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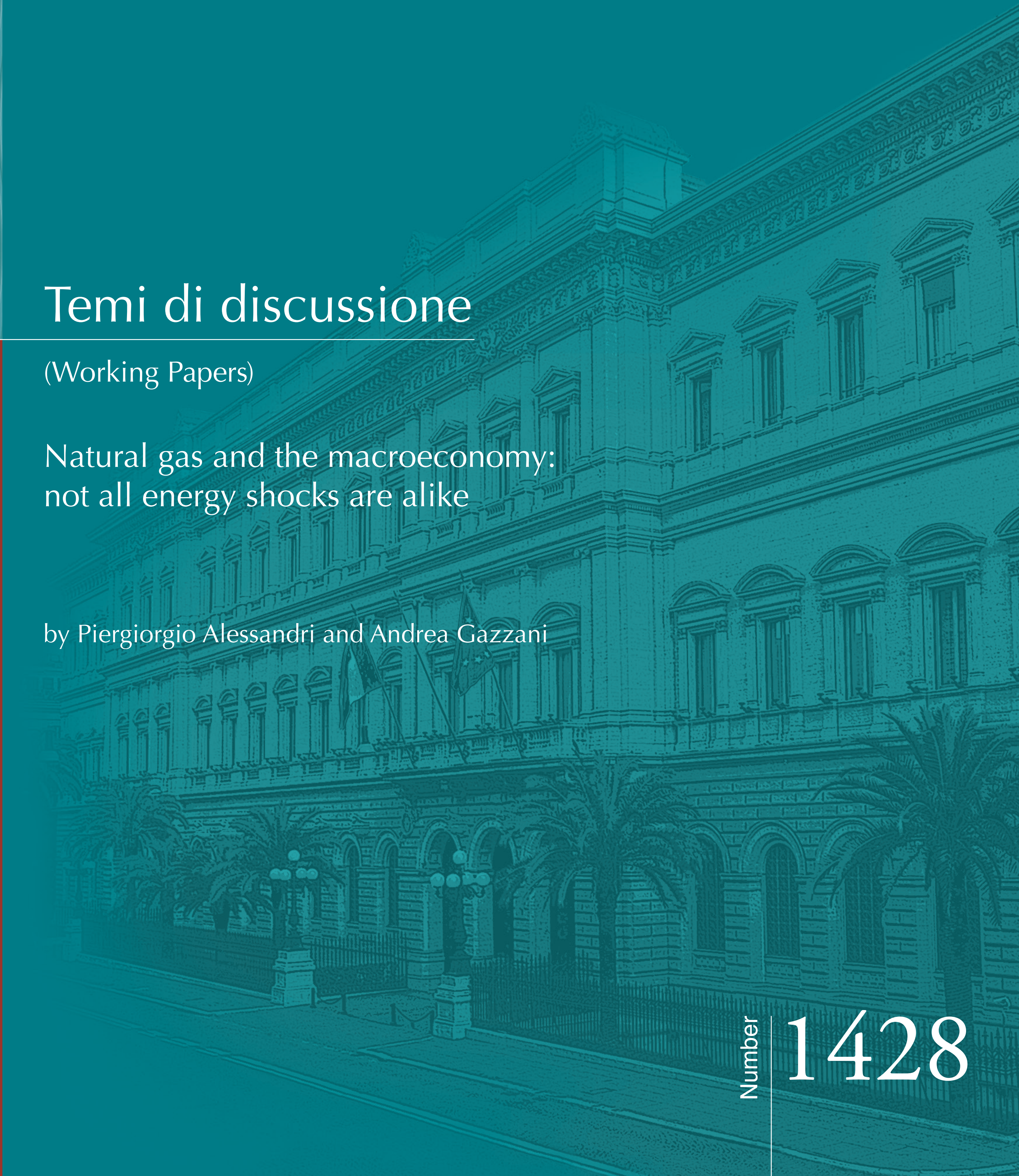

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NATURAL GAS AND THE MACROECONOMY: NOT ALL ENERGY SHOCKS ARE ALIKE

by Piergiorgio Alessandri* and Andrea Gazzani*

Abstract

How do shifts in the supply of natural gas affect output and inflation? To answer this question, we construct an instrument for gas supply shocks using a large set of daily news on the European gas market over the 2010-2022 period and use the instrument within a Bayesian VAR model. We find that negative supply shocks are stagflationary and that their effects materialize over far longer horizons than those of oil supply shocks, with peaks (troughs) in core inflation (industrial production) that follow the shock by two years or more. This pattern is consistent with the structural features of the gas market, and it suggests that European economies are still grappling with the large price spikes that took place in 2022.

JEL Classification: E31, E32, Q35, Q43.
Keywords: natural gas prices, inflation, narrative identification, Bayesian VAR.
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Contents

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* Bank of Italy, Directorate General for Economics, Statistics and Research.

1 Introduction[1]

The procurement of natural gas has been a sticking point for European economies over the last two years. The political tensions that built up in 2021, culminating in the Russian invasion of Ukraine in February 2022, triggered dramatic jumps in gas prices and a collapse in gas flows from Russia to Europe, turning a previously neglected commodity into a key issue on the media and in policy debates. Yet, unlike oil, gas represents an unknown from a macroeconomic perspective. There is scant evidence on how demand and supply factors affect gas prices, or on the influence that gas prices have on inflation and economic activity. Furthermore, the gas market has a number of peculiar features that could in principle affect the propagation of the shocks: trading traditionally took place through long-term contracts in fragmented markets, the contractual structures and regulations weaken the link between wholesale and retail prices, and strong seasonality characterizes natural gas consumption such that buyers maintain large storage capacities.[2] A cursory look at the data suggests that these factors may matter from a macroeconomic perspective. In Figure 1 we show the coefficients obtained from a simple regression of the energy component of the Euro Area consumer price index on the level of gas or oil prices observed in the previous months.[3] The difference is stark: an increase in wholesale oil prices is immediately incorporated into the energy price index, whereas an increase in gas prices takes about one year to propagate fully, with a final impact that is about 5 times larger than the initial impact. The estimates are suggestive of heterogeneity in the propagation of gas and oil shocks. However, moving from the correlations in Figure 1 to causal statements on the relevance of gas supply shocks is not trivial. Distinguishing between supply and demand shocks in energy markets is notoriously difficult; seasonality, regulation and contractual frictions further complicate the identification of gas supply shocks, particularly for econometricians that are forced to rely on relatively short samples that include the break caused by the Covid pandemic.

