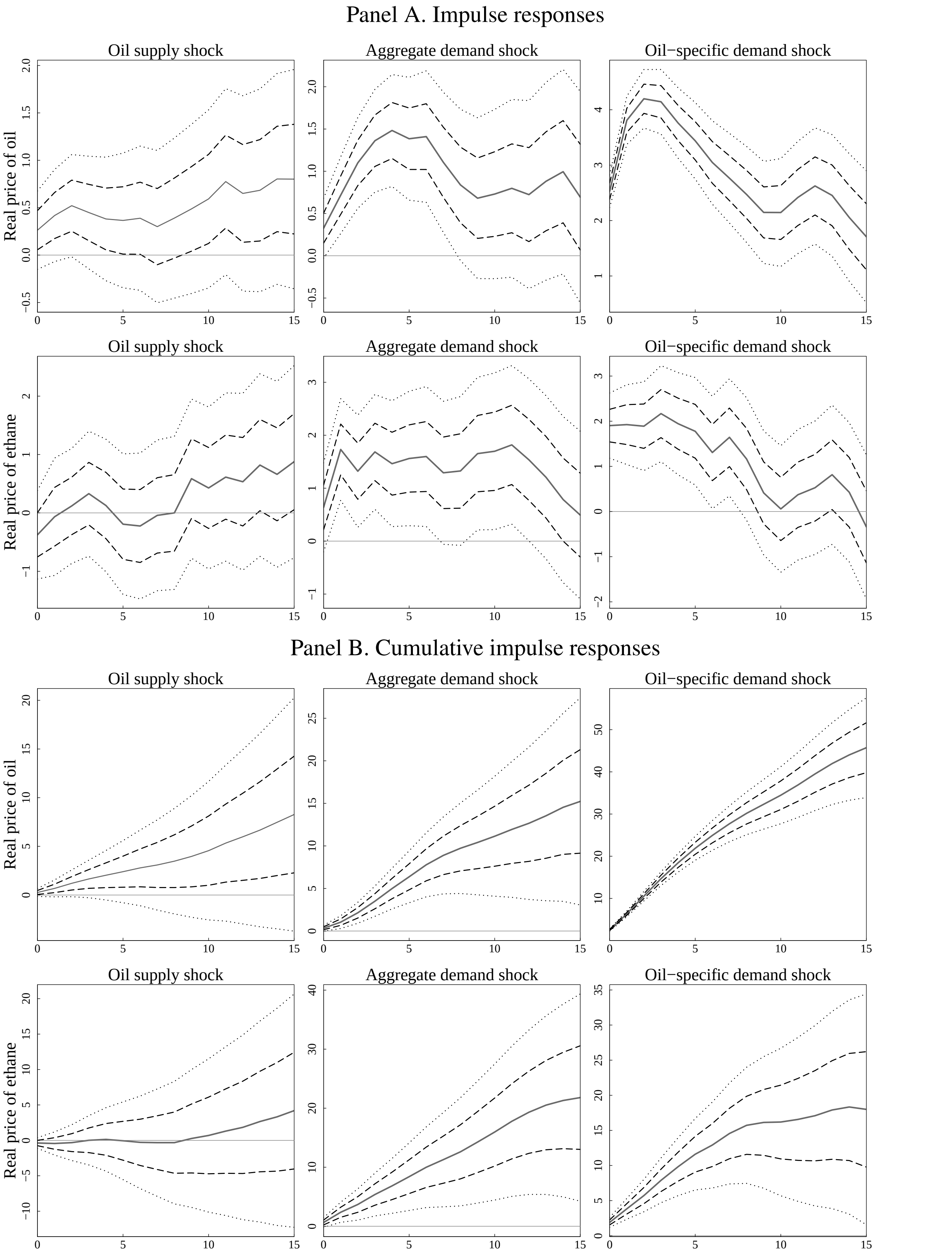

Figure 4. Responses and cumulative responses of *ethane* to one-standard deviation structural shocks in the crude oil market: Point estimates with one- and two-standard error confidence bands.

