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ENERGY PRICE SHOCKS AND THEIR EFFECTS ON THE MAIN MACROECONOMIC VARIABLES: A BAYESIAN SVAR ANALYSIS

by Luigi Infante*, Francesca Lilla* and Michela E. Pasetto*

Abstract

This paper integrates the global crude oil market and the European natural gas market into a Bayesian SVAR model to investigate the sources and macro effects of energy price movements. We identify shocks to oil and gas supply and demand. The contribution of oil supply shocks in explaining real oil-price movements is smaller than that of oil-specific demand shocks. Similarly, gas-specific demand shocks contribute more than gas supply shocks to the real gas-price movements. More specifically, gas-specific demand accounts for about 60 per cent of the gas price movements observed between March and December 2022, whereas supply factors contributed for about 30 per cent. In 2023, oil supply and aggregate demand shocks had a non-negligible role in explaining the swing in the real price of oil. Finally, the shocks arising in both oil and gas markets negatively affect Italian industrial production, value added and investment in energy-producing, energy-intensive and non-energy intensive sectors. The impacts are stronger for energy-intensive sectors in the case of an adverse oil supply shock.

JEL Classification: C32, Q43, D25.

Keywords: energy prices, crude oil, natural gas, Bayesian VAR, macroeconomic impacts, energy-producing, energy-intensive and non-energy-intensive sectors.

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1 Introduction[1]

In conjunction with the exceptional economic recovery that followed the COVID-19 pandemic and, later, the Russian invasion of Ukraine, energy prices experienced a period of extremely high growth. During the summer of 2022 energy prices, in particular gas prices, reached their historical records, spurring a wide debate among policymakers and economists on the potential negative implications for the economy. Based on past experiences, a common concern is that energy price increases are followed by disruptions of production capacity that end up in inflation, higher unemployment and recessions.

In this paper, we assess the relative importance of supply and demand factors in explaining oil and gas market fluctuations and the effects of energy price increases on Italian economic activity (namely industrial production, value added and investment). Our contribution to the literature is twofold. First, we integrate in a comprehensive Structural VAR model the global oil market and the European natural gas market. Second, we provide evidence on the impact of demand and supply shocks in both energy markets on macroeconomic variables, distinguishing the aggregate impacts from the ones specific to energy-producing, energy-intensive and non-energy-intensive sectors.

A large literature, typically based on a structural VAR framework, has attempted to decompose the historical fluctuations in oil prices into different shocks to understand their relative importance. A first wave of analysis (Hamilton, 1983, 2003, 2009) treats price changes as exogenous and as equivalent to oil supply shocks, assuming a close link between the political events in the Middle East and changes in the price of oil. Therefore, the innovation in the oil price equation is included as an exogenous shock, which is equivalent to ordering the oil first in the Cholesky decomposition. A different view, based on the evidence that oil supply shocks explain only part of price fluctuations, suggests that most of the movements in oil prices can be ascribed to shocks to global demand (Barsky and Kilian, 2002) or demand shocks specific to the oil market (Kilian, 2009). Following this idea, the benchmark specification includes the joint dynamics of three variables: the change in oil production, a global activity index and real oil prices. This baseline specification has been extended in many ways. Kilian and Murphy (2014)

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note that another important factor in interpreting short-run comovements of quantities and prices is the behavior of inventories. As a consequence, the trivariate specification has been augmented by including a fourth variable, the change in global crude oil inventories (Kilian and Murphy, 2014; Baumeister and Hamilton, 2015).

The identification methods varied from the recusive structure (Kilian, 2009), to sign restrictions (Kilian and Murphy, 2012; Lippi and Nobili, 2012; Baumeister and Hamilton, 2015) or narrative analysis (Caldara et al., 2019). However, as noted by Baumeister and Hamilton (2019), imposing a short-run oil supply elasticity of zero as in Kilian (2009) or assuming an upper bound for it as in Kilian and Murphy (2012), may map onto implausible values of the oil demand elasticity.

The Bayesian approach proposed by Baumeister and Hamilton (2019) is an attempt to overcome these limitations. It can be thought of as a less restrictive way to impose restrictions on the structural parameters of the VAR while supplementing them with imperfect information about demand and other features of the economic structure.[2]

The literature on the natural gas market relies on the long debate that occurred for the oil market. Using the recursive structural VAR, based on Kilian (2009), Arora and Lieskovsky (2014) show that energy demand shocks explain an important fraction of the natural gas price variation, while a lower fraction of the price variance is explained by supply shocks. Wiggins and Etienne (2017) follow the four-equation approach by Kilian and Murphy (2012), where overground inventories are included in the model. Their results suggest that demand, supply and economic activity shocks explain around 30 percent of the price variance. Rubaszek et al. (2021), using quarterly data from 1978 to 2020, replicate the model by Baumeister and Hamilton (2015) substituting oil variables with gas variables and find that market-specific demand shocks explain almost 80 percent of the natural gas price variability in the short term. Inventory shocks are found to be twice as important as supply shocks for natural gas price dynamics, while the role of economic activity is modest.

Among the attempts to link the crude oil and natural gas markets in a structural VAR, Nguyen and Okimoto (2019) use a recursive natural gas market VAR augmented for the real price of oil. They conclude that oil prices are not responding to gas market shocks, while

[2] Caldara et al. (2019) argue that the selection of the elasticities is essential for understanding sources and consequences of oil market fluctuations, and that seemingly small changes in these elasticities have large effects on the relative importance of demand and supply forces. Small changes in the oil price elasticities, i.e. supply and demand, have large and material implications for quantifying the determinants of fluctuations in oil prices and oil production.

the reactions of gas market variables to natural gas and oil prices are of about the same size. Jadidzadeh and Serletis (2017) do an opposite exercise, by using a trivariate structural VAR model for the crude oil market, enhanced for the real price of gas. Shocks originated in the oil market explain half of the natural gas price variation. In all these papers, only one of the two markets (oil or gas) is specified in a structural way while the other is represented simply by a price equation. Furthermore, for both oil and gas markets, no structural distinction between supply and demand shocks is made.

A closely related strand of the literature focuses on the macroeconomic effects of energy price shocks. Energy, in fact, is a key input in the entire business production process making its price important for the functioning of the economy. Edelstein and Kilian (2007), for instance, argue that changes in firms' investment expenditures is one of the primary channels through which energy price shocks are transmitted to the economy. Furthermore, according to Elder and Serletis (2010), uncertainty about oil prices tends to depress current investment and aggregate output. Alessandri and Gazzani (2023), after identifying gas supply shocks using an external instrument in a VAR model, find that negative shocks to gas supplies cause a decline in industrial production at the Euro Area level, while recently Neri (2024) finds a negative impact of price shocks on consumption and economic activity.

In this paper we proceed in three steps. We first augment the Bayesian SVAR model proposed by Baumeister and Hamilton (2019) for the global oil market with an extra block modeling the European natural gas market and identify five shocks: oil supply, aggregate demand, oil-specific demand, gas supply and gas-specific demand shocks, over the period from January 1996 to December 2023. We next run a local projection exercise of Italian industrial production, value added and investment on the identified shocks[3], covering the period from the 1st quarter of 1999 to the 4th quarter of 2023. Finally, we assess whether and to what extent the results are stronger for sectors more exposed to energy shocks.

Our analysis delivers the following results. Unexpected drops in oil and gas supply negatively affect oil and gas production and cause an increase in energy prices that are persistent and significant. whereas positive oil- and gas-specific demand shocks have the opposite effect. An unexpected increase in oil-specific demand does not cause a significant rise in gas production while it has an impact on real gas prices, although with a one month delay.

[3]In these exercises, the shocks are averaged at quarterly frequency, as illustrated in Section 4. Value added and investment are transformed into real terms by using the harmonized index on consumer prices. Industrial production index is based on production volumes. All the variables are seasonally adjusted. A full description of data used in the analysis is reported in the Appendix.

Based on the historical decomposition, the contribution of oil supply shocks in explaining real oil price movements is smaller than that of oil-specific demand shocks. Similarly, gas-specific demand shocks contribute more than gas supply shocks to the real gas price variability. More specifically, the observed movements in the real price of gas between March and December 2022 are mainly due to gas-specific demand rather than to gas supply, whereas the sharp increase in the real price of oil appears to be the consequence of a rise in oil-specific demand. In 2023, oil supply and aggregate demand shocks have a non-negligible role in explaining the swing in the real price of oil.

We then regress Italian industrial production, value added and investment on the identified shocks, both at the aggregate level (industrial sector) and considering separately energy-producing, energy-intensive and non-energy-intensive sectors. Our results show that adverse oil and gas supply shocks decrease all three aggregate variables. The impacts are stronger for the energy-intensive sectors, compared to energy-producing and non-energy-intensive sectors, when an adverse oil supply shock is considered. The rise of the gas price due to a gas supply shock affects the sectors considered mainly in the short run, peaking after two quarters in almost all cases. An oil-specific and a gas-specific demand shock also have an immediate but transitory negative effect on industrial production, value added and investment. Finally, an unanticipated aggregate demand expansion causes a statistically significant increase in production, value added and investment, for all sectors.

The paper is organised as follows. In Section 2 we present the empirical model and the identification strategy. In Section 3 we discuss the main findings for the global oil market and the European natural gas market. Section 4 investigates how the identified shocks affect industrial production, value added and investment. Finally, Section 5 concludes.

2 The structural VAR model for oil and gas markets

The structure describing the joint dynamics of the global crude oil market, the European natural gas market and the global economy is given by the following VAR:

$$Az_t = Bx_{t-1} + u_t \tag{1}$$

where z_t is a $n \times 1$ vector of endogenous variables, A is a $n \times n$ matrix summarizing the contemporaneous structural relations, x_{t-1} a $k \times 1$ ($k = np + 1$) vector containing p lags of z_t and a constant, B is a $n \times k$ matrix of parameters associated with lagged variables. The vector

u_t collects the structural shocks and is assumed to have a Gaussian distribution with zero mean and diagonal variance-covariance matrix D.