We take up the challenge by combining two tools that are widely used in empirical macroeconomic studies: 'narrative' identification and Bayesian VAR models. To identify supply shocks, we parse a large dataset of daily news about the European gas market over the 2010-2022 period. We focus on dates in which the prices of gas futures recorded

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[1] We thank Gabriele Cappadona for outstanding research assistance. This paper has benefited from presentations at Banca d'Italia and feedbacks from Riccardo Cristadoro, Riccardo Degasperi, Fabrizio Ferriani, Leonardo Melosi, Ivan Petrella, Fabrizio Venditti, Giovanni Veronese. All errors are our own.

[2] See Ason (2022) for a review of the contractual features of the natural gas market.

[3] The data is described in Section 2. The regression is a reduced-form local projection of (the log-levels of) retail energy prices in month $t + h$ on wholesale gas or oil prices in month t, with four lags of all variables used as additional controls. The gas and oil coefficients are normalized to 1 for $h = 1$ to facilitate the comparison.

large swings, and resort to a careful line-by-line analysis of the underlying daily news to separate events that are clearly symptomatic of shifts in the supply of natural gas (mostly but not exclusively from Russia) to those relating to changes in demand and other confounding factors. Our definition of supply disturbances encompasses changes in actual gas flows, news on future gas flows and variation in risk of future supplies. We then use the change in prices in days driven by supply news as an external instrument or proxy in a Bayesian VAR model that includes economic activity indicators and consumer prices. The Bayesian setup allows us to (i) model the potentially 'long and variable' lags that separate shocks and economic responses despite the relatively small size of the sample; (ii) sterilize the confounding effect of the volatility caused by the Covid pandemic (following Lenza and Primiceri, 2022); and (iii) obtain estimates that are robust to the large fluctuations and non-stationarity displayed by gas prices in 2021 and 2022.

We find that negative shocks to gas supplies are stagflationary, and that their impact on inflation is more gradual but ultimately larger than that of oil supply shocks. Oil shocks cause a sudden increase in energy prices that propagates to the 'core' component of the consumer price index within a few months. Gas shocks, by contrast, cause a slow increase in energy prices and an even slower increase in the price of core goods, with a peak occurring almost 2 years after the shock. Quantitatively, a 5% increase in gas prices ultimately leads to a 0.2% increase in core inflation; depending on the specification, gas shocks account for a share of 35 to 50 per cent of the variance of core prices in our sample. The overall pass-through to core inflation, defined as the ratio between the cumulative responses of core and energy prices at the one-year horizon, is about 8% for gas shocks and 4% for oil shocks. The results are robust to various departures from the baseline setup, such as replacing the VAR with larger Factor-Augmented VAR (FAVAR) models, using local projections, or resorting to an identification scheme based on heteroscedasticity (à la Rigobon, 2003) that does not require the instrument to be exogenous. Although our narrative instrument draws most of its power from the volatility caused by the war, the results are also qualitatively similar in the pre-2022 or pre-2020 sample.

Related literature. Our work joins a debate on the relation between energy markets and the macroeconomy that has recently gained significant visibility in both research and policy fora. Researchers have traditionally focused on the oil market. The impact of oil price shocks on GDP is relatively well established.[4] The relation between oil and inflation is more controversial. Earlier studies identified a significant influence of oil or gasoline prices on both inflation and inflation expectations, pointing to rising fuel prices as a key factor behind the puzzling behaviour of US inflation during the Great

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[4] Hamilton (1983), Kilian (2009), Baumeister and Hamilton (2019), Känzig (2021), Degasperi (2021).

Recession;[5] subsequent contributions suggest instead that the link is at best tenuous and only relevant in the short run.[6] This link is also relevant for the natural gas market, which in the case of Europe is equally if not more important than oil.[7] Our analysis documents a clear pass-through from gas supply shocks to core inflation, and suggests that standard identification schemes could fail to capture the slow and gradual propagation of these shocks. Boeck and Zörner (2023) and Casoli et al. (2022) study the impact of gas supply shocks in monthly VAR models identified through a mixture of sign and zero restrictions, finding that the shocks have strong effects on output, inflation and inflation expectations in Europe.[8] The key advantage of our approach is that, by constructing an instrument based on daily news, we can isolate the shock at a higher frequency and avoid prior restrictions on the impact that disruptions to gas supplies may have on the economy. Both factors are likely to be important in the light of the identification challenges associated to the peculiar nature of the gas market (see Section 2). Our results also speak to the policy side of the debate on energy markets. The calibration of monetary and fiscal policy interventions requires reliable estimates of the economic impact of the war for European countries, but these estimates are hard to agree on. Analysts suggested that a 30% contraction in oil and gas supplies could reduce output by up to 14% in Europe within two years[9]; recent model-based simulations indicate that a break in oil, gas and coal imports could cost Germany – a country that depends on Russia for about one third of its energy consumption – between 0.5% and 3% of its GDP.[10] We provide direct evidence on the magnitude of these channels. Our results show that gas shocks affect inflation more than output and that their propagation requires in both cases a long period of time, thus partly reconciling the large contraction estimated in macro models with the resilience displayed by European economies in 2022 and 2023. Finally, a better understanding of gas shocks could inform the introduction of energy markets in macroeconomic models. Recent new-keynesian models with heterogeneous agents typically treat energy as a single homogeneous good.[11] The same is true of the workhorse models employed by policy institutions such as the IMF, which typically assume full substitutability between oil and natural gas. Our findings suggest that oil and gas shocks have different implications for inflation, calling for a more articulated modeling framework.

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[5] Coibion and Gorodnichenko (2015); see also Conflitti and Cristadoro (2018) and Coibion et al. (2020).

[6] Kilian and Zhou (2022a), Kilian and Zhou (2022b).

[7] Oil and natural gas contributed respectively for 33% and 25% of primary energy consumption in the EU in 2021, but gas prices determine the electricity price being the marginal fuel of electricity production.