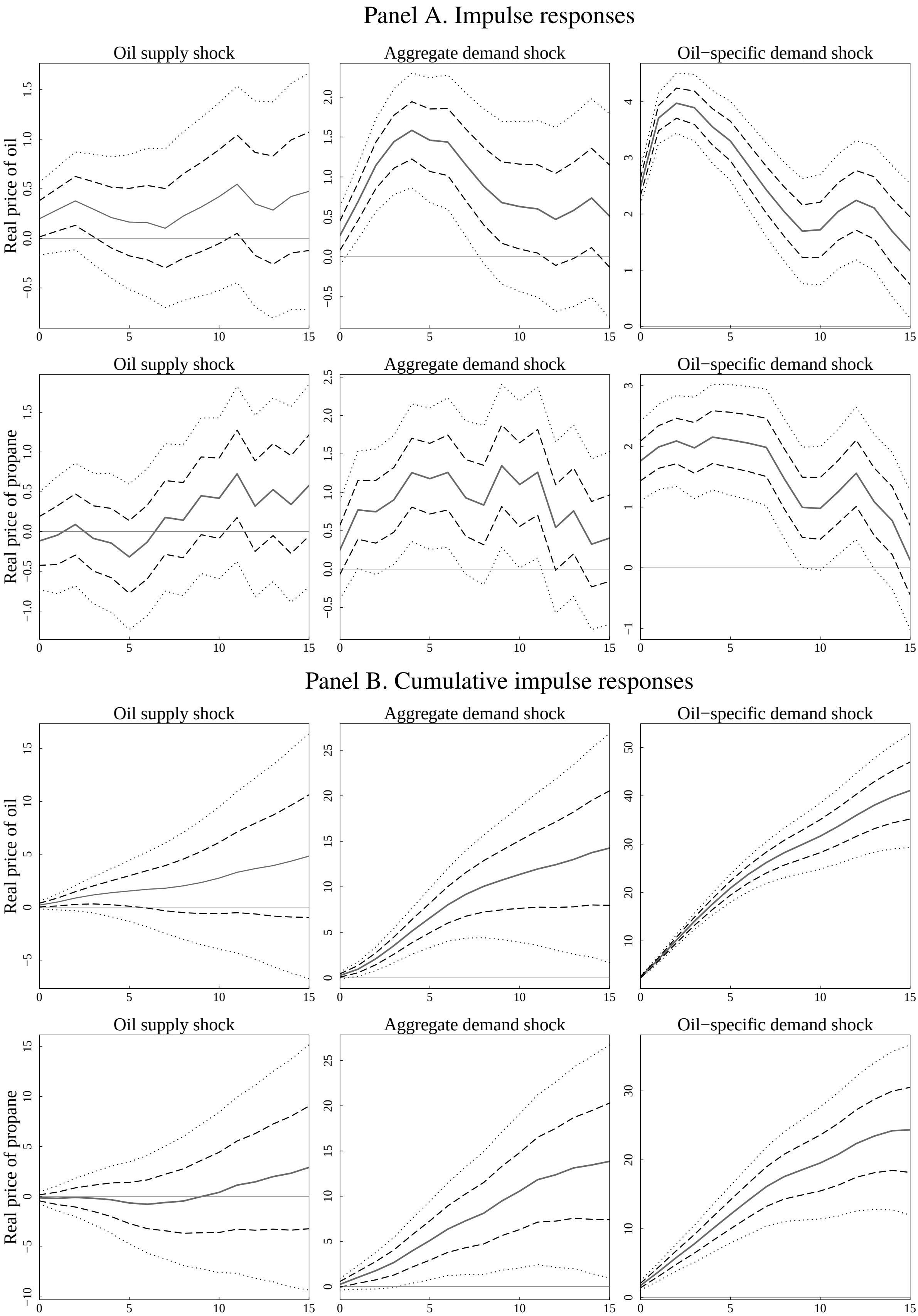

Figure 5. Responses and cumulative responses of *propane* to one-standard deviation structural shocks in the crude oil market: Point estimates with one- and two-standard error confidence bands.

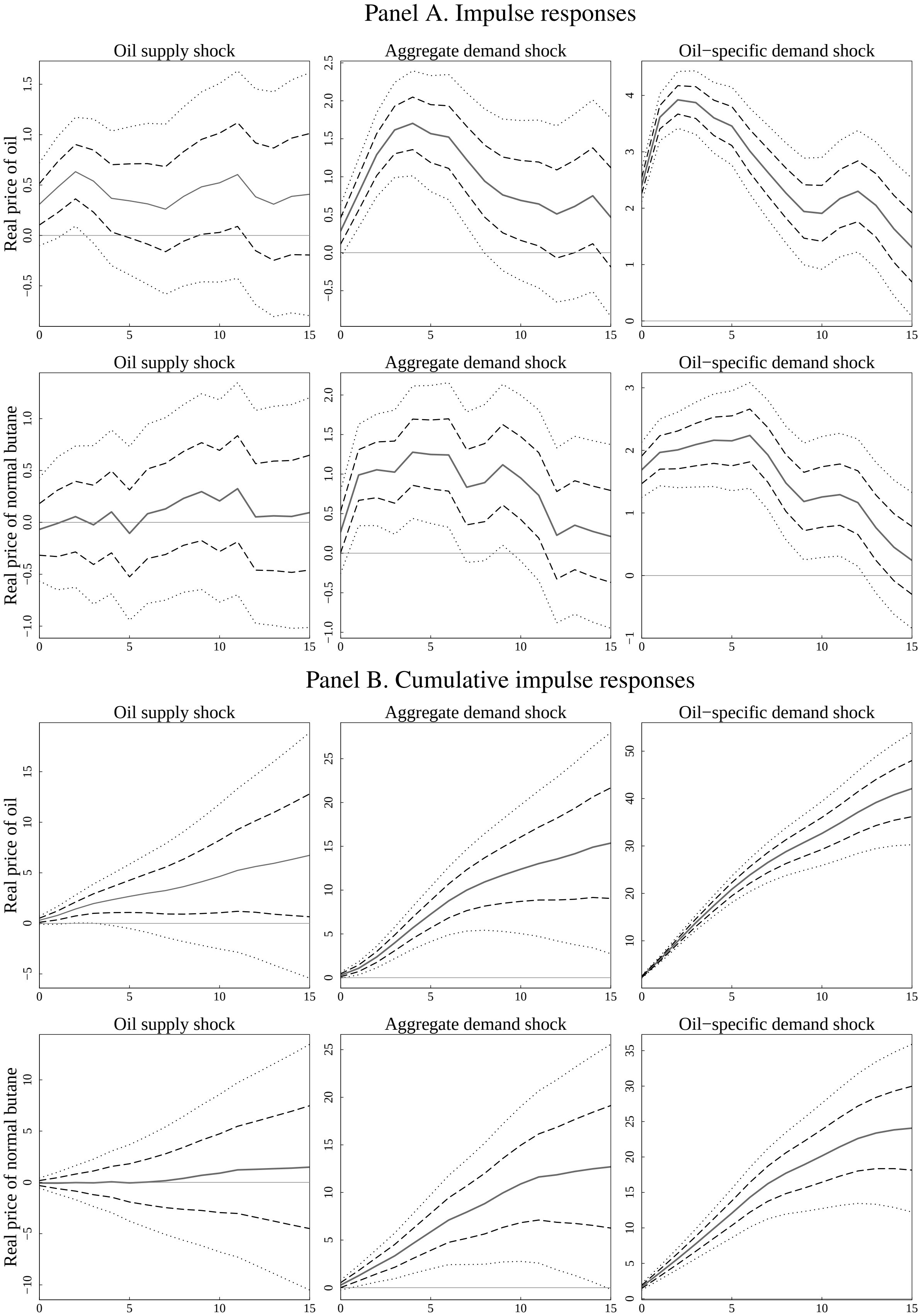

Figure 6. Responses and cumulative responses of *normal butane* to one-standard deviation structural shocks in the crude oil market: Point estimates with one- and two-standard error confidence bands.