The model is estimated on monthly data (from January 1996 to December 2023) following the Bayesian Structural Vector Autoregression approach proposed by Baumeister and Hamilton (2019), which incorporates the identification assumptions about structural shocks in the priors for coefficients in matrix A, including a constant and 12 lags. The oil market, in vector z_t, is accounted by the growth rate of monthly world crude oil production, q_t and the log difference of real price of crude oil, p_t. The gas market is described by the growth rate of the quantity of natural gas supplied in the European market, g_t and the log difference of real price of gas, r_t.[4] Global economic activity is measured by the growth rate of the extended version of the OECD's index of monthly industrial production proposed by Baumeister and Hamilton (2019), y_t. Appendix A describes data in details.

Our estimation sample includes the pandemic period, which is characterized by an unprecedented variation in many key macroeconomic variables potentially distorting parameter estimates from linear models such as those employed in this paper. Indeed, between February 2020 and March 2020, the price of crude oil fell by 51 percent. The decline in world oil production was milder (about 14 percent between April and May 2020) while world economic activity fell by 9 percent in April 2020. In contrast, the gas variables seem to be unaffected by the pandemic shock, as the volatility of these data in 2020 was not markedly different from that observed in previous turbulent periods, such as during the 2009 Russian-Ukrainian gas conflict.

One possibility to handle a sequence of extreme observations is by dummying them out. However, while this can be acceptable for the purpose of parameter estimation, it turns out to be inappropriate for the prediction or forecast exercises since the exclusion of the observations leads to underestimation of the uncertainty (Lenza and Primiceri, 2022). Furthermore, it could be argued that the extreme values are not void of economic content and should not be dummied out (Ng, 2021). In order to deal with COVID-19 observations, we estimate a VAR model with volatility changes modeled as in Lenza and Primiceri (2022) for $\tilde{z}_t = (q_t, y_t, p_t)$, obtaining the posterior distribution of the volatility scaling factor. Then we take the median along this

[4]Natural gas prices vary across markets because of the complex transportation infrastructure. In fact, most of the natural gas is transported through pipeline, giving rise to fragmented global market. This explains our choice to use information drawn from the European gas market. In the case of oil, the use of information of world crude oil hinges on the fact the market for crude oil is integrated and tends to be traded at a single price.

distribution, rescale the variables in $\tilde{z}_t$ and use them in the following model.[5]

The structural model of interest consists of the following five equations:

$$q_t = \alpha_{qp} p_t + b_1{}' x_{t-1} + u_t^{os} \quad (2)$$

$$y_t = \alpha_{yp} p_t + \alpha_{yr} r_t + b_2{}' x_{t-1} + u_t^{ad} \quad (3)$$

$$q_t = \beta_{qy} y_t + \beta_{qp} p_t + b_3{}' x_{t-1} + u_t^{osd} \quad (4)$$

$$g_t = \alpha_{gr} r_t + b_4{}' x_{t-1} + u_t^{gs} \quad (5)$$

$$g_t = \beta_{gr} r_t + \beta_{gy} y_t + \beta_{gp} p_t + b_5{}' x_{t-1} + u_t^{gsd} \quad (6)$$

Equations (2) and (4) describes the oil market, equations (5) and (6) the gas market while equation (3) describes the global activity.

More specifically, equation (2) represents the oil supply curve, in which α_{qp} is the short-run price elasticity of supply. The oil supply shock u_t^{os} captures disturbances to the current physical availability of crude oil due to, for instance, discoveries of new oil reserves, technological innovations in oil extraction, geopolitical events and natural disasters.

Equation (4) describes the oil-specific demand: oil demand is allowed to respond contemporaneously to the level of economic activity and to oil prices. The parameter β_{qp} denotes the short-run price elasticity of demand, holding economic activity constant. The parameter β_{qy} represents the income elasticity: higher income boosts oil demand for a given oil price. Oil-specific demand shock u_t^{osd} reflects changes in oil prices due to shifts in specific demand for crude oil. The holding of oil stocks may be driven by different reasons, for instance news about oil discoveries or uncertainty about future oil supply shortfalls.[6] In addition, the demand of crude oil to maintain a certain level of inventories may also anticipate future rising oil prices and in this sense the shock may capture speculative purchases (Alquist and Kilian, 2010). This shock also accounts for the presence of preference shocks, that have to be interpreted as sudden changes in the current demand for oil driven by technological progress, shifts in preferences

[5]In this paper, due to the availability of shorter gas data for the European market, we cannot use the sample for the crude oil market from 1973 or before, as done in previous studies. Even though the oil market has always experienced more extreme fluctuations compared to typical macro variables, running the model proposed by Baumeister and Hamilton (2019) with crude oil production, world economic activity and the real oil price from January 1973 to December 2023 the estimation of the Impulse Response Functions are not consistent with those obtained if we do not consider the observations after March 2020, suggesting the presence of a bias introduced by these observations. On the contrary, if we make the Covid-adjustment based on the method proposed by Lenza and Primiceri (2022), the estimates are basically the same.

[6]One can interpret precautionary demand shocks as arising from a shift in the conditional variance, as opposed to the conditional mean, of oil supply shortfalls. Such shifts in uncertainty may arise, even controlling for the global business cycle and the global supply of crude oil. See, for instance, Kilian (2009).

(e.g. voluntary efforts to save oil) or weather shocks (Kilian and Murphy, 2014).

Concerning the gas market, equation (5) refers to the natural gas supply curve with price elasticity measured by α_{gr}. Similarly to the oil market block, gas supply shock u_t^{gs} captures exogenous disruption in gas production, due for instance to a natural disaster, geopolitical events or to decisions by gas producers to cut production independently from demand conditions.

Equation (6) describes the natural gas demand schedule. We assume that gas demand responds simultaneously to the level of economic activity, to gas prices and to oil prices. The parameter β_{gr} is the short-run gas price elasticity while β_{gy} represents the income elasticity of gas demand. We assume that the coefficient β_{gp} measures the strength of complementarity or substitutability between the two energy sources. Therefore our restrictions imply that crude oil prices have a direct and contemporaneous impact on gas market but rule out the inverse interaction. This assumption is meant to capture the idea that the gas market is regional compared to the oil market, which is certainly global. However, changes in gas prices have an indirect contemporaneous effect on the oil market by inducing changes in the economic activity. The shock u_t^{gsd} captures unexpected shifts in natural gas demand that arise from higher precautionary, speculative, demand for gas inventories, in response to exogenous political events that creates uncertainty about possible shortfalls of the supply of natural gas relative to its demand along with changes in preferences or unexpected changes in temperature conditions (Güntner et al., 2024).

Finally, equation (3) describes the economic activity. Our model assumes that global economic activity responds within the period to both oil and gas prices, with α_{yp} and α_{yr} measuring the impact. The shock u_t^{ad} refers to the aggregate demand shock and captures innovations to global real economic activity that cannot be explained based on crude oil and gas market shocks. In other terms, u_t^{ad} represents shocks to the current demand for crude oil and natural gas driven by fluctuations in the global business cycle.

All endogenous variables are allowed to be affected by their past values, which are included, with a constant, in the vector x_{t-1}.

2.1 Identification of structural shocks: priors on the impact matrix

This section discusses the prior information used to identify the five structural shocks, i.e. the prior distributions for model parameters A, in equation (1). Here we follow Baumeister and Hamilton (2019) choices for the crude oil market and the literature on natural gas market demand and supply elasticities.

Equations (2) - (6) imply the following representation for the contemporaneous structural relations among variables in z_t:

$$A = \begin{bmatrix} 1 & 0 & -\alpha_{qp} & 0 & 0 \\ 0 & 1 & -\alpha_{yp} & 0 & -\alpha_{yr} \\ 1 & -\beta_{qy} & -\beta_{qp} & 0 & 0 \\ 0 & 0 & 0 & 1 & -\alpha_{gr} \\ 0 & -\beta_{gy} & -\beta_{gp} & 1 & -\beta_{gr} \end{bmatrix} \tag{7}$$

Concerning the oil block, Baumeister and Hamilton (2019) shows that the short-run supply elasticity α_{qp} and the short-run demand elasticity β_{qp} are unlikely to be much bigger than 0.5 in absolute term. We set the prior for β_{qp} as a t-Student with mode at -0.1, scale parameter at 0.2 and 3 degrees of freedom and truncated to be negative, which in shorten notation is denoted with $t_{<0}(-0.1, 0.2, 3)$. Similarly, our prior for α_{qp} is $t_{>0}(0.1, 0.2, 3)$, implying a 10 percent probability that $\alpha_{qp} > 0.5$. Finally, the prior for β_{qy} is chosen as a Student-t distribution with mode -0.7, scale 0.2, 3 degrees of freedom and truncated to be positive.

Considering the gas market, we assume that the supply for natural gas is more price-inelastic than oil production.[7] We represent this with a prior for α_{gr} equal to a t-Student with mode at 0.05, scale parameter at 0.2, 3 degrees of freedom and truncated to be postive.

For the remaining parameters, we form our prior belief on previous studies on price and income elasticity of natural gas demand in Europe. Asche et al. (2008), using yearly data for 12 European countries, estimate a short-run price elasticity for natural gas price between -0.24 and 0.02 and a short-run income elasticity ranging from 0.03 and 0.33. Based on several European countries, Dilaver et al. (2014) finds a short-run price elasticity of -0.16 and an income elasticity of 1.19. Using more recent data, Erias and Iglesias (2022) estimate, based on a panel of 25 European countries, a monthly short-run price elasticity ranging from -0.04 to 0.15 and a short-run income elasticity equal to 0.09.[8] As regards the price elasticity, given that gas products are price inelastic, we set the prior for β_{gr} as $t_{<0}(-0.1, 0.4, 3)$ which is consistent

[7]The production of natural gas is a complex process, whose exploration activities need long time before the extraction. Furthermore, gas has to be conditioned (i.e. it is treated to eliminate contaminants) and finally transported. All these steps, along with high investment required, make producers react quite slowly to prices (Ponce and Neumann, 2014; Rubaszek et al., 2021).

[8]Other studies analyse price and income elasticities, both in the short and in the long run, for other countries, such as USA, China, some OECD countries. See for instance, Burke and Yang (2016) and Erias and Iglesias (2022) and reference therein.

with the meta-analysis conducted by Labandeira et al. (2017) on energy prices changes.[9] For the income elasticity of gas demand, β_{gy} we use a Student t density with mode at 0.3, scale parameter 0.4, 3 degrees of freedom and truncated to be positive.