[8] See also Nick and Thoenes (2014) and Rubaszek et al. (2021), which analyze the drivers of natural gas markets rather than the macro-financial implications of gas supply shocks.

[9] Cook et al. (2022)

[10] Garicano et al. (2022), Bachmann et al. (2022), Lan et al. (2022).

[11] See e.g. Pieroni (2023) and the open-economy model of Auclert et al. (2023).

Structure of the paper. The remainder of the paper is organized as follows. In Section 2 we discuss the identification strategy and illustrate the properties of the instrument based on gas news. In Section 3 we study the impact of gas supply shocks on financial indicators using simple daily regression models. In Section 4 we move to the VAR analysis. Section 5 explores alternative empirical specifications. Section 6 focuses on the comparison between gas and oil shocks. Section 7 concludes the paper. A detailed description of the data employed in the paper is provided in appendix.

2 Empirical approach

2.1 The identification problem

Before explaining the details of our empirical strategy, we develop a simple example to illustrate the identification problem that arises in disentangling supply-side and demand-side drivers of natural gas prices (and potentially other commodity prices). Consider estimating a small VAR that includes monthly observations on real gas prices (*gas*) from the *Title Transfer Facility* (TTF - the main European benchmark), the core harmonized index of consumer prices (*core hicp*) and industrial production (*ip*) for Europe over the period January 2010 to December 2022.[12] The model is estimated using Bayesian techniques. We defer a more detailed explanation of our modeling and estimation strategy to Section 4. A simple option to quantify the impact of shocks to gas prices could be to compute the impulse-response functions (IRFs) under a Cholesky identification. If *gas* is ordered first, assuming the TTF to be unaffected by contemporaneous macroeconomic news, the gas price shock is nothing but the reduced-form residual of the first equation of the VAR. The impact of this shock is shown in Figure 2. The responses show a marked and persistent increase in *core hicp*, but also a quick and persistent rise in *ip*, which increases on impact and then barely turns into negative territory after two-to-three years. These dynamics suggest that, under this naive identification scheme, the shock is likely to capture a combination of demand and supply factors; the figure suggests that demand factors are quantitatively more important, both in general and in shaping the short-run *ip* response. As in the case of oil, demand shocks that are not commodity-specific are less interesting because they lack a specific causal interpretation: they reflect changes in business cycle conditions that have nothing to do with the gas market. Our strategy is designed to identify genuine shocks to the supply of natural gas and gauge their consequences for prices and economic activity in Europe.

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[12] Our preferred measure of gas prices comes from the World Bank Pink Sheet, that combines TTF quotes with prices in the UK trading hub gas market prior to 2015, while coincides with the TTF after 2015 (see Section 4). Results are virtually identical if we use the TTF series over the whole sample.

2.2 Narrative identification

To construct our instrument we examine a rich sample of daily news spanning the period between January 1st 2010 and November 30th 2022. By using a relatively long sample we reduce our reliance on the volatility caused by the Russian invasion of Ukraine in 2022 for identification. The period we consider includes for instance the conflict between Russia and Ukraine in 2014, as well as phases of greater political and financial stability prior to 2014 and between 2016 and 2021.[13] We end the sample in November 2022 because on December 3rd the European Union agreed to cap the price of natural gas to reduce the volatility created by the conflict. This unprecedented intervention may have altered the market in non-trivial ways, rendering the most recent observations not directly comparable to the historical data.

We construct the instrument in two steps. The first step consists of isolating days that are characterized by quantitatively significant fluctuations in TTF futures. Defining what ′significant′ means is not trivial because gas prices are much more volatile in the last part of our sample. Table 1 reports the results of a non-parametric test of constant variance for the TTF daily growth rate before and after 2019. The null hypothesis of a constant variance is overwhelmingly rejected; the standard deviations of the series in the two sub-samples are about 2 and 5.8 percentage points.[14] Based on this evidence, we pick all the dates for which the absolute value of the daily percentage change in the front-month TTF future exceeds a threshold of, respectively, 5% in the pre-2019 data and 10% in the post-2019 data. This gives a set of 125 trading days that were characterized by price shifts of two standard deviations or more within each regime. In order to focus on persistent changes in price levels, we exclude from this sample 15 dates in which the one-day ahead, front-month and one-year ahead futures move in different directions.[15] The final sample thus consists of 110 dates.

In the second step we collect and carefully vet the news about the gas market associated to each of these dates. We begin by extracting from Refinitiv all news in English whose titles contain the strings ″TTF″, ″LNG″ (for Liquified Natural Gas) and/or

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[13] Russia and Ukraine officially ended the conflict by signing the Minsk II agreements on February 12th 2015. The agreement included *inter alia* the withdrawal of heavy weapons from the front line and an OSCE-observed unconditional ceasefire from February 15th.

[14] The break in December 2019 allows us to account for the Covid pandemic as well as a significant escalation in the political tensions between Russia and Ukraine; Ukraine was granted NATO Enhanced Opportunity Partner status on 12 June 2020, and President Zelensky approved a new national security plan with the explicit aim of joining NATO on 14 September 2020.

[15] This filter may somewhat weaken the power of the instrument, but it allows us to focus on shocks that affect the level (rather than slope or curvature) of the future curve and are perceived to be persistent by market operators. Hevia et al. (2018) document the quantitative relevance of level, slope, curvature and stochastic seasonality in futures on heating oil and soy bean; Garratt and Petrella (2022) fit a similar multi-factor model to over 20 commodities including natural gas.

"GAZP" (for Gazprom; excluding this keyword has little impact on the results). The search returns over 8,000 news. Upon cleaning the database from noisy information, the total drops to 4,290 news, with a mean and median of respectively 39 and 29 news per date. The frequency of gas-related news displays large fluctuations over time, with a maximum of 150 entries (on September 7th 2022), a minimum of 2 entries (on August 28th 2014), and a standard deviation of about 30. We then examine the news individually, considering the body as well as the title of each entry, and assign a "demand" or "supply" flag to the items that have a clear interpretation. All remaining news are marked as ambiguous or irrelevant; this residual category includes *e.g.* a large number of wires that merely comment on data released in previous days, or report minor updates on the routes followed by LNG tankers. This process isolates 50 daily supply shocks. The remaining 60 dates are classified as (i) not sufficiently relevant, (ii) dominated by demand shocks, or (iii) characterized by an ambiguous mixture of demand and supply shocks, and excluded from the analysis. The classification is deliberately conservative: we rule out all dates for which supply-side events might be polluted by concurrent changes in demand in order to preserve the validity of the instrument.