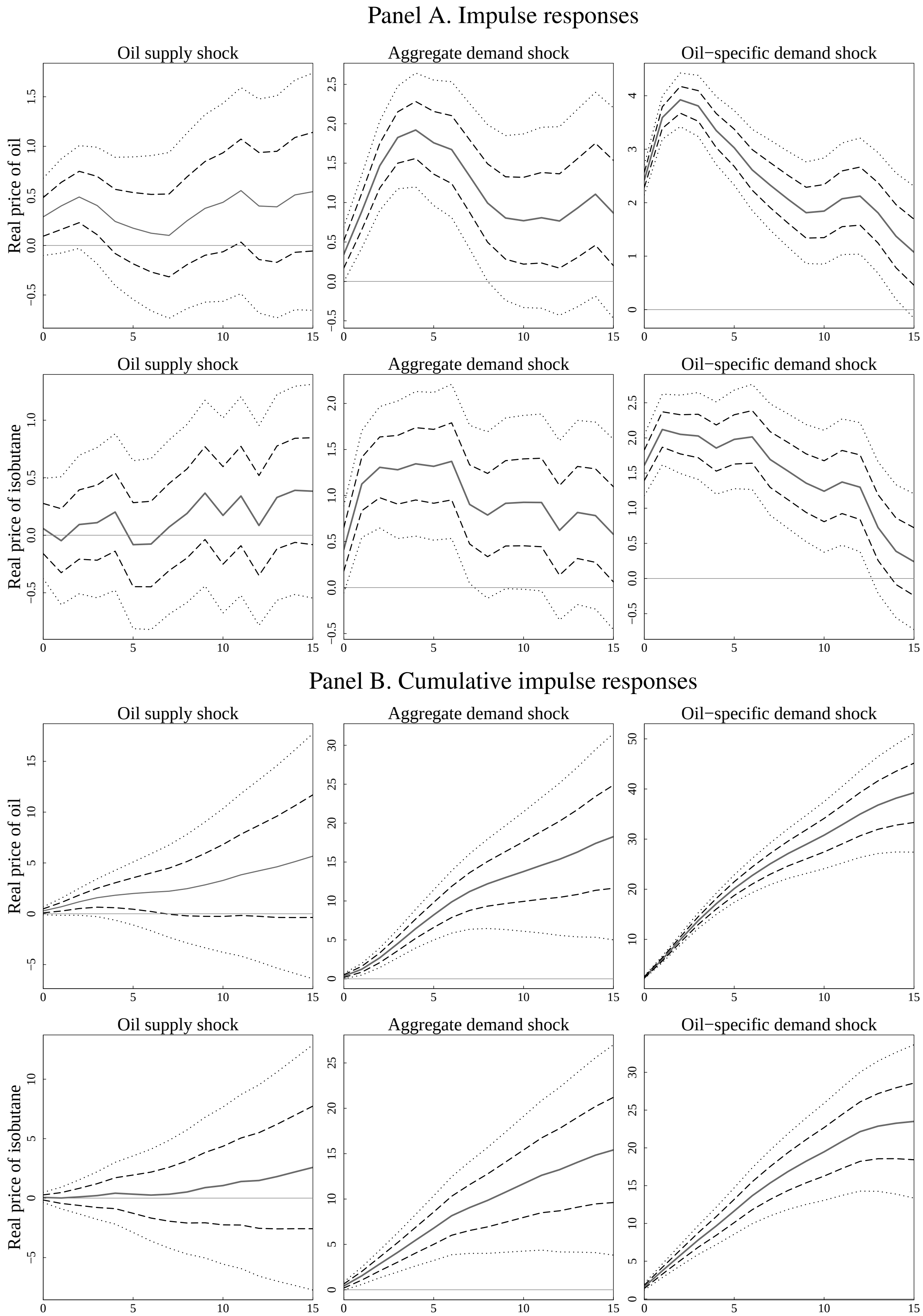

Figure 7. Responses and cumulative responses of *isobutane* to one-standard deviation structural shocks in the crude oil market: Point estimates with one- and two-standard error confidence bands.