The parameter β_{gp} in equation (3) captures the effect of oil prices on natural gas demand. To the best of our knowledge, there is no clear evidence in the literature about the link between these two commodities, even if it could be reasonable to suppose the existence of a substitution between them in the short term. This suggests to use a relatively uninformative prior for this parameter, taking β_{gp} to be an unrestricted t-Student, centered at 0 with scale parameter 0.5 and three degrees of freedom.

Looking at equation (3), the parameter α_{yr} reflects the effect of gas prices on economic activity. Since in Europe the ratio of natural gas expenditures over the GDP is small (lower than 2 percent), we use a $t_{<0}(-0.05, 0.06, 3)$, which imply a 90 percent probability that α_{yr} is smaller than -0.02. Applying the same argument to the effect of oil prices on economic activity, we use for α_{yp} a Student-t distribution with mode at -0.05, scale 0.1, 3 degrees of freedom and truncated to be negative.

We also make use of prior belief about the equilibrium impact of shocks, introducing prior information about how the various element of A may interact, giving an economic interpretation on that. Specifically, the impact matrix is given by:

$$\frac{\partial y_t}{\partial u_t} \quad = \quad H = A^{-1} = \frac{1}{det(A)} C \tag{8}$$

where C is the adjoint of A. The elements of H could be positive or negative, meaning that all shocks could have either positive or negative impacts on any variable. We set the prior on the parameter $h_1 = det(A)$, which determines how strongly endogenous variables react to structural shocks, putting much or little weight on the prior belief that $h_1 > 0$. To this end, h_1 follows an asymmetric t-distribution with mode parameter equal to 0.45 and scale parameter at 0.5. Both parameters are determined by generating 50000 draws from the densities decribed before (see Baumeister and Hamilton, 2018 for details); the skewness parameter is set to 1 and the degrees of freedom to 3, implying a 95 percent prior probability that $h_1 > 0$.

In this way, this last restriction together with the restrictions on the parameters in equations

[9] It is clear from this brief literature survey that economic studies, using several methods and data, offer a rather wide range of estimates for the price and the income elasticities of gas demand. Labandeira et al. (2017) uses a meta-analysis to quantitatively summarize the emprical evidence on energy price changes, finding an average price elasticity for natural gas demand equal to -0.18.

(2)-(6), define the sign of some elements of the impact matrix in equation (8):

$$sign(H) = \begin{bmatrix} ? & + & + & + & - \\ ? & + & ? & + & - \\ - & + & + & + & - \\ ? & ? & ? & ? & + \\ ? & ? & ? & - & + \end{bmatrix} \tag{9}$$

As shown by question marks in equation (9), the impact matrix displays still some ambiguities; for example, this is the case of the effect of oil supply shocks on crude oil production and economic activity. Kilian (2008), Lippi and Nobili (2012), Kilian and Murphy (2012) and Baumeister and Hamilton (2019), among others, show that oil supply disruption causes a decline in global oil production and a temporary reduction of real economic activity. We incorporate these results in the priors of element (1,1) and (2,1) of the matrix in equation (8), denoted as h_{11} and h_{21} respectively. The prior for h_{11} is a symmetric Student t-distribution with location at 0.8, scale at 0.2 and 3 degrees of freedom, while for h_{21} we set location at 0.4, which imply, respectively, a 98.6 and 93 percent prior probability of being positive. Figure 1 plots all the prior distributions about the contemporaneous coefficients in A and H as well as the posteriors.

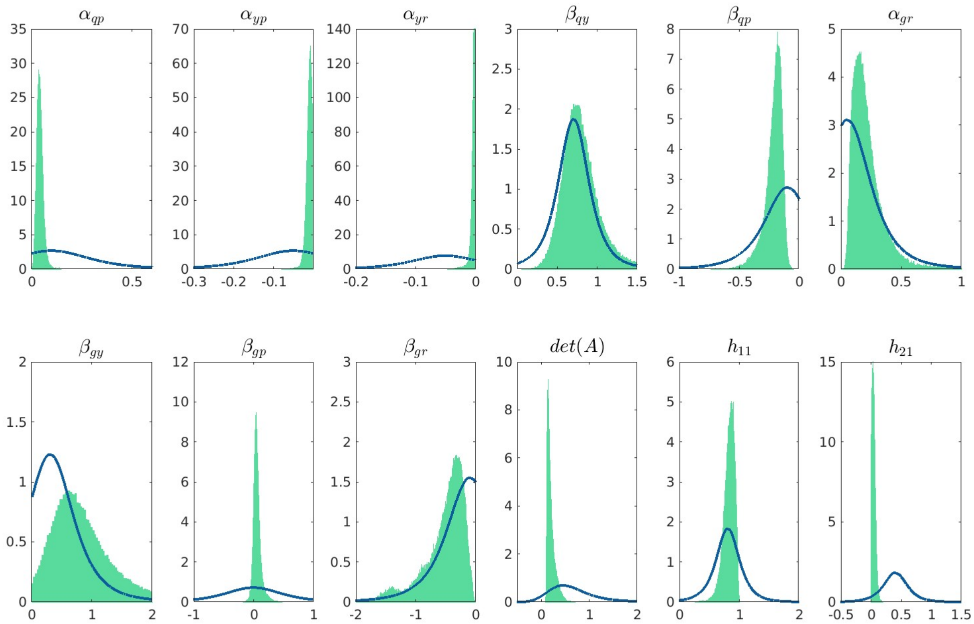


Figure 1: Baseline prior and posterior distributions of contemporaneous coefficients and equilibrium impacts. The solid blue lines depict the prior, whereas the posterior is represented in light green.

2.2 The other priors for the empirical model

This subsection discuss the choices related to the distributions representing prior information about the variance-covariance matrix of structural shocks, $p(D|A)$, and the parameters associated with lagged variables, $p(B|A, D)$. The discussion follows Baumeister and Hamilton (2019).

Prior for $D|A$. Prior beliefs about structural variances should reflect in part the scale of the underlying data. We choose the priors for the reciprocals of the structural variances as independent Gamma distributions, $d_i^{-1}|A \sim \Gamma(k_i, \tau_i(A))$. The rate parameter $\tau_i(A)$ is set equal to $k_i\alpha_i'\hat{S}\alpha_i$ where $\hat{S}$ is the estimated variance-covariance of twelfth-order univariate autoregressions fitted to the five elements of z_t over the full sample and α_i denotes the $i - th$ row of A. The shape parameter k_i is chosen equal to 2, which, as shown in Baumeister and Hamilton (2015), means that the prior carries a weight equivalent to $2k_i$ observations of data.

Prior for $B|A, D$. The priors for the lagged coefficients in the $i - th$ structural equation are independent Normals, $b_i|A, D \sim N(m_i, d_{ii}M)$. Since changes in endogenous variables are all hard to forecast and assuming low persistence of endogenous variables, being expressed as growth rates, we set the prior of expected value for most coefficients equal to zero, i.e. $m_i = 0$ for $i = 1, \ldots, 5$.

We allow for the possibility that the one-period-lag response of oil supply and oil-specific demand to a price increase could be similar to the contemporaneous magnitudes, and for this reason we set the third element of m_1 equal to α_{qp} and the third element of m_3 to β_{qp}. In the same vein, we take into account that the one-period lag reaction of gas supply and gas-specific demand to gas price changes is equal to α_{gr} and β_{gr}, respectively. In this way, the reaction of oil and gas producers and consumers to price changes may be distributed in time, providing little more information to try to distinguish supply and demand shocks in both energy markets (Baumeister and Hamilton, 2019; Rubaszek et al., 2021).

For the variance coefficients, we use smaller values for the diagonal elements for M associated with higher lags, in line with the literature. Therefore, the diagonal elements of M depend on three hyperparameters: λ_0 summarizes the overall confidence in the prior, λ_1 governs how much more confident we are that higher lag coefficients are 0, and λ_3 is a separate parameter governing the tightness of the prior for the constant term. Following the baseline specification in Baumeister and Hamilton (2019) we set λ_0 equal to 0.5 (smaller value corresponds to greater weight given to the prior), λ_1 equal to 1 (greater value means more quickly the prior for lagged coefficients tightens to 0 as the lag increases) and λ_3 equal to 100 (making the prior on the costant term essentially irrelevant).

3 Empirical Results

The posterior median of the short-run price elasticity of oil supply, α_{qp} is 0.039, which is lower than our prior. This value is higher than the 0.0258 estimate of Kilian and Murphy (2012) and below the results in Caldara et al. (2019) and Baumeister and Hamilton (2019) (0.11 and 0.15, respectively). Caldara et al. (2019), in their narrative analysis, argue that the use of a larger set of exogenous oil supply disruption episodes induces a larger estimate of the oil supply elasticity. Since our sample excludes the pre-1996 period, a lower value for the oil supply elasticity seems reasonable.[10] For oil-specific demand elasticity, β_{qp}, the posterior distribution is relatively close to the prior. The posterior median is -0.1979, which is slightly below the estimates in Baumeister and Hamilton (2019).

The posterior median for the short-run price elasticity of gas supply, α_{gr}, is 0.19, which is significantly higher than our prior. The posterior median of the short-run price elasticity of gas-specific demand, β_{gr}, is -0.43, slightly higher than the values reported in the literature about gas price elasticity in the European countries. Our estimate implies that changes in natural gas prices exert a strong impact on demand for gas in the short-run.

Finally, concerning the parameter measuring the effect of oil prices on natural gas demand, the posterior median of β_{gp} is positive and equal to 0.047. This would imply that the existence of a substitution effect between oil and gas is plausible, even if the reaction of gas demand to oil price changes is quite weak and not significant.

3.1 Impulse responses

Figure 2 shows the impulse responses to a one unit-change in the structural innovations. An unanticipated disruption in oil supply reduces oil production by about 0.8 percent and leads to a persistent increase in oil prices, which rise by 4 percent on impact and remain elevated thereafter. At the same time, this shock causes a small and transitory reduction of global economic activity that is statistically significant only on impact. By contrast, there seems to be no significant effect on gas production and real gas prices.

[10] Caldara et al. (2019) identify twenty large drops in oil production between January 1985 to October 1995.