Table 2 reports a selected sample of supply shocks, showing for each date the news and the observed daily percentage change in one-month TTF future (further details are available in the online annex). Negative shocks include the US government's threat to sanction North Stream 2 (June 2020), the invasion of Ukraine (February 2022), the shutdown of the Yamal pipeline (March 2022) and Gazprom's decision to only accept payments in roubles (March 2022). A sequence of restrictive shocks occurs during summer 2022, between June and August, in relation to the continuous decline in Nord Stream gas flows. Positive shocks are often associated to conciliatory statements by Gazprom or unexpected pickups in pipeline flows. As the table makes clear, we do not discriminate between actual changes in gas flows, news on future flows and changes in the uncertainty about future flows. These shocks are likely to have fairly similar effects on macroeconomic outcomes. Discriminating among them could be interesting in principle, but would require a larger database and a more subtle (and potentially contentious) interpretation of the news. Figure 3 shows the instrument at the monthly frequency. This is a simple monthly average of the TTF price changes observed around the selected dates, and it is what we use in practice to instrument the residuals of the VAR models used in the empirical analysis. The largest shocks take place in the build-up and aftermath of the Russian invasion of 2022, but there are a number of significant episodes in the sample that predates Covid (2014-2019) and the Crimean conflict (2010-2014). In Figure 4, we compare the TTF price (orange line) to a counterfactual series obtained by cumulating price changes stemming from supply events (blue line). Supply shocks capture very accurately the steep rise and subsequent decline of the TTF between 2020 and 2022. TTF futures were far less volatile before 2020: our analysis suggests that in this period supply shifts were less frequent and the market mostly moved in response to (smaller and potentially less powerful) shifts in demand.

There are clear trade-offs involved in constructing the instrument: an algorithm-based textual analysis would allow us to expand the sample quantitatively, while focusing on relatively few dates allows us to study the news in greater depth. We choose depth over width for two reasons. One is that the data is noisy and some sources of noise would be nearly impossible to spot through automated textual analyses.[16] The other one is that the nature of the news and the lack of pre-defined recurrent announcements (like the OPEC announcements on oil production) creates a significant risk of misinterpreting various important episodes. Consider the Fukushima accident on March 14th 2011 (the first shock in Table 1). The accident forced Japan to abruptly increase its LNG imports to replace nuclear energy, and this unexpected spike in demand caused a 5% increase in the TTF: since production is fixed in the short run, exogenous shifts in *demand* in the rest of the world (due e.g. to infrastructural breakdowns or abnormal temperatures) translate into shifts in *supply* for European consumers. Exploiting this mechanism through textual analysis could be difficult. September 7th 2022 (that does not appear in the table) provides another good illustration of identification challenges. This is the date for which we obtain a record of 150 gas-related news. President Putin announces that Russia's gas sales would stop altogether if the EU introduced a gas price cap: his remarks have a significant resonance on the media, appearing in various forms in many of the 150 entries. But Italy's Shell and Germany's Uniper sign new agreements on LNG supplies, and news spread about an earlier-than-expected reactivation of Freeport (the second-biggest US LNG export plant, shut in June). An algorithm would probably classify this episode as a supply contraction, but there are good reasons to be skeptical about gas supply expectations shifting at all.

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[16] Price updates consisting of one-line comments (of the type *"gas prices in [country] increases by [x]% in [reference period]"*) would be easy to filter out automatically. News about LNG tankers are somewhat more problematic because they typically look like boosts to European supplies, but (with a few exceptions of re-routed cargoes) they are not really news in that they simply confirm destinations and arrival times of scheduled gas deliveries. Repetitions can be particularly tricky. On 29/11/2022, for instance, the news of a potential expansion of LNG supplies to Germany shows up in three different forms within 10 minutes (*Qatar to supply Germany with LNG as EU seeks secure energy options*, FT, 14:14; *Germany to get new Qatari LNG flows through QatarEnergy - ConocoPhillips deal*, RTRS, 14:20; *The Qatar minister sees no upper limit to LNG deliveries to Germany* , RTRS, 14:22). On 26/7/2022, spikes in gas pressures are blamed sequentially on Russia (*Ukraine says Russia increased gas pipeline pressure without prior notice*, 15:03) and Gazprom (*Ukraine Accuses Gazprom Of Sharply Hiking Gas Pipeline Pressure*, 16:58). In these cases irregular time patterns and changes in wording are likely to confound any unsupervised, machine-based processing of the data.

2.3 Properties of the shocks

In exploiting changes in gas futures around key dates for identification we follow the logic used by Känzig (2021) for the oil market. The key idea is that these fluctuations in prices are driven by exogenous shifts in supply and are not related to changes in business cycle conditions. To check the power of the instrument we regress the TTF residual from the VAR model described in Section 2.1 on our set of shocks. The results are shown in Figure 5, which compares the VAR residual and the instrument over the entire sample (left panel) and more specifically in the 2021-2022 period (right panel). The chart confirms that the instrument has a strong correlation with the unexpected changes in gas prices obtained from the VAR. This first-stage regression gives an R^2 coefficient of 0.26 and an F statistic of about 33, with a p-value that is extremely close to zero.