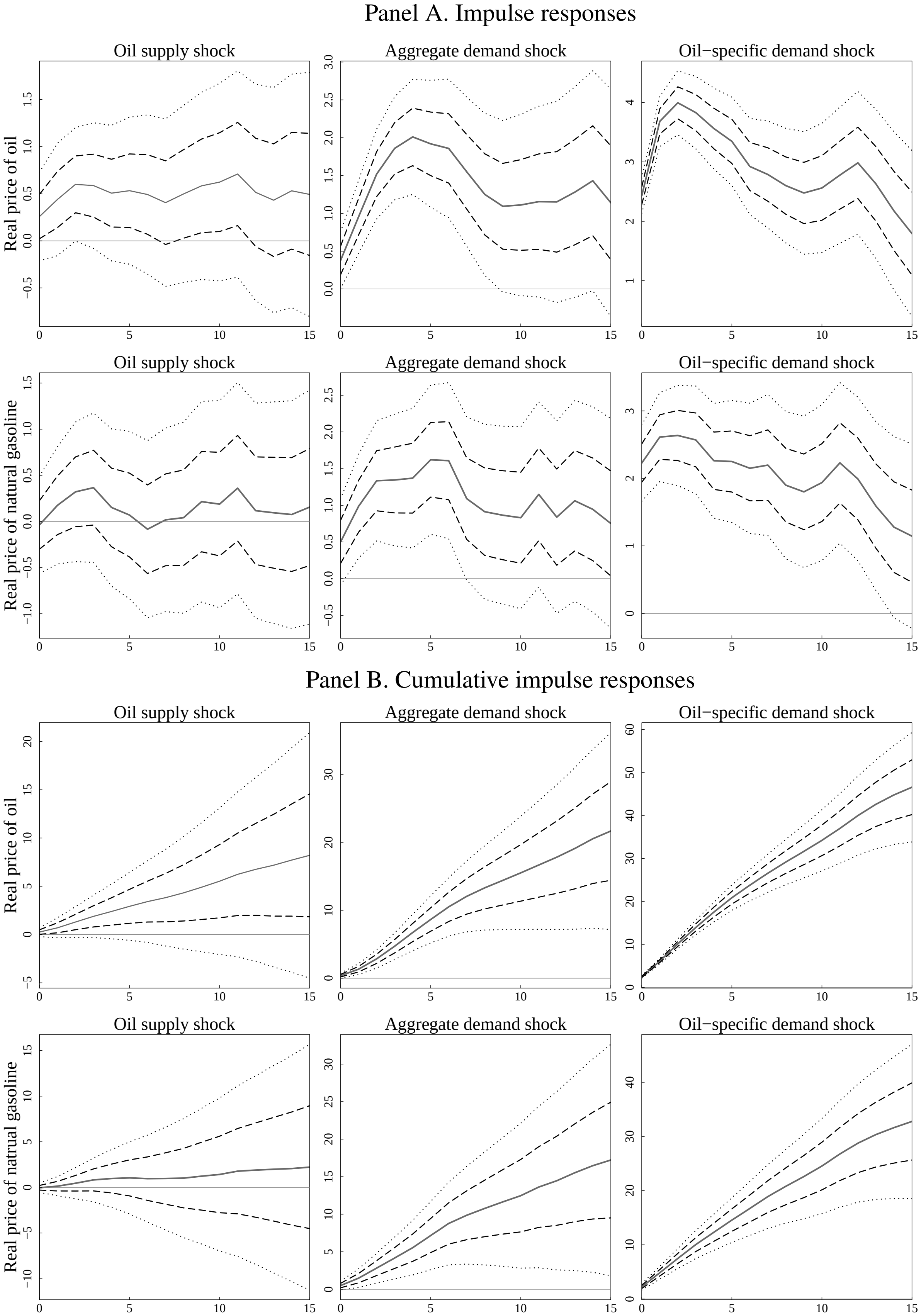

Figure 8. Responses and cumulative responses of *natural gasoline* to one-standard deviation structural shocks in the crude oil market: Point estimates with one- and two-standard error confidence bands.

The forecast-error-variance decompositions in Tables 3-7 quantify the effects of the structural shocks on the real price of ethane, propane, normal butane, isobutane and natural gasoline, respectively. Although in the short-run the effects of the two structural shocks in the crude oil market (the oil supply shock and aggregate demand shock) on the NGL prices are negligible (for example, the combined explanatory power of these two shocks on impact is less than 3% of the variation of each of the NGL prices), the explanatory power increases as the forecast horizon increases. The interesting result is the high explanatory power of oil-specific demand shocks in the short run on NGL prices; they explain 13%, 18%, 28%, 28% and 45% of variation in the real price of ethane, propane, normal butane, isobutane and natural gasoline, respectively.

Table 3. Percent contribution of supply and demand shocks in the crude oil market to the overall variability of the real price of *ethane*.

	Shock			
Horizon	Oil supply	Aggregate demand	Oil-specific demand	Other
1	0.52	1.50	13.35	84.63
2	0.28	6.52	14.03	79.17
3	0.22	7.20	15.24	77.34
15	1.41	16.88	15.75	65.96
∞	4.80	19.40	34.71	41.08

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

Table 4. Percent contribution of supply and demand shocks in the crude oil market to the overall variability of the real price of *propane*.

	Shock			
Horizon	Oil supply	Aggregate demand	Oil-specific demand	Other
1	0.08	0.36	18.03	81.52
2	0.06	2.30	24.74	72.90
3	0.07	3.29	30.92	65.73
15	1.11	9.35	28.92	60.62
∞	4.94	22.26	23.81	48.99

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

In the long run, the oil supply shock, the aggregate demand shock, and the oil-market specific demand shock together account for about 59%, 51%, 56%, 59% and 57% of the variability in the real price of ethane, propane, normal butane, isobutane, and natural gasoline price, respectively. This suggests that structural shocks in the global crude oil market are an important fundamental for the NGL markets, with the largest contributor being the precautionary demand shocks in the case of ethane, propane and natural gasoline (accounting for about 35%, 24%, 35%, respectively), followed by aggregate demand shocks (accounting for about 19%–22%), and oil supply shocks (accounting for about 2%–5%). The largest contributor in the normal butane and isobutane markets is the aggregate demand shocks (accounting for about 28% and 31% , respectively), followed by precautionary demand shocks (accounting for about 24% and 23%, respectively), and oil supply shocks (accounting for about 5%). The rest of the variation in the NGL prices (accounting for about 41%–48%) is attributed to market-specific shocks in each of the NGL market or generally other shocks.

Table 5. Percent contribution of supply and demand shocks in the crude oil market to the overall variability of the real price of *normal butane*.

	Shock			
Horizon	Oil supply	Aggregate demand	Oil-specific demand	Other
1	0.05	0.71	28.02	71.23
2	0.02	5.05	32.37	62.55
3	0.03	7.36	36.67	55.94
15	0.32	11.14	37.96	50.59
∞	4.36	27.83	23.59	44.22

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

Table 6. Percent contribution of supply and demand shocks in the crude oil market to the overall variability of the real price of *isobutane*.