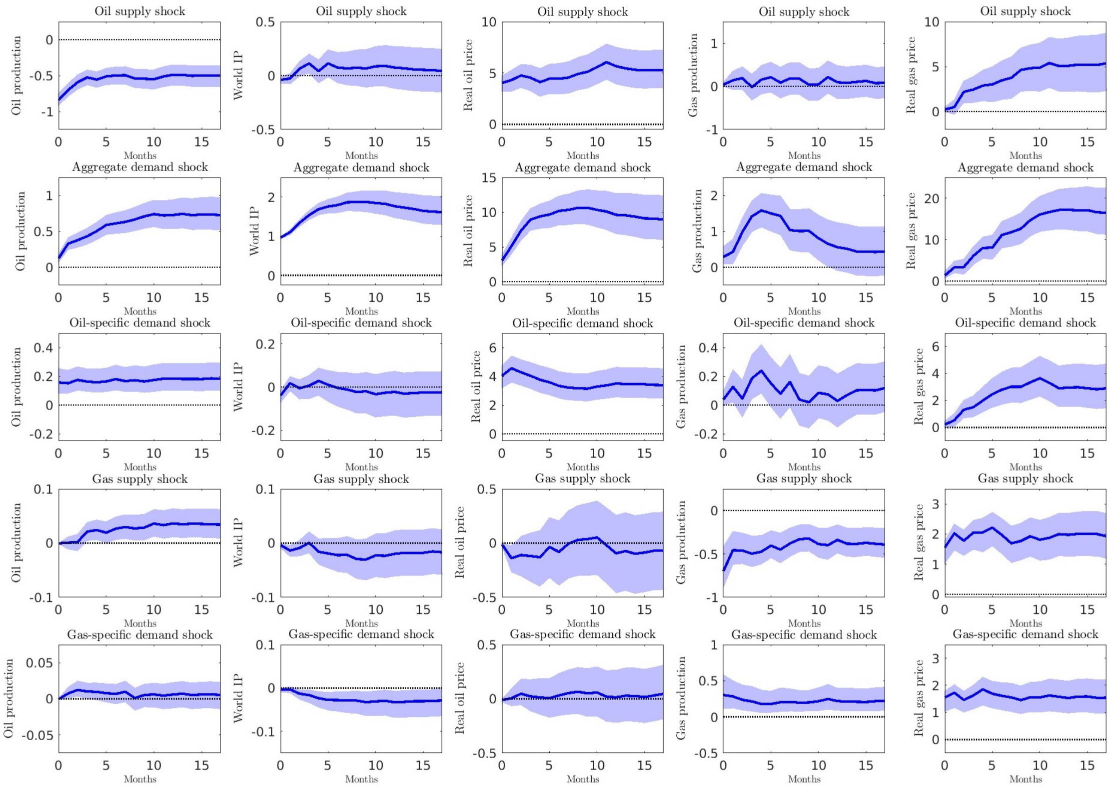


Figure 2: Impulse Responses to an oil supply shock, an aggregate demand shock, an oil-specific demand shock, a gas supply shock and a gas-specific demand shock. The solid lines depict median responses of the specified variable to a one unit-change in the identified shock. The light shaded bands represent the 68 percent posterior credible sets. The horizontal axis measures months after the shock. In columns structural shocks are reported, while rows indicate the variables.

The effect of an unexpected aggregate demand increase on world economic activity is very persistent and highly significant. An aggregate demand shock also causes a persistent and statistically significant increase in crude oil production and the real price of oil. This shock is also associated with an increase in gas production, which becomes not significant after 11 months, and a persistent and statistically significant increase in real gas prices. In quantitative terms, gas production increases by 1.6 percent after four months from shock occurrence, whereas real gas prices rise by about 17 percent after one year.

Oil-specific demand shock leads to an increase in oil production of about 0.2 percent and a rise in real oil prices of about 4 percent. It causes a small temporary reduction of world industrial production which is statistically significant only on impact. Oil-specific demand increases do not cause a significant rise in gas production while the increase in the real gas prices is delayed and it amounts to about 1.5 percent after three months.

Unexpected gas supply downturns cause a large, persistent and statistically significant decrease in gas production, which amount to about 0.7 percent on impact. The effect of these shocks on natural gas prices is very persistent and highly significant: it amounts to about 2 percent in the very short period. A reduction in gas production due to an unanticipated decrease in natural gas supply has also a small and transitory negative impact on world industrial production and real oil prices. At the same time, this shock triggers a small negative impact on oil production which is statistically significant only on impact.

An increase in natural gas prices that results from an increase in gas demand alone, has a persistent and statistically significant effect on both gas production and natural gas prices. In particular, our estimates imply that this shock would increase gas production by 0.3 percent and would rise real gas prices by 1.6 percent on impact. By contrast, positive shocks to gas-specific demand induce a persistent negative effect on world industrial production, a small negative increase in oil production, that is significant only on impact while they seem to have no effect on real oil prices after the shock occurrence.

Table 1 presents the value of impulse responses on impact and after one year, where each shock is normalized as an event that leads to a 1 percent increase in the real oil price at time 0, in the case of oil supply, aggregate demand and oil-specific demand shocks, and in the real gas price in the case of gas supply and gas-specific demand shocks. Note that this is a different normalization from that used in Figure 2, where the effect plotted is that of a one unit-change in the structural shock. Our estimates imply that a negative oil supply shock that raises the real oil price by 1 percent lowers oil production by 0.21 percent on impact while the effect is

Table 1: Impulse Responses to an oil supply shock, an aggregate demand shock, an oil-specific demand shock, a gas supply shock and a gas-specific demand shock. Each shock is normalized as an event that leads to a 1 percent increase in the real oil price at time 0, in the case of oil supply shock, aggregate demand shock and oil-specific demand shock, and in the real gas price in the case of gas supply shock and gas-specific demand shock. Values are in percentage points. Values in paretheses represents the 68 percent credible sets; h indicates the number of months after the shock.

		Oil supply shock	Aggregate demand shock	Oil-specific demand shock	Gas supply shock	Gas-specific demand shock
Oil production	h = 0	-0.21 (-0.29, -0.16)	0.039 (0.02, 0.05)	0.039 (0.03, 0.06)	0.000 (-0.00, 0.00)	0.000 (-0.00, 0.00)
	h = 12	-0.123 (-0.19, -0.08)	0.239 (0.16, 0.34)	0.047 (0.03, 0.07)	0.024 (0.01, 0.05)	0.005 (-0.01, 0.02)
World IP	h = 0	-0.010 (-0.02, 0.00)	0.316 (0.24, 0.43)	-0.010 (-0.02, 0.00)	-0.003 (-0.01, 0.00)	-0.003 (-0.01, 0.00)
	h = 12	0.019 (-0.03, 0.07)	0.586 (0.42, 0.83)	-0.006 (-0.03, 0.02)	-0.014 (-0.04, 0.02)	-0.024 (-0.04, -0.01)
Real oil price	h = 0	1 (1, 1)	1 (1, 1)	1 (1, 1)	-0.008 (-0.02, 0.00)	-0.008 (-0.03, 0.00)
	h = 12	1.418 (1.01, 1.93)	3.146 (2.18, 4.53)	0.903 (0.70, 1.12)	-0.064 (-0.33, 0.18)	0.011 (-0.16, 0.18)
Gas production	h = 0	0.010 (0.00, 0.02)	0.095 (0.03, 0.21)	0.010 (-0.01, 0.02)	-0.434 (-0.85, -0.23)	0.189 (0.11, 0.32)
	h = 12	0.023 (-0.07, 0.12)	0.181 (-0.03, 0.43)	0.008 (-0.04, 0.06)	-0.216 (-0.46, -0.09)	0.141 (0.08, 0.23)
Real gas price	h = 0	0.055 (-0.01, 0.12)	0.439 (0.21, 0.85)	0.055 (-0.01, 0.12)	1 (1, 1)	1 (1, 1)
	h = 12	1.269 (0.58, 2.08)	5.622 (3.82, 8.22)	0.764 (0.41, 1.14)	1.341 (0.96, 1.84)	1.108 (0.83, 1.40)

smaller on aggregate industrial production. By contrast, this shock leads to an increase in the real oil price by about 1.4 percent after 12 months. Gas production rises by 0.1 percent after a normalized aggregate demand shock while real gas prices increase by about 0.4 percent and by 5.6 percent after one year. The oil-specific demand shock that raises the real oil price by 1 percent leads to an increase in oil production of about 0.04 percent and a decrease of about 0.01 percent in world economic activity, while the effect on the other variables is not statistically significant on impact. A gas supply shock that increases the real gas price by 1 percent reduces gas production by 0.4 percent while real gas prices increase by 1.3 percent after a year. Finally, if gas prices rise as a consequence of a shock to gas demand, gas production increases by 0.2 percent while there is no significant effect on oil production, world economic activity and real oil prices. By contrast, the real gas price rises by about 1.1 percent after a year.

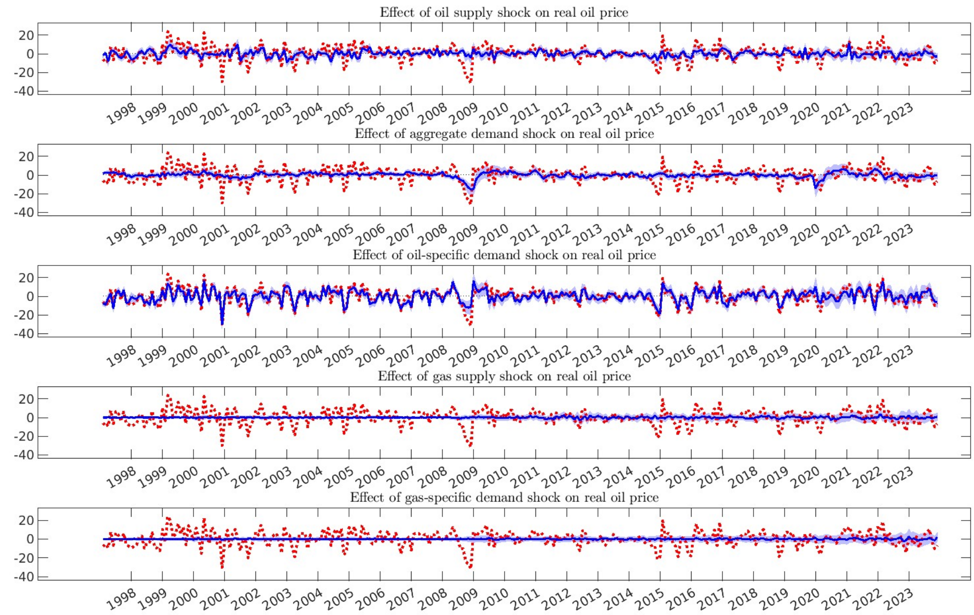
3.2 Historical Decomposition

Figure 3 depicts the historical decomposition of real oil price (panel a) and real gas price (panel b) movements in terms of structural shocks. Historically, the contribution of oil supply shocks in explaining movements in the real price of oil has been lower than that of oil-specific demand shock. As pointed out by Kilian (2009) and Kilian and Murphy (2012), this is consistent with the view that precautionary demand shocks reflect rapid shifts in the oil market assessment of the uncertainty about the future level of oil supply. Gas market shocks do not seem to have any relevant role in explaining real oil price fluctuations. At the same time, panel (b) of Figure 3 suggests that gas supply and gas-specific demand shocks have played a similar role in gas price fluctuations. The contributions of aggregate demand shocks are comparatively small for both energy prices.