The validity of the instrument is notoriously trickier to corroborate. In principle the shock should not overlap with other structural shocks. To investigate this issue, we first check how the volatility of gas prices and the volatility of other commodity and asset price indicators change on shock dates *vis-a-vis* non-shock dates. If (i) our identification picks up shocks that truly originate in the gas market (as opposed to generic macro-financial disturbances), and (ii) these shocks have a larger impact on gas prices than on the other indicators, then the variance of the TTF should increase on shock dates more than the variance of the other series. The results are shown in Table 3. The table reports the ratio between the volatility of TTF on shock- and no-shock dates (column 1) and a range of analogous ratios computed using oil prices, coal prices, wheat prices, equity prices, the VSTOXX volatility index, the 3-month Euribor rate and the geopolitical risk index (GPR, from Caldara and Iacoviello, 2022) (columns 2 to 7). The volatility of TTF futures is 25 times larger on shock dates. No other indicator displays a comparable increase in variance except for the coal price. However, since coal is a partial substitute of natural gas for power generation in Europe, volatility could arise in this case precisely as a response to gas supply shocks.[17] This pattern emerges clearly in the pre- and post-2020 samples: in both cases the TTF is the only indicator for which volatility is one order of magnitude larger on shock dates. The results are particularly interesting for the oil price and the GPR index. Oil prices are actually 40% less volatile around the shock dates included in the 2020-2022 time window, confirming that gas and oil markets followed largely different patterns over this period and that the risk of capturing combinations of energy shocks of different kinds is low. The potential overlap between gas shocks and geopolitical shocks is another potentially important concern, as the conflict between Russia and Ukraine certainly caused a widespread increase in uncertainty and a deterioration in

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[17] See for instance Di Bella et al. (2022), OIES Quarterly Review 19 and OIES demand response to high gas prices where gas prices are typically compared to coal prices, rather oil prices, at energy content parity.

business conditions after 2022. However, the volatility of the GPR index also turns out to be lower on shock dates, suggesting that at the daily frequency geopolitical events are not systematically synchronized with (what we identify as) changes in gas supply. Our robustness tests deliver additional evidence on this point, showing that -despite a significant loss of power- the instrument delivers qualitatively similar estimates of the response of output and inflation to gas shocks in the pre-2022 sample (see Section 5). As a further diagnostic test, we compute the correlations between the instrument and a range of other structural shock estimates available in the literature, focusing again on shocks that relate to energy markets and geopolitical risk. The results are reported in Table 4. The correlations between our instrument and oil, carbon or geopolitical risk shocks are both small (between -0.03 and 0.13) and statistically insignificant (with an average p-value of about 0.4). We provide a final piece of evidence on the validity of the identification procedure in Section 4, showing that macroeconomic and financial variables have no predictive power over our proxy of gas supply shocks. All in all, the tests consistently corroborate the conclusion that the shocks we identify are exogenous, unexpected and specific to the gas market.

3 The financial effects of gas supply shocks

Before moving to the VAR analysis we study the impact of gas prices on various financial indicators using local projection models based on daily data. Besides being interesting per se, these models also offer an indirect way to validate our identification strategy. The local projection coefficients measure the conditional correlations between gas futures and other asset or commodity prices at various horizons. As such, they capture the impact of gas shocks on those prices (in line with our identification), but potentially also the common response of the indicators to unobserved shocks of a different nature (which would be a worrying sign that our identification fails): one can use theory and common sense to discriminate between the two possibilities.

The impulse-response based on daily LP models are shown in Figure 6. On impact, an increase in TTF (top left corner) is associated to a drop in the Eurostoxx equity index, a rise in VSTOXX, and a rise in the prices of Asian LNG and UK gas and electricity. Oil prices (Brent) respond only mildy consistently with the mild substitutability between the two fuels in Europe. Conversely, coal prices respond strongly in line with the higher coal-gas substitutability in Europe discussed in Section 2.3. These responses are consistent with our instrument capturing genuine shocks to gas supply, that cause a repricing of the profitability and risk for European firms as a result of the increased energy costs faced by households and firms. Furthermore, both VIX and oil prices do not move much and the GPR index that is basically flat, suggesting that the potential overlap with other shocks is limited. Over time, the shock is also followed by an increase in US gas prices and a drop in carbon emission prices, potentially pointing to pressures on US supplies and a slow-down of carbon-intensive activities. Finally, our gas supply shock elicits an increase in the short-term interest rate and inflation swaps, i.e. an implicit measure of inflation expectations. The stronger magnitude of the response in the 1-year inflation swaps compared to longer-duration contracts signal that agents believe most of the effect on inflation will be concentrated in the short-term.[18]

4 The macroeconomic effects of gas supply shocks

4.1 Econometric framework

Consider the standard VAR model:

$$\mathbf{y}_t = \mathbf{a} + \mathbf{A}_1\mathbf{y}_{t-1} + \cdots + \mathbf{A}_p\mathbf{y}_{t-p} + \mathbf{u}_t \tag{1}$$

where p is the lag order, $\mathbf{y}_t$ is a $n \times 1$ vector of endogenous variables, $\mathbf{u}_t$ is a $n \times 1$ vector of reduced-form innovations with covariance matrix $\text{Var}\left(\mathbf{u}_t\right) = \mathbf{\Sigma}$, $\mathbf{a}$ is a $n \times 1$ vector of constants, and $\mathbf{A}_1, \ldots, \mathbf{A}_p$ are $n \times n$ matrices. The innovations $\mathbf{u}_t$ can be expressed as a linear combination of the structural shocks ε_t under the assumption of invertibility:

$$\mathbf{u}_t = \mathbf{B}\varepsilon_t$$

$\text{Var}\left(\varepsilon_t\right) = \Omega$ is diagonal as the structural shocks are by construction uncorrelated. Conversely, $\Sigma = \mathbf{B}\Omega\mathbf{B}'$ is not diagonal as, generally, the reduced-form residuals are correlated. We are interested in estimating the causal impact of a unique shock in the system, i.e. the gas supply shock $\varepsilon_{1,t}$. The task amounts at recovering a single column $\mathbf{b}_1$ of the impact matrix $\mathbf{B}$.

Bayesian VAR estimation. Due to the large fluctuations in our relatively short-sample related in particular to the Covid pandemic and to the energy crisis, we employ Bayesian methods to estimate the VAR model in eq.(1). We impose a standard Minnesota prior on the parameters of the BVAR according to which all univariate equations behave as a random walk. To fix the volatility induced, especially in measures of economic activity, by the Covid shock, we re-scale the size of the reduced form residuals in March, April and

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[18] The more forward looking measure of inflation expectations are the 2y5y and 5y5y, i.e. the 2 years forward expectations inflation starting 3 years ahead and the 5 year forward expected inflation starting 5 year ahead.

May 2020 as suggested in Lenza and Primiceri (2022). The hyper-parameters that control the prior and the scaling factors for the residuals are determined by jointly optimizing the marginal data density. Our results are virtually identical if we control for the Covid shocks by including in the VAR Covid cases and deaths as suggested by Ng (2021).