	Shock			
Horizon	Oil supply	Aggregate demand	Oil-specific demand	Other
1	0.04	1.86	28.11	69.99
2	0.03	7.30	36.03	56.64
3	0.05	10.97	39.43	49.56
15	0.60	14.14	35.38	49.88
∞	5.03	30.54	23.39	41.05

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

Table 7. Percent contribution of supply and demand shocks in the crude oil market to the overall variability of the real price of *natural gasoline*.

	Shock			
Horizon	Oil supply	Aggregate demand	Oil-specific demand	Other
1	0.01	2.31	45.35	52.32
2	0.15	5.65	54.17	40.03
3	0.42	9.27	57.69	32.62
15	0.48	17.12	60.50	21.91
∞	2.66	19.83	34.85	42.67

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

In Figures 9–13 we present monthly structural residuals of model (1) estimated for each of ethane, propane, normal butane, isobutane and natural gasoline markets, respectively. All structural shocks are constructed to have the same variance, and the observations start in 1987:1, reflecting the lags used up in estimating the VAR model. As in Kilian (2010), the largest aggregate demand shock occurred in late 2008, during the global financial crisis, the largest positive oil-market specific demand shock occurred in 1990 after Iraq's invasion of Kuwait, and the largest negative oil-market specific shock occurred in early 1986 with the collapse of the Organization of the Petroleum Exporting Countries (OPEC). Most recent example is the impact of COVID-19 on oil prices. The structural oil supply shocks are episodically positive and negative after March 2019 (see the first plots in Figures 9–13). There are fairly large negative supply shocks from May to September 2019, then the market experiences positive supply shocks for the rest of 2019 and another negative supply shocks in the beginning of 2020. In general, the structural aggregate demand shocks show both large positive and negative spikes after the incidence of COVID-19 (see the second plots). Although the structural oil-specific demand shocks (the third plots) are signaling high precautionary demands in 2019, it drops dramatically in early 2020 which is the main cause for oil price falls. It is also to be noted that although large crude oil shocks are important in explaining movements in real NGL prices, a sequence of small shocks of the same sign and type, occurring over several periods, may have more dramatic effects on the real prices of NGL than any single large demand or supply oil shock. As Kilian (2010) put it, in his investigation of fluctuations in gasoline prices, "this is particularly true of the sequence of positive aggregate demand shocks after 2002."

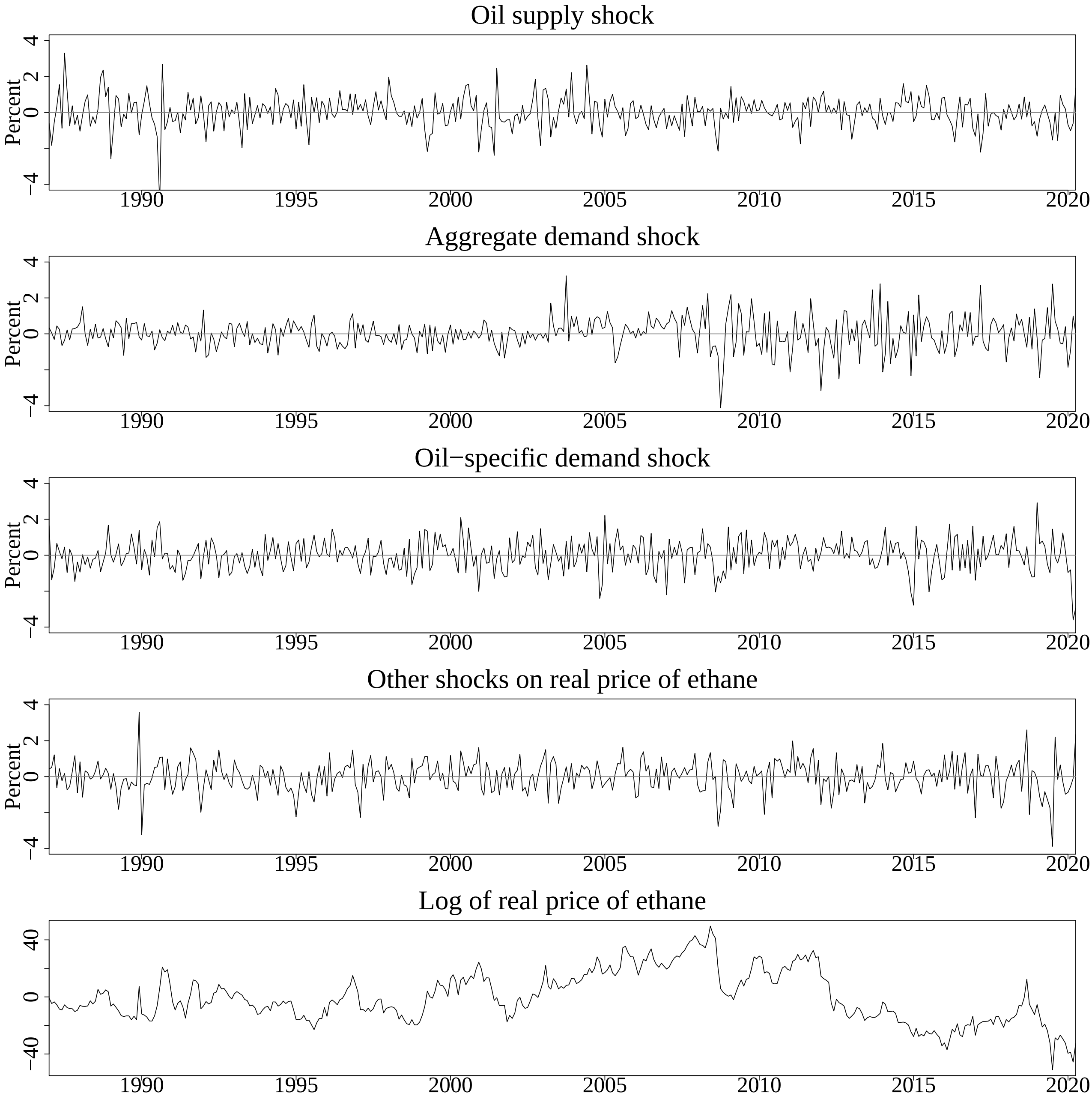

Figure 9. History of demand and supply shocks on *ethane* prices, 1987:M1-2020:M4.