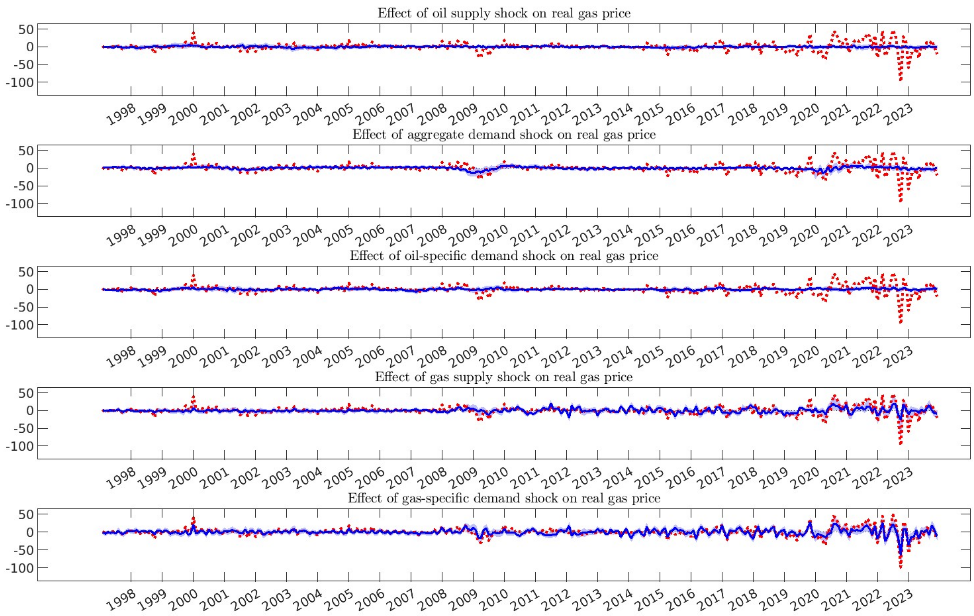
Although more than one shock matter for oil and gas markets on average, their relative importance is heterogeneous across different episodes. To illustrate this aspect, Figure 4 zooms in on specific episodes involving large changes in real oil and gas prices. Before focusing on the most recent crisis periods, following the COVID-19 wave and the Russia-Ukraine conflict, we analyse the global financial crisis and the 2014-2015 oil price slump.

Panel 4a reports the estimated historical decomposition for the July 2008-December 2009 period, characterized by the global financial crisis. Much of the movements in the price of oil is attributed to oil-specific demand shocks. The role of aggregate demand shocks in driving real oil prices is more relevant toward the end of 2008 when world industrial production begins to decline. Oil supply shocks have only small effects on oil price dynamics. A similar conclusion is reached by Caldara et al. (2019). During 2008, gas-specific demand and aggregate demand shocks have a prominent role in explaining the real gas price. In January 2009, the real gas price increase was driven by supply and gas-specific demand shocks. The first force is attributed to the interruption of imports from Russia transported through Ukraine while the latter is linked to extraordinarily low temperatures recorded in many European countries. The observed increase in the gas price has been lower than that induced by the supply and demand shocks. In fact, our decomposition attributes a nontrivial role to aggregate demand shocks, which contributes negatively to the gas price rise. This is because of the financial crisis and the consequent economic downturn, which, as pointed out also by Nick and Thoenes (2014), influenced considerably oil and gas markets.

Panel 4b displays the estimated historical decomposition for the July 2014- January 2016

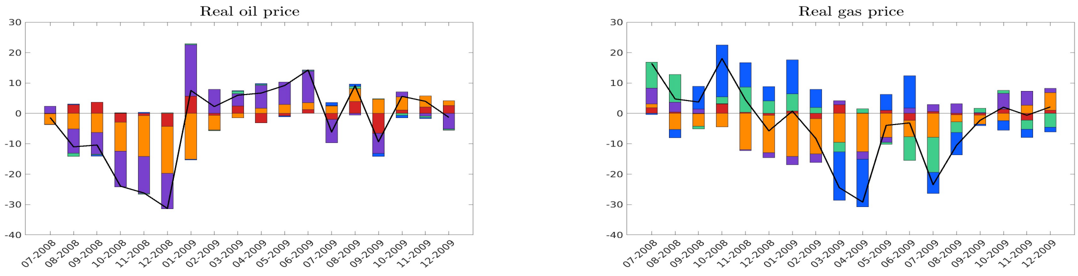


(a) Real oil prices

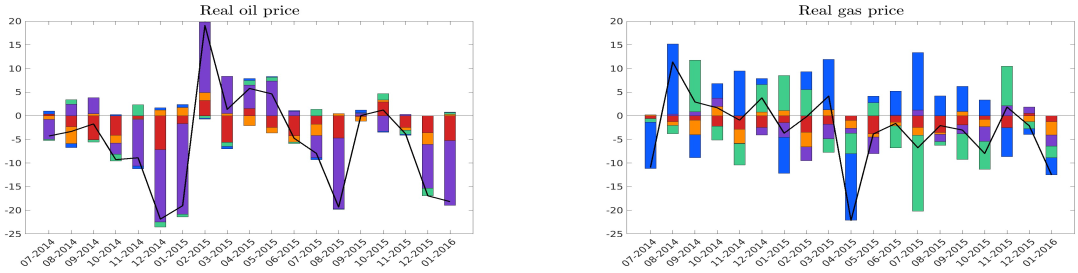


(b) Real gas prices

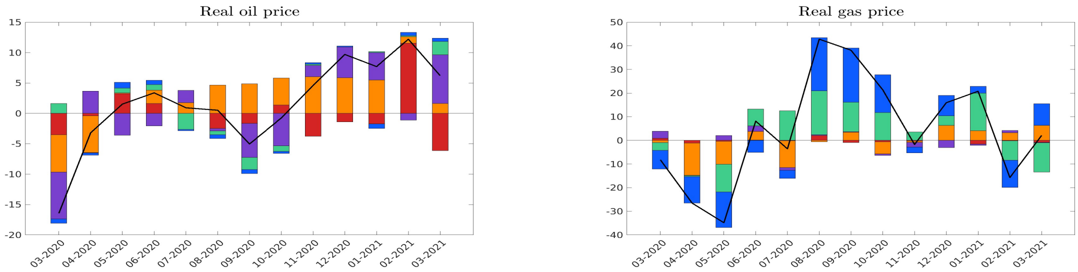
Figure 3: Historical decomposition of real oil prices (panel a) and real gas prices (panel b). Observed percentage changes in prices (dotted red lines) and median estimate of the historical contribution of each structural shock (blue lines). Light blue areas indicate 95 percent posterior credibility regions.



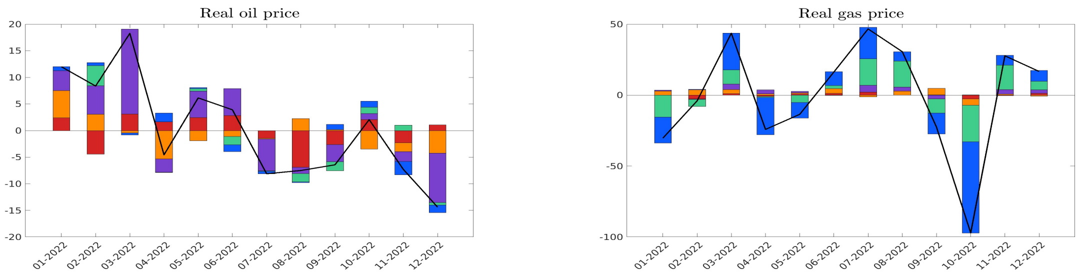
(a) The Global Financial Crisis



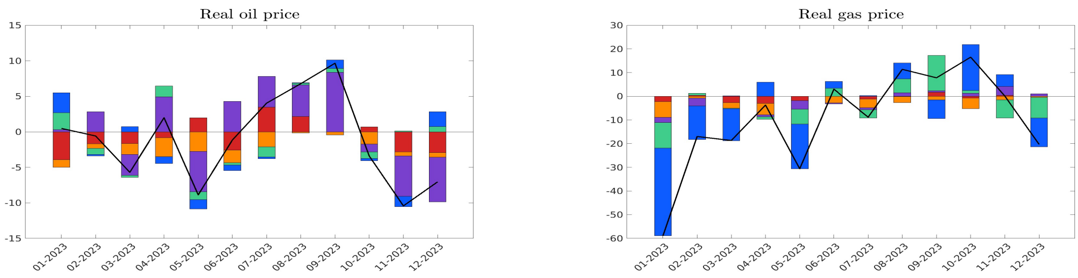
(b) The 2014-2015 Oil Price Slump



(c) The COVID-19 Lockdowns and Reopening



(d) The Russian-Ukrainian War



(e) Energy prices reduction and the outset of new tensions (the Israel-Hamas conflict)

Figure 4: Historical decomposition, for specific periods, of oil supply (red), aggregate demand (orange), oil-specific demand (purple), gas supply (green), and gas-specific demand (blue) shocks. The solid black lines depict the percentage monthly growth rate (i.e. percentage logarithmic differences) of each series.

period, characterized by a major slump in the real price of oil. Our estimates attribute most of the decline and the rebound in real oil price to oil-specific demand shocks. We also find that oil supply shocks explain less than half of the oil price collapse in that period. These findings are consistent with the analysis in Baumeister and Kilian (2016), Caldara et al. (2019) and Baumeister and Hamilton (2019). Throughout this period, both gas supply and gas-specific demand shocks are the main drivers of real gas price movements.