Identification via external instruments. Underlying the VAR identification via external instruments lies the assumption that, given the series z_t

$$\begin{aligned} \mathbb{E}\left[z_t \varepsilon_{1,t}\right] &= \alpha \neq 0 \quad \textit{(relevance)} \\ \mathbb{E}\left[z_t \varepsilon_{2:n,t}\right] &= 0 \qquad\quad \textit{(exogeneity)} \end{aligned} \tag{2}$$

where $\varepsilon_{1,t}$ is the gas supply shock and $\varepsilon_{2:n,t}$ are the remaining structural shocks.[19] Under those conditions the column $\mathbf{b_1}$ is correctly estimated, up to scale and sign as

$$\mathbf{b}_1 \propto \frac{\mathbb{E}\left[z_t \mathbf{u}_t\right]}{\mathbb{E}\left[z_t \mathbf{u}_{1,t}\right]'} \tag{3}$$

We employ the narrative series of gas supply shifts described in Section 2.2 as an external instrument as in Mertens and Ravn (2013).

Baseline specification. Our baseline specification, already introduced in Section 2.1, includes *gas*, *core hicp*, *ip* and 12 lags. The variables enter in log-levels following Sims et al. (1990). *gas* and *core hicp* are seasonally adjusted using the Census X13. *gas* is the Pinksheet World Bank series for european natural gas prices, that complements the TTF prices with additional information prior to 2015. Results obtained by using the TTF are nonetheless very similar. We estimate the VAR for European economy on monthly data spanning from January 2010 to December 2022. We focus on this sample because this is the period for which our series of external instrument for gas supply shocks is available. However, results are robust to extending backwards the sample to January 2004 while setting the proxy to zero when not available as shown in Noh (2018). Our external instrument passes the invertibility test, the null of no Granger causality from the VAR residuals to the proxy cannot be rejected (p-value 0.27).

4.2 Main results

Impulse Response Functions. Figure 7 reports the IRFs of the three endogenous variables to a gas supply shock identified via the external instrument approach. *gas* respond strongly to the shock corroborating the evidence on the strength of the instrument already provided in Section 2.3. Both *core hicp* and *ip* respond with delay to the gas supply shock,

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[19] A third conditions is actually required as shown in Miranda Agrippino and Ricco (2018) but we abstract from it in the present exposition.

consistently with the lagged pass-through from wholesale to retail prices that strongly characterize the gas market and that would make alternative identification approaches, such as sign restrictions, unsound. The effect of gas supply shocks on *core hicp* peaks after two years and gradually reverses, reaching zero after four years. The negative response of *ip* takes even more time to build, peaking at about three years. Quantitatively, a 5% increase in *gas* leads to a 0.2% peak increase in *core hicp* and a 0.6% fall in *ip*. Differently from the Cholesky identification in Figure 2, *ip* does not increase on impact, suggesting that we are correctly removing any fluctuation in demand from our measure of supply shocks.

Forecast error variance. Figure 8 displays the contribution of gas supply shocks to fluctuations of the endogenous variables of the VAR through a forecast error variance decomposition (FEVD). The shock accounts in the long term for about 50% of the variance of TTF futures. It also explains a non-negligible and statistically significant share of the variance of both industrial production (30%) and core inflation (45%). These large variance shares may reflect two distinct issues. First, these figures may be related the specific nature of our sample, in which (specially after 2021) the fluctuations in gas supply were fairly large, and particularly critical for European economies, in particular for inflation, after several years of subdued dynamics. Second, the validity of the FEVD hinges on the full invertibility of the gas supply shocks in our three-variable. VAR information insufficiency may introduce a bias in the forecast error variance decomposition (Forni et al., 2019). To alleviate this concern, in the robustness analysis we estimate a FAVAR model that includes a far larger set of variables; in this setup the contributions of the shock are smaller but still sizable and statistically significant (see Section 5).

5 Robustness and extensions

In this section we replicate the analysis modifying our empirical strategy along many dimensions, including identification scheme, specification of the VAR model, sample period, treatment of the Covid-19 break. The results of the tests are available in the annex or upon request.

Identification via heteroskedasticity. Our results are virtually unchanged if we lift our assumption on the exogeneity of the instrument and employ instead an identification scheme based on heteroskedasticity. The assumption underlying this strategy is that the *relative variance* of supply and demand shocks changes over time (Rigobon, 2003; Rigobon and Sack, 2004; Känzig, 2021, 2022). More formally, suppose that – besides being a noisy proxy of gas supply shocks, as commonly assumed in the literature – our external instrument is potentially contaminated by shocks that are not related to gas supply:

$$z_t = \varepsilon_{1,t} + \sum_{j>1} \varepsilon_{j,t} + \nu_t \tag{4}$$

Although the exogeneity assumption is violated, we can still identify the supply shocks by mixing the external instrument approach with identification via heteroskedasticity. In essence, we compare the dates in which TTF swings are predominantly caused by shifts in supply (T) to a control group of dates in which prices move under the influence of demand factors or unknown combinations of demand and supply factors (C) (that, as such, are excluded in our baseline analysis). The identification assumption is that the ratio of the variances of supply and demand shocks varies between T and C:

$$\begin{aligned} &\frac{\sigma^2_{\varepsilon_1,T}}{\sigma^2_{\varepsilon_j,T}} \neq \frac{\sigma^2_{\varepsilon_1,C}}{\sigma^2_{\varepsilon_j,C}} \quad \text{for } j = 2, \dots, n \\ &\sigma^2_{\nu,C} = \sigma^2_{\nu,T} \end{aligned} \tag{5}$$

If this condition holds, the impact of gas supply shocks can be recovered as

$$\mathbf{b}_1 = \frac{\mathbb{E}_T\left[z_t \mathbf{u}_t\right] - \mathbb{E}_C\left[z_t \mathbf{u}_t\right]}{\mathbb{E}_T\left[z_t^2\right] - \mathbb{E}_C\left[z_t^2\right]} \tag{6}$$

Rigobon and Sack (2004) show that the coefficient can be equivalently recovered through an IV approach as $\mathbf{b}_1 = (\tilde{\mathbf{z}}'\mathbf{z})^{-1}(\tilde{\mathbf{z}}'\mathbf{u})$, where $\tilde{\mathbf{z}} = (\mathbf{z}'_T, -\mathbf{z}'_C)'$ and $\mathbf{z} = (\mathbf{z}'_T, \mathbf{z}'_C)'$. This procedure delivers results that are virtually identical to our baseline estimates – see Figure A1.