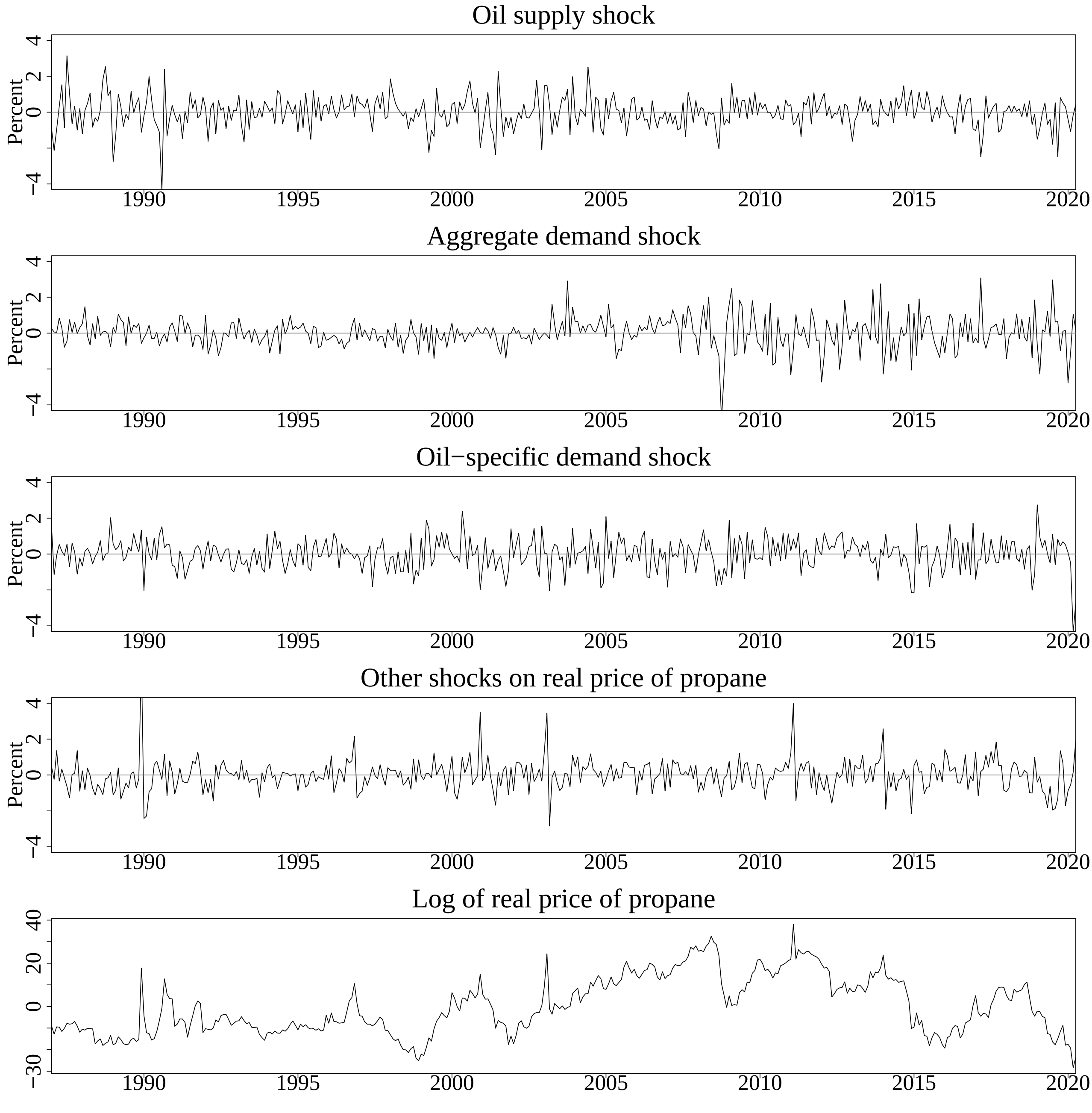

Figure 10. History of demand and supply shocks on *propane* prices, 1987:M1-2020:M4.