The results in Panel 4c suggest that the observed decrease of the real oil price during the lockdown period of March 2020-April 2020 can be attributed mainly to aggregate demand shocks since the virus and the measures taken to protect public health-induced sharp declines in economic activity, consistently with the findings in Gazzani et al. (2024). Aggregate demand shocks play also a central role in explaining the decrease of the real gas price during the lockdown period. Our estimates attribute most of the oil price rebound at the end of 2020 to strong demand, while the rise in gas price observed after July 2020 is attributed both to gas supply and gas-specific demand, in roughly equal proportions.

Panel 4d displays the estimated historical decomposition for the January 2022-December 2022 period. This is the year not only of the recovery of the international economy from the negative effects of the COVID-19 pandemic but also of the Russia-Ukraine conflict. The observed increase in the real price of gas after February 2022 cannot be attributed to gas supply disruption alone. Indeed, the model identifies another important channel through which the Russia-Ukraine conflict may have affected the real price of gas, that is gas-specific demand. As this conflict grew, gas market participants may have become more concerned about the gas supply shortage in the European Union. The contribution of gas supply shock is maybe lower than expected, since European countries were able to compensate for the gradual Russian supply shortfalls by additional imports from other gas producers.[11]. While the main driver of the increase in the real price of oil, in early 2022, was the cumulative effect of aggregate demand due to the post-pandemic, the sharp increase in the real price of oil following the beginning of the Russia-Ukraine conflict was due to a rise in oil-specific demand. Russia is a relevant crude oil exporter and the market accounted for the risk that political tensions could affect also Russian oil exports, translating into a rise in oil-specific demand.

[11]During 2022, firms implemented various strategies to limit the impact of energy price shock, especially those not protected by fixed-price energy contracts, derivatives, or other instruments. A small portion of companies, using natural gas, replaced it, at least partially, with other energy sources. Additionally, a significant number of companies generated part of their electricity from renewable sources, with a notable portion of their total energy consumption coming from self-produced electricity Banca d'Italia (2023)

Finally, Panel 4e shows the decomposition during the last period of our sample, from January to December 2023. Oil-specific demand shocks explain a large part of oil price dynamics however, a nontrivial role can be ascribed to oil supply and aggregate demand. During the second half of 2023 further geopolitical tensions along with concerns about the future level of oil production have re-emerged, causing upward pressure on oil prices[12], largerly attributed to oil-specific demand shocks. Oil supply shocks contributed to the decline of the price of oil at the end of 2023, consistent with narrative suggesting that oil markets remained relatively stable, with limited reaction to the Hamas-Israel conflict. Gas-specific demand shocks largely explain the decrease in real gas prices during the first half of 2023. Our decomposition attributes most of the rise in gas price observed after June 2023 both to gas supply and gas-specific demand, likely resulting from the rising violence in the Middle East coupled with Europe's dependence on liquefied natural gas (LNG) supplies.

4 Quantifying the macroeconomic effects of energy shocks in Italy

Energy shocks may be transmitted to the economy through an increase in the energy component of the production cost and a decrease in the demand for firms' output, resulting from a reduction in consumer expenditures. In this section we estimate the transmission of all identified energy shocks on the Italian industrial sector, excluding construction, in particular on industrial production, value added and investment. The response of these macroeconomic variables is also analysed separately for groups of sectors defined as energy-producing, energy-intensive and non-energy-intensive sectors (based on NACE classification).[13]

The energy-producing sectors include the following NACE economic activities: mining and quarrying, manufacture of coke and refined petroleum products, electricity, gas, steam and air conditioning supply, and water collection, treatment and supply. Paper and paper products, chemicals and chemical products, other non-metallic mineral products and basic metals all fall in the energy-intensive sectors.[14] The remaining industrial sectors are defined as

[12]On June 2023, OPEC+ members announced they would extend crude oil production cuts through the end of 2024. Following this meeting, Saudi Arabia declared an additional voluntary oil production cut for July. Finally, in early September, Saudi Arabia announced it would extend its voluntary production cuts through the end of 2023, putting upward pressure on crude oil prices.

[13]The definition of the groups follows Corsello et al. (2023). The degree of energy intensity is based on the ratio between energy consumption (expressed in Terajoule) and the value added (expressed in millions of euro) of each industrial subsector. Similar classification approaches have been employed by Gunnella et al. (2022) and De Santis and Tornese (2023). Further details are reported in the Appendix A.

[14]Investment data are available with a slightly different level of sectoral aggregation. Therefore energy-intensive

non-energy-intensive.

We estimate different local projections of Italian industrial production, value added and investment for these groups in response to each identified shock. Because data on Italian investment and value added by industry are available at annual frequency, we obtain quarterly estimates of these variables through a Chow-Lin disaggregation. We construct a measures of quarterly industrial production (available at monthly frequency) by averaging the monthly values for each quarter. Coherently, we average the monthly structural shocks for each quarter (as done, for instance, in Kilian, 2009).[15]

The quarterly variables are affected by the pandemic shock, as the volatility of economic variables in 2020 was markedly different from that observed in other turbolent periods. In order to deal with COVID-19 observations we estimate the posterior distribution of the volatility scaling factor as in Lenza and Primiceri (2022). Then we use the resulting scaled variables as the dependent variable in the local projections, similarly to what has been done previously in the VAR estimate.

To measure the dynamic effect of the shock u_t on a particular variable y_t, h quarters after the shock, we run local projections of this form:

$$y_{t+h} = \alpha(h) + \beta(h)z_{t-1} + \psi(h)u_t + \epsilon_{t+h}\ ,\ \ h = 0, 1, \dots H \tag{10}$$

where z_{t-1} is a vector of pre-determined controls and ϵ_{t+h} is a residual. The dynamic multiplier, i.e. the impulse response function of the variable y_t to the shock u_t at horizon h, is represented by $\psi(h)$ which is recovered by running $H + 1$ least squares regressions (Jordà, 2005). We estimate these local projections[16] for each variable and for each structural shock and horizon h from zero to twelve quarters following the shock. In all of our specifications the controls z_{t-1} include four lags of the endogenous variable together with the other macroeconomic variables included in the monthly Structural VAR (i.e. oil and gas prices). The sample period starts from the 1st quarter of 1999 to the 4th quarter of 2023 (see Appendix A for more

sectors include wood, paper and publishing industries, manufacture of chemical products, manufacture of rubber and plastic products and other non-metallic mineral processing products and metallurgical activities and manufacture of metal products, excluding machinery and equipment as the energy-intensive sectors.

[15] Alessandri et al. (2021) show that as long as the data-generating process is a VAR, averaging the high-frequency proxy to a lower frequency delivers consistent estimates of the responses in a broad range of empirical setups and model specifications.

[16] We follow the smooth local projections approach proposed by Barnichon and Brownlees (2019). The empirical results are in line with those obtained withouth smoothing (Jordà, 2005), both qualitatively and quantitatively.

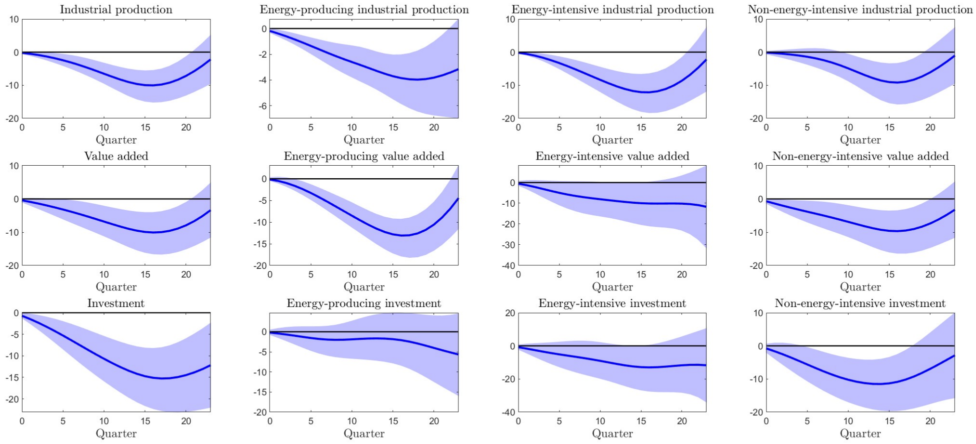
details).[17] According to the identification of the model presented in Section 2, the impulse response tracks the response of variables to a one-unit change in the structural shock. In some cases, impulse response to a shock that raises energy prices by 10 per cent may result more interesting from a policy analysis perspective. In our exercises, we therefore normalise the dynamic multiplier by the contemporaneous effect of the shock on the percentage change in the price of oil, when u_t represents the oil market shocks and the aggregate demand shock. In the case of gas supply shock and gas-specific demand shock the standardization refers to the price of natural gas. In all cases, we consider a 10 percent increase in both the oil and the gas price at time 0.