Alternative VAR specifications. Replacing industrial production with the unemployment rate has no implications for the baseline results: the inflationary impact of the shock is virtually unchanged and the unemployment rate responds positively, reaching its peak about 30 months after the shock. The same is true if we replace the core component of the HICP (which excludes food and energy) with the headline HICP (which includes all items) or with the producer price index. We stick to core consumer inflation in our baseline model because this measure is more directly relevant for monetary policy decisions; the relation between energy and core prices is interesting in its own right and we study it in detail in Section 6. Most of our sample period overlaps with the Russo-Ukrainian war, that reached a climax in 2022 but began with the invasion of Crimea in 2014. In order to control for the confounding effect of the uncertainty associated to the conflict, we estimate larger VAR models that include either the geopolitical risk index of Caldara and Iacoviello (2022) (GPR, in its global or Russia-specific version - Figure A4) or the New York Fed Global Supply Chain Pressure Index (GSCPI - Figure A5). None of these specifications generates results that differ significantly from those of the baseline model. The results are also unchanged if we account for the influence of the Covid pandemic by explicitly including health-related variables in the VAR instead of allowing for breaks in variances, as suggested by Ng (2021).[20] In our setup, we can thus remain agnostic on whether the pandemic represented a shift in the distribution of pre-existing shocks (Lenza and Primiceri, 2022) or the emergence of new shocks of a different type (Ng, 2021).

Alternative sample periods. Our sample starts in 2010 (reliable data on gas prices in Europe are harder to find before then, see Section 2) and it includes both the Covid pandemic of 2020-2021 and the bout of volatility caused by the Russian invasion in 2022. To assess the stability of the results we run two experiments. In the first case we extend the sample back to 2004, setting the value of the instrument to zero when it is missing (as shown in Noh, 2018), and truncate it in February 2022 (Russia invaded Ukraine on February 22nd, the largest price rises materialized from March onward and prices peaked in August). The responses are extremely similar to the baseline in terms of both magnitudes and statistical significance (see Figure A7). In the second case we restrict the sample to 2014-2019 to totally exclude the EU energy crisis (since 2021). We are forced to start the sample for this exercise in 2014 given that, prior to this year, our IV provides very little variation for identification which is not compensated by the post-Covid years as in the baseline. This test is particularly demanding because the sample is shorter and the instrument looses most of its power due to the omission of the post-2019 observations.[21] The uncertainty around the estimates is much larger in this setup, particularly at long horizons, and the impact of the shock on gas prices is less persistent, suggesting that the shocks observed in 2020-2022 are somewhat different from those observed in normal times. Nevertheless, the shock is again followed by a slight decline in IP and an increase in core inflation (see Figure A11).

Local projections. Estimating local projections (LPs) that mimic the specification of our baseline VAR makes little sense because these regressions would completely ignore the structural break caused by Covid. However, the strategy suggested by Ng (2021) can be easily deployed in the LP context too. We thus estimate LPs that include lags of the number of Covid cases and Covid-related deaths among the controls (along with inflation, industrial production and gas prices), instrumenting the gas price with our news-based instrument. The results are shown in Figure A2. The LP-IV approach confirms the results of the Proxy-SVAR, generating IRFs that are very similar in terms of both shape and magnitude. Importantly, the LPs estimate a slow and delayed response of *HICP core* to the shock, confirming that this is a genuine feature of the data that does

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[20] We use data on the number of Covid cases and Covid-related deaths obtained from the *European Centre for Disease Prevention and Control*.

[21] See Figure 5. The inference is in this case based on Montiel Olea et al. (2021).

not depend in any way on the parametric restrictions imposed by VAR models.[22]

FAVAR. A potential limitation of the baseline VAR model is that it includes a small set of variables. However, our results are confirmed by a Bayesian FAVAR model that includes four principal components extracted from a set of 54 macrofinancial indicators (see annex for details; we report a selection of the responses in Figure A13). The FAVAR shows that EuroCoin, a synthetic indicator of economic activity in the Eurozone, is more responsive than *ip*. It also provides a richer description of the propagation of negative gas supply shocks: the shocks cause a drop in gas import and consumption, a slight temporary depreciation of the euro and an increase in 3M-Euribor rates that seems consistent with a stagflationary scenario. Oil prices do not comove with gas prices on impact, suggesting that the identification strategy is successful in isolating shifts in the supply of natural gas from shocks that affect the oil market. The results from the FAVAR are also robust to extending the sample backwards to 2004, varying the number of factors between 2 and 6, and extending the number of lags to 24 to directly estimate the IRFs over longer horizons. The FEVD obtained from the FAVAR is displayed in Figure A3. The model gives a more conservative assessment of the quantitative relevance of gas supply shocks compared to the baseline VAR: in the long run, the shock accounts for about 20% of the variance of industrial production and 30% of the variance of core inflation.

Country-specific results. When re-estimating the baseline model with country-level data, we find that negative supply shocks generate a drop in industrial production and a rise in prices almost everywhere but magnitude and significance of the responses vary across European countries (see Figures A14 to A17). Output contracts relatively more in Italy, Greece and Spain, and it expands in Norway (an important gas exporter). Consumer prices rise significantly in Poland, in the Netherlands and in Greece, but remain unchanged in Finland. There is a positive cross-sectional relationship between the magnitude of the responses and the intensity of gas usage: both industrial production and inflation respond more to the shock in countries where gas accounts for a larger share of the overall primary energy consumption (see Figure A18). The correlation is far from perfect because there are obviously many additional factors that affect the overall propagation of the shocks, including for instance the nature and size of the fiscal measures adopted between 2019 and 2022 in response to Covid and/or the energy crisis itself. However, the pattern of the responses is intuitive and it provides further evidence in support of the validity of the identification strategy.

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[22] To cross-check the estimates we also constructed a counterfactual dataset where the first 6 months of 2020 are replaced by the forecasts produced by the baseline VAR model in December 2019. This procedure replaces the actual observations for 2020H1 with the data that would have been observed (presumably) without the Covid shock. On this dataset, LP models that only include *gas*, *ip*, and *HICP core* deliver responses that are very similar to those shown in figure A2.