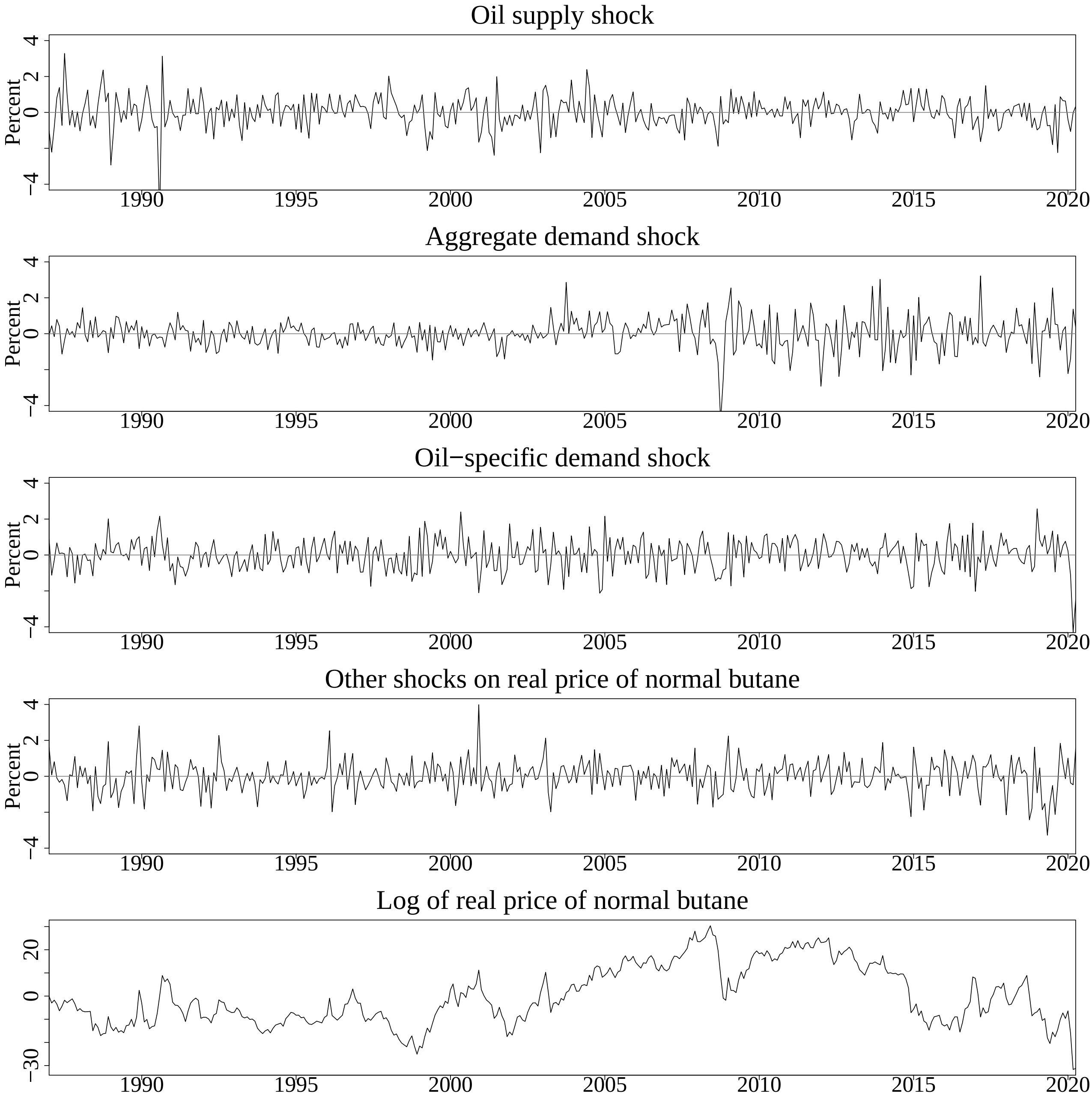

Figure 11. History of demand and supply shocks on *normal butane* prices, 1987:M1-2020:M4.

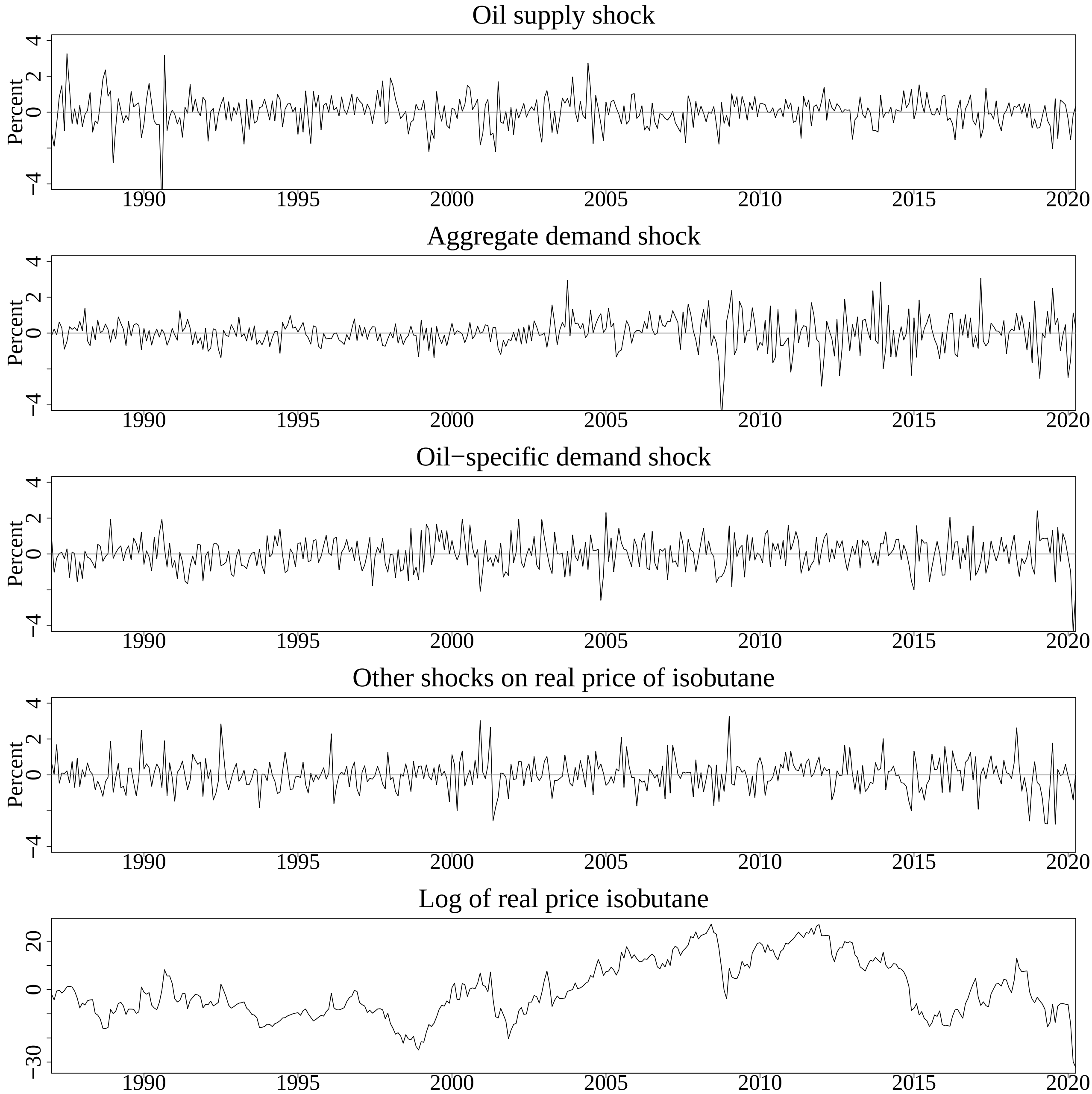

Figure 12. History of demand and supply shocks on *isobutane* prices, 1987:M1-2020:M4.