The resulting IRFs for oil supply shock are displayed in Figure 5 (Panel a). An adverse oil supply shock persistently reduces industrial production, value added, and investment. The effect is negative and persistent for all sectors considered. However, the response of industrial production for energy-intensive sectors is more pronounced while the impact is lower for energy-producing sectors, over all horizons. In the short run, these developments are confirmed also for value added whereas, two years after the shock hits, the effect becomes stronger for energy-producing sectors. The reaction for non-energy-intensive sectors is smaller, in the short run, than for the other two groups of economic activities. Over longer horizons differences across sectors tend to narrow, suggesting that the reductions of the production and value added observed for energy-producing and energy-intensive sectors eventually spill over to non-energy intensive ones due to the presence of sectoral linkages. Finally, energy-producing sectors decrease investment spending much less than the other two sectors, with statistically not significant impacts at all horizons.[18]

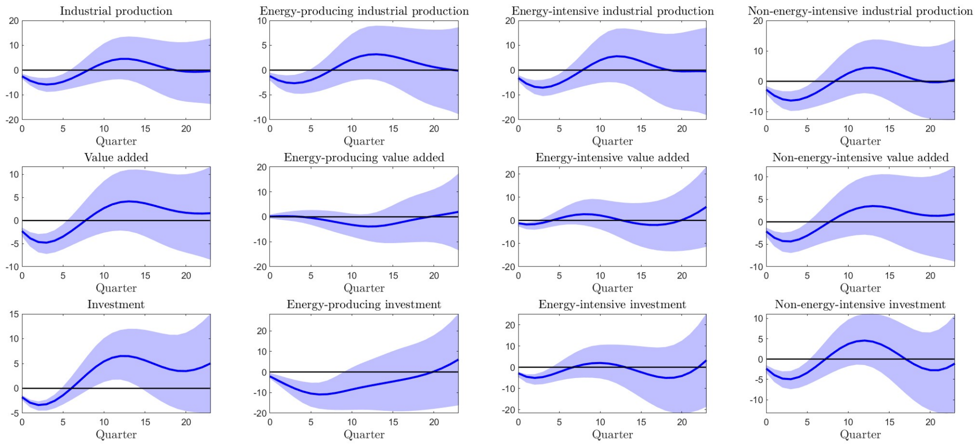
Figure 5 (Panel b) displays the impact of an oil-specific demand shock which increases the oil price on impact by 10 percent. In the short run, a positive oil-specific demand shock elicits a negative response of industrial production, value added and investment. The negative impact is mostly statistically significant but transitory, in fact it becomes uncertain after six quarters

[17] The transmission of energy price shocks to macroeconomic variables may be nonlinear, depending, for instance, on asymmetries in the response of the economy to positive and negative shocks. Kilian and Vigfusson (2011), Kilian and Vigfusson (2017), Herrera et al. (2011) and Alsalman and Herrera (2015), among others, study the asymmetric propagation in the oil market. De Santis and Tornese (2023) uncover nonlinearities in the propagation of energy supply shocks, finding that the transmission of these shocks to consumer prices is stronger in high-inflation regimes. However, in this paper, we choose not to address such nonlinearity and leave this question for future research.

[18] Although higher oil prices could generate larger revenues for firms operating in energy-producing sectors, firms might consider difficult to cover the high fixed costs of investment, particularly in presence of small oil price increases (Kilian, 2009, Melek et al., 2018).



(a) oil supply shock



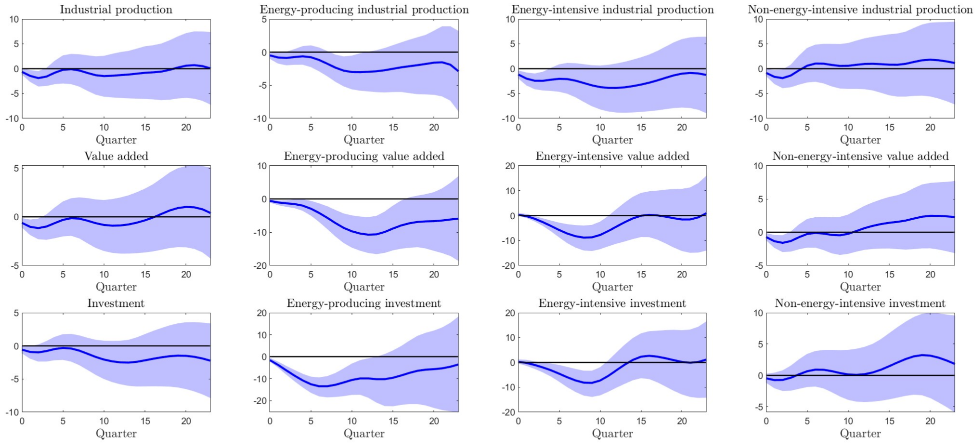
(b) oil-specific demand shock

Figure 5: Cumulated response of Italian industrial production, value added and investment, both at the total industrial sector and separately for the energy-producing, energy-intensive and non-energy-intensive sectors, to a oil supply shock and to a oil-specific demand shock, identified as in Section 2. The response regarding oil supply and oil-specific demand is normalized as an event that leads to a 10 percent increase in the oil price on impact. The solid lines depict impulse response functions that are estimated using local projections. The light shaded bands represent the 68 percent posterior credible sets. The horizontal axis measures quarters after the shock.

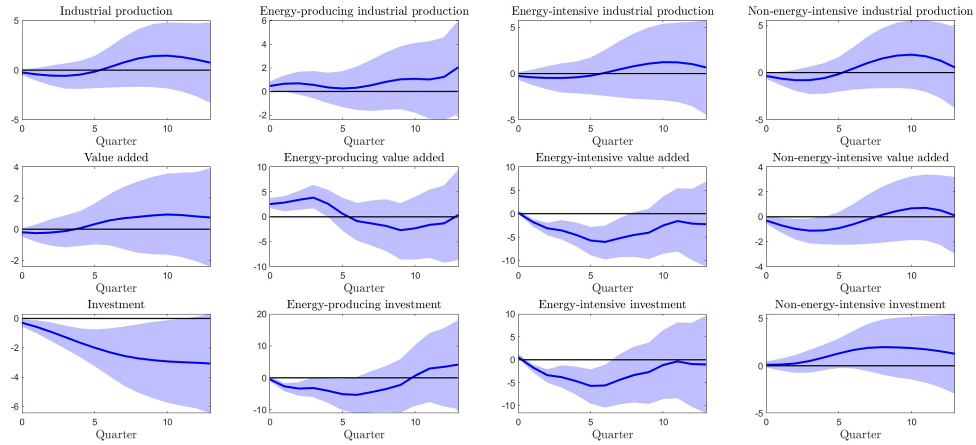
in the majority of the cases, as signalled by the wide range of the 68th percentiles.[19]

The impact response of industrial production and value added is immediate and negative after an adverse gas supply shock that raises the gas price by 10 percent, as shown in Figure 6 (Panel a). The negative response is more pronounced and significant in the short run,

[19] Elder and Serletis (2010) find evidence that uncertainty in oil prices lead to a decline of real output to a positive oil shock. Similar results are estimated in the case of fixed investment.



(a) gas supply shock



(b) gas-specific demand shock

Figure 6: Cumulated response of Italian industrial production, value added and investment, both at the total industrial sector and separately for the energy-producing, energy-intensive and non-energy-intensive sectors, to a gas supply shock and to a gas-specific demand shock, identified as in Section 2. The response regarding gas supply and gas-specific demand is normalized as an event that leads to a 10 percent increase in the gas price on impact. The solid lines depict impulse response functions that are estimated using local projections. The light shaded bands represent the 68 percent posterior credible sets. The horizontal axis measures quarters after the shock.

peaking after two quarters in almost all cases. In the case of energy-producing and energy-intensive sectors, the effect on value added remains statistically significant also in the long run. Investment, instead, does not respond significantly when non-energy-intensive sectors are considered. The negative investment response is pronounced for energy-producing sectors and statistically significant for about ten quarters.

Gas-specific demand shock, which raises the gas price to 10 percent, has a negative impact on the three variables analysed and for almost all the sectors (Figure 6, Panel b). In the case of energy-producing sectors, the production and value added record a transitory increase, more likely to match shifts in preference to maintain certain level of gas storages.[20]

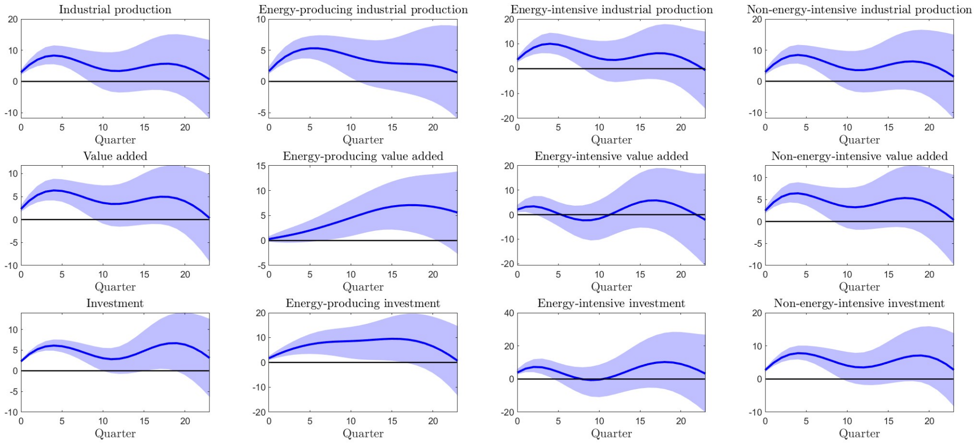


Figure 7: Cumulated response of Italian industrial production, value added and investment, both at the total industrial sector and separately for the energy-producing, energy-intensive and non-energy-intensive sectors, to an aggregate demand shock, idenitfied as in Section 2. The response regarding the aggregate demand is normalized as an event that leads to a 10 percent increase in the oil price on impact. The solid lines depict impulse response functions that are estimated using local projections. The light shaded bands represent the 68 percent posterior credible sets. The horizontal axis measures quarters after the shock.

Finally, as shown in Figure 7, an unanticipated aggregate demand expansion due to an increase in the oil price of 10 percent, causes a statistically significant increase in industrial production, value added and investment. For energy-producing sectors, the impact remains positive and statistically significant also after three years the shock hits. Therefore, the direct stimulus of higher aggregate demand seems to dominate the indirect negative effect of higher energy prices.

[20]For Germany, Güntner et al. (2024) find an increase of net gas imports due to a storage demand.

5 Conclusions

In this paper, using the Bayesian perspective by Baumeister and Hamilton (2019), we propose a Structural VAR model in which we consider both the global oil market and the European natural gas market. We then run a local projection of Italian industrial production, value added and investment on the identified shocks, exploring possible specificities of sectors with a more intense use of energy.

Overall the analysis points to a significant macroeconomic impact of the shocks identified. In particular, unexpected downturns in oil and gas supply lead to an increase in energy prices that is persistent and significant. Similarly, oil- and gas-specific demand shocks increase real oil prices and real gas prices, respectively. Based on the historical decomposition, the contribution of supply shocks is lower than market demand shocks in explaining the price movements in both the markets. More specifically, the observed movements in the real price of gas between March and December 2022 are mainly due to changes in gas-specific demand rather than to gas supply. Our decomposition attributes most of the rise in gas price observed after June 2023 both to gas supply and gas-specific demand, likely resulting from the rising violence in the Middle East coupled with Europe's dependence on liquefied natural gas supplies.