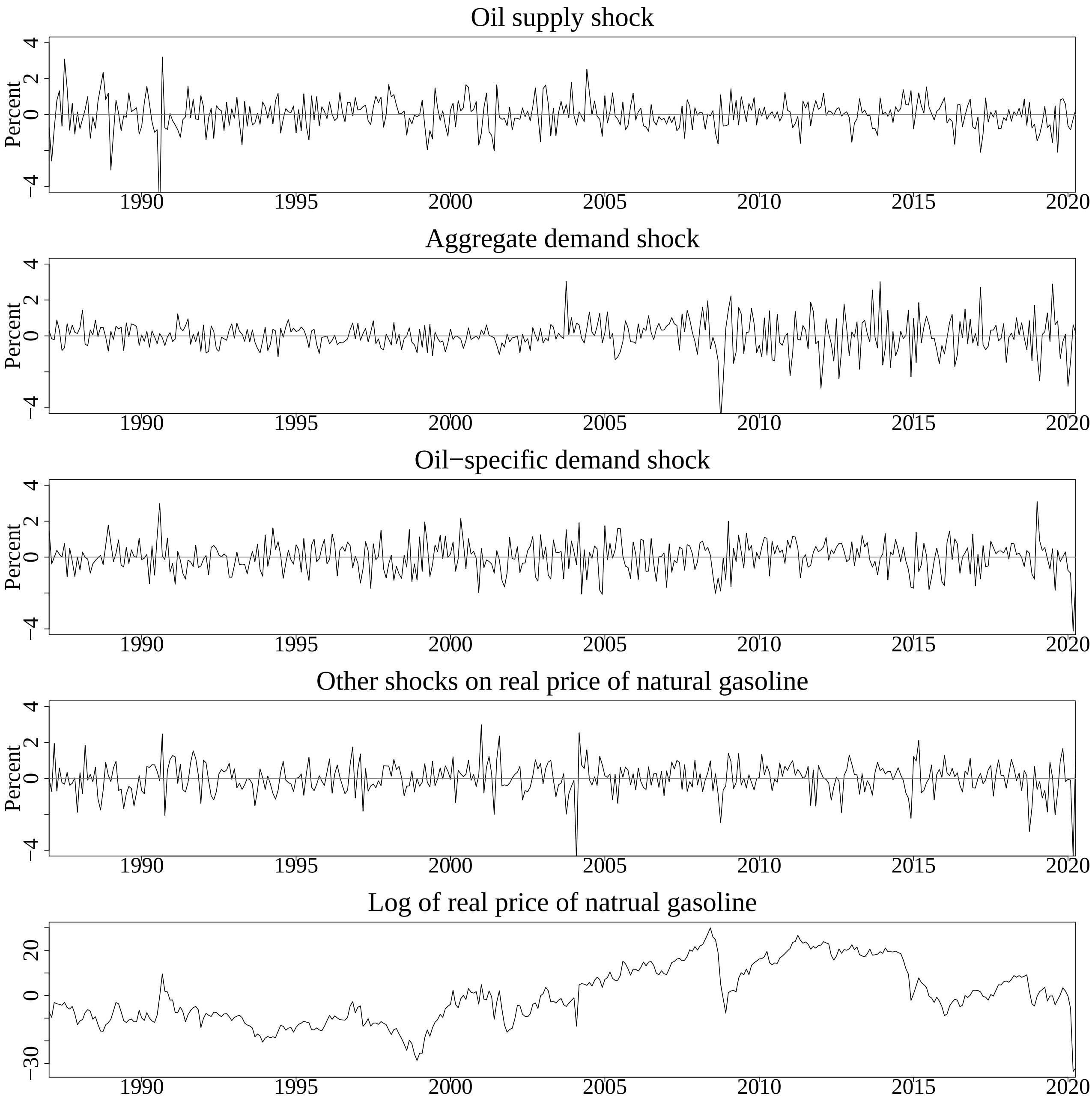

Figure 13. History of demand and supply shocks on *natural gasoline* prices, 1987:M1-2020:M4.

6. Conclusions

We have disentangled the causes underlying crude oil price changes and investigate the impact of oil market structural shocks on the prices of natural gas liquids (NGLs). We follow Kilian (2009) and focus on the structural shocks that explain the volatility in the global oil market, instead of focusing on an aggregate oil price impact. Our results, based on an identified structural VAR and monthly data from 1985:1 to 2020:4, show that more than 55% of the variation in the real price of NGLs is explained by the structural shocks in the global crude oil market in the long run. We also show that shocks in the NGLs market account for about 41%–45% of the long run variability of the real prices of NGLs, thus causing episodic decoupling of the real prices of NGLs from the real price of crude oil.

Based on our findings, we reach the following policy implications for natural gas investors and policymakers:

- All shocks, including negative supply and positive demand shocks, affect NGLs prices, but the effects of negative supply shocks on NGLs prices are temporary.
- Demand-side shocks have permanent and persistent impacts on NGLs prices and should be of main concern to investors aiming to develop gas wells and NGLs producing technologies.
- Gas producers can improve their profitability by adapting their investments, paying attention to the different sources of oil price shocks and the heterogeneous effects of oil demand and oil supply shocks on the different types of natural gas liquids.

Conflict of interest

All authors declare no conflicts of interest in this paper" in this section.

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