Focusing on Italian macroeconomic variables, we observe a reduction of industrial production, value added and investment in response to adverse oil and gas supply shocks. The fall is stronger for the energy-intensive sectors, when an adverse oil supply shock is considered. The rise of the gas price due to a gas supply shock affects all the sectors in the short-run. Oil-specific and gas-specific demand shocks have an immediate but transitory negative effect on the three variables considered. Finally, an unanticipated aggregate demand expansion causes a statistically significant increase in production, value added and investment, for all the sectors.

We have set aside the possibility of capturing nonlinearities in the propagation of oil and gas shocks to the economy. A potential direction for future research could be to incorporate these features to study the macroeconomic effects of energy shocks.

References

Alessandri, P. and A. Gazzani (2023). Natural gas and the macroeconomy: not all energy shocks are alike. *Bank of Italy Temi di Discussione (Working Paper) No 1428*.

Alessandri, P., A. Gazzani, and A. Vicondoa (2021). The real effects of financial uncertainty shocks: A daily identification approach.. *DOCUMENTO DE TRABAJO 2021*, 61.

Alquist, R. and L. Kilian (2010). What do we learn from the price of crude oil futures? *Journal of Applied econometrics 25*(4), 539–573.

Alsalman, Z. and A. M. Herrera (2015). Oil price shocks and the u.s. stock market: Do sign and size matter? *Energy Economics 51*, 571–581.

Arora, V. and J. Lieskovsky (2014). Natural gas and US economic activity. *The Energy Journal 35*(3).

Asche, F., O. B. Nilsen, and R. Tveteras (2008). Natural gas demand in the European household sector. *The Energy Journal 29*(3).

Banca d'Italia (2023). Relazione annuale. Technical Report 1, Banca d'Italia. Annual Report.

Barnichon, R. and C. Brownlees (2019). Impulse response estimation by smooth local projections. *Review of Economics and Statistics 101*(3), 522–530.

Barsky, R. B. and L. Kilian (2002). Oil and the macroeconomy since the 1970s. *Journal of Economic Perspectives 18*(4), 115–134.

Baumeister, C. and J. D. Hamilton (2015). Sign restrictions, structural vector autoregressions, and useful prior information. *Econometrica 83*(5), 1963–1999.

Baumeister, C. and J. D. Hamilton (2018). Inference in structural vector autoregressions when the identifying assumptions are not fully believed: Re-evaluating the role of monetary policy in economic fluctuations. *Journal of Monetary Economics 100*, 48–65.

Baumeister, C. and J. D. Hamilton (2019). Structural interpretation of vector autoregressions with incomplete identification: Revisiting the role of oil supply and demand shocks. *American Economic Review 109*(5), 1873–1910.

Baumeister, C. and L. Kilian (2016). Lower oil prices and the US economy: Is this time different? *Brookings Papers on Economic Activity 2016*(2), 287–357.

Burke, P. J. and H. Yang (2016). The price and income elasticities of natural gas demand: International evidence. *Energy Economics 59*, 466–474.

Caldara, D., M. Cavallo, and M. Iacoviello (2019). Oil price elasticities and oil price fluctuations. *Journal of Monetary Economics 103*, 1–20.

Corsello, F., M. Flaccadoro, and S. Villa (2023). Quantity versus price dynamics: the role of energy and bottlenecks in the italian industrial sector. *Bank of Italy Occasional Paper* (781).

De Santis, R. A. and T. Tornese (2023). Energy supply shocks nonlinearities on output and prices.

Dilaver, Ö., Z. Dilaver, and L. C. Hunt (2014). What drives natural gas consumption in Europe? analysis and projections. *Journal of Natural Gas Science and Engineering 19*, 125–136.

Edelstein, P. and L. Kilian (2007). The response of business fixed investment to changes in energy prices: a test of some hypotheses about the transmission of energy price shocks. *The BE Journal of Macroeconomics 7*(1).

Elder, J. and A. Serletis (2010). Oil price uncertainty. *Journal of Money, Credit and Banking 42*(6), 1137–1159.

Erias, A. F. and E. M. Iglesias (2022). Price and income elasticity of natural gas demand in Europe and the effects of lockdowns due to Covid-19. *Energy Strategy Reviews 44*, 100945.

Gazzani, A., F. Venditti, and G. Veronese (2024). Oil price shocks in real time. *Journal of Monetary Economics 144*, 103547.

Gunnella, V., V. Jarvis, R. Morris, and M. Tóth (2022). Natural gas dependence and risks to activity in the euro area. *Economic Bulletin Boxes 1*.

Güntner, J., M. Reif, and M. Wolters (2024). Sudden stop: Supply and demand shocks in the german natural gas market. *Journal of Applied Econometrics*.

Hamilton, J. D. (1983). Oil and the macroeconomy since world war II. *Journal of political economy 91*(2), 228–248.

Hamilton, J. D. (2003). What is an oil shock? *Journal of econometrics 113*(2), 363–398.

Hamilton, J. D. (2009). Causes and consequences of the oil shock of 2007-08. Technical report, National Bureau of Economic Research.

Herrera, A. M., L. G. Lagalo, and T. Wada (2011). Oil price shocks and industrial production: Is the relationship linear? *Macroeconomic Dynamics 15*(S3), 472–497.

Jadidzadeh, A. and A. Serletis (2017). How does the US natural gas market react to demand and supply shocks in the crude oil market? *Energy Economics 63*, 66–74.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American economic review 95*(1), 161–182.

Kilian, L. (2008). The economic effects of energy price shocks. *Journal of economic literature 46*(4), 871–909.

Kilian, L. (2009). Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. *American Economic Review 99*(3), 1053–1069.

Kilian, L. and D. P. Murphy (2012). Why agnostic sign restrictions are not enough: understanding the dynamics of oil market var models. *Journal of the European Economic Association 10*(5), 1166–1188.

Kilian, L. and D. P. Murphy (2014). The role of inventories and speculative trading in the global market for crude oil. *Journal of Applied econometrics 29*(3), 454–478.

Kilian, L. and R. J. Vigfusson (2011). Are the responses of the u.s. economy asymmetric in energy price increases and decreases? *Quantitative Economics 2*(3), 419–453.

Kilian, L. and R. J. Vigfusson (2017). The role of oil price shocks in causing u.s. recessions. *Journal of Money, Credit and Banking 49*(8), 1747–1776.

Labandeira, X., J. M. Labeaga, and X. López-Otero (2017). A meta-analysis on the price elasticity of energy demand. *Energy policy 102*, 549–568.

Lenza, M. and G. E. Primiceri (2022). How to estimate a vector autoregression after March 2020. *Journal of Applied Econometrics 37*(4), 688–699.

Lippi, F. and A. Nobili (2012). Oil and the macroeconomy: a quantitative structural analysis. *Journal of the European Economic Association 10*(5), 1059–1083.

Melek, N. C. et al. (2018). The response of US investment to oil price shocks: Does the shale boom matter? *Economic Review, Federal Reserve Bank of Kansas City forthcoming*.

Neri, S. (2024). The transmission of energy price shocks in the euro area. *Working Paper*.

Ng, S. (2021). Modeling macroeconomic variations after COVID-19. Technical report, National Bureau of Economic Research.

Nguyen, B. H. and T. Okimoto (2019). Asymmetric reactions of the US natural gas market and economic activity. *Energy Economics 80*, 86–99.

Nick, S. and S. Thoenes (2014). What drives natural gas prices?a structural var approach. *Energy Economics 45*, 517–527.

Ponce, M. and A. Neumann (2014). Elasticities of supply for the us natural gas market.

Rubaszek, M., K. Szafranek, and G. S. Uddin (2021). The dynamics and elasticities on the US natural gas market. a bayesian structural var analysis. *Energy Economics 103*, 105526.

Wiggins, S. and X. L. Etienne (2017). Turbulent times: Uncovering the origins of US natural gas price fluctuations since deregulation. *Energy Economics 64*, 196–205.

A Data

Our dataset for the energy markets consists of monthly data spanning the period from January 1996 to December 2023.

The crude oil production, expressed as thousand barrels per day, is drawn from the Energy Information Administration.

The spot price of Brent crude oil and the Europe TTF natural gas price are taken from the International Monetary Fund database. Both prices are converted into euros by the Euro/dollar exchange rates and deflated by the EU Consumer Price Index, both retrieved from the Istat database.

As a proxy for global economic activity, we use industrial production measure developed by Baumeister and Hamilton (2019).

Regarding the European natural gas supply, we take monthly data for natural gas balance from Eurostat and compute the production by summing to primary production the imports and subtracting exports for the European Union (27 countries).[21] The final gas supply series is expressed in terajoules and, for consistency with natural gas price, it is converted into Million British thermal units.

Industrial production index, value added and investment (i.e. gross fixed capital formation) of the Italian industrial sector, excluding construction, are retrieved from Istat database. The energy-producing sectors include: mining and quarrying, manufacture of coke and refined petroleum products, electricity, gas, steam and air conditioning supply, and water collection, treatment and supply (NACE). The energy-intensive sector group is defined by aggregating paper and paper products, chemicals and chemical products, other non-metallic mineral products and basic metals, defined according to the statistical classification of economic activities in the European Community. The remaining sectors are defined as non-energy-intensive.

Data on value added and investment by sectors are available with annual frequency and are temporally disaggregated by using the total series of value added and investment, available quarterly. In the case of industrial production, information are available monthly and are aggregated at quarterly level by using time-varying weights, defined on the sectoral value added. In the case of investment, the data are available with a slightly different level of sectoral aggregation. For ease of comparability with industrial production and value added, we

[21]For the period preceding 2008, the variables used for constructing gas production are available only at an annual frequency. Therefore, for this period, monthly data are obtained by applying the Chow-Lin disaggregation.

consider wood, paper and publishing industries, the manufacture of chemical products, the manufacture of rubber and plastic products and other non-metallic mineral processing products and metallurgical activities and the manufacture of metal products, excluding machinery and equipment as the energy-intensive sectors. Value added and investment are transformed into real terms by using the harmonized index on consumer prices. Industrial production index is based on production volumes.

The sample period of this last dataset starts from the 1st quarter of 1999 to the 4th quarter of 2023.

Finally, all the variables have been tested for seasonality and, whenever seasonality has been detected, we seasonally adjust the series.