6 Are all energy shocks the same?

One important question is to what extent gas shocks resemble oil shocks in terms of impact and propagation mechanisms.[23] To investigate this issue, we re-estimate the FAVAR model instrumenting oil instead of gas prices and compare the dynamics generated by the two shocks. The instrument for oil supply shocks is the variation in the price of Brent oil futures around OPEC announcements, as in Känzig (2021). Since the instrument is weak in our baseline 2010-2022 sample and small-scale VAR model, we perform the comparison exploiting the longer 2004-2022 sample and the FAVAR model. The responses of industrial production, energy prices and core inflation to oil and gas supply shocks are reported respectively in Figure 9 and Figure 10. Like gas shocks, oil shocks cause a slowdown in *ip* and an increase in both *HICP energy* and *HICP core*. However, the dynamics differ in two interesting ways. The rise in energy inflation is significantly faster for oil shocks. In the case of an oil shock, *HICP energy* increases significantly on impact and peaks after about 10 months. In the case of a gas shock, the initial response is muted and the peak occurs about 16 months after the shock. *HICP core* takes even longer to adjust, peaking after more than 20 months, and responds relatively more to gas shocks. The literature on oil shocks does not provide obvious benchmarks for these estimates because it mostly focuses on the US economy and on different (typically longer) time periods[24]. However, our results are consistent with the conclusion by Giannone et al. (2014) and Conflitti and Luciani (2019) that in the Euro Area oil shocks affect mostly if not only the energy component of the HICP, with limited spillovers on the price of non-energy goods.

The elasticity of core to energy prices. The IRFs suggest that the timing of the responses differ and that the spillover or pass-through from energy to core prices might be stronger for gas supply shocks. To investigate this issue, we use the IRFs to calculate horizon- and shock-specific measures of passthrough (PT) based on the following definition:

$$\mathrm{PT}_h^s = \frac{\sum_{1:h} \mathrm{IRF}_h^s(\textit{HICP core})}{\sum_{1:h} \mathrm{IRF}_h^s(\textit{HICP energy})} \tag{7}$$

(where h is the horizon in months and s denotes either oil or gas supply shocks). PT_h^s is

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[23] Notable differences exist in several dimensions of the two markets. First, the contractual structure differs greatly: the gas market is mainly based on long-term contracts indexed to past prices and retail prices are regulated and adjust with lags to wholesale prices; the oil market is typically based on spot-contracts and the transmission to gasoline is relatively fast. Second, the usage of the two commodities is extremely heterogeneous: in the EU transportation absorbs about 65% of oil consumption while 15% is employed as non-energy production input in industry; conversely, natural gas affects directly or indirectly (through electricity, of which is a crucial fuel for production, and whose price is determined by gas prices since gas is considered the marginal fuel of production 65% of the final energy consumption in the industrial sector.

[24] See e.g. the recent contributions by Coibion et al. (2020); Kilian and Zhou (2022a,b)

nothing but the *HICP core* response scaled by the *HICP energy* response observed in the same months. As such, the ratio represents the response of the core price index that one would expect to see in period *h* after a one unit increase in energy prices stemming from a contration in oil or gas supplies.[25] The results, reported in Figure 11, show that the gas PT is almost twice as large as the oil PT. The dynamics of the IRFs and the PT ratios are obviously constrained by the parametric nature of the FAVAR model. However, the PTs obtained from LP-IV estimates of the IRFs (which impose no restrictions on the timing of the responses) are very similar: see Figure 12.

FEVD and historical decomposition. Variance decompositions provide an alternative way to measure the spillovers from energy to core prices. The FEVDs indicate that gas supply shocks explain a share of about 35% of the variance of core prices, nearly double the share explained by oil shocks (about 20%; see figures 13 and 14). On average, gas shocks clearly played a more important role in the sample we consider. Figures 15 and 16 display historical decompositions and counterfactual inflation series obtained assuming alternatively gas or oil supply shocks to be the only source of macroeconomic volatility. The shocks closely fit the behavior of the *TTF* and *Brent* series, confirming that 'supply matters' in both markets. However, their performances in replicating the pattern of *HICP energy* and *HICP core* are very different. Oil shocks explain most high-frequency changes in *HICP energy* but fail to capture the low-frequency fluctuations of the series, and miss almost entirely the rise and subsequent decline in energy prices observed in 2021-2022 (Figure 16). Gas shocks, in contrast, capture the cyclical component of *HICP energy* and closely match the behavior of the series in the last two years of the sample (Figure 15). A similar pattern emerges for *HICP core*. Gas shocks fit the rise in core inflation after 2021 surprisingly well, whereas oil shocks have virtually nothing to do with it. The figures clearly show the predominance of gas as a driver of European inflation over the past two years.

7 Conclusions

The Russian invasion of Ukraine in February 2022 placed natural gas – a previously somewhat neglected commodity – at the centre of heated policy debates in Europe and elsewhere. However, little is known about the relation between the natural gas market and the business cycle. In order to fill this gap, we identify gas supply shocks through a

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[25] The indicator is reminiscent of the 'multipliers' that are often calculated in the fiscal policy literature scaling the GDP response by the response of public expenditure (G). One of its advantages is that it puts the shocks on an equal footing because, by normalizing the *core* response on the basis of the *energy* response, it makes the (unobserved) size of the shocks less relevant.

narrative approach and estimate their impact on Euro Area economies using Bayesian VAR and local projection methods. Our identification and estimation strategies are designed to cope with the specificity of the setup, where short-samples, breaks and the instabilities associated to Covid and the Ukraine war significantly complicate the task of separating demand- and supply-side factors. We find that negative shocks to gas supplies are stagflationary, leading to a drop in economic activity and a significant rise in both energy and core consumer prices. We also find that their influence is more gradual, but ultimately larger and more long-lasting than that of oil shocks. Oil shocks generate sharp responses in economic activity and energy prices in the short run, but these abate quickly leaving core inflation relatively unaffected. Gas shocks have little impact in the short run, but significantly increase energy and core prices over longer horizons. After a year, the pass-through to core inflation is almost twice as large for gas shocks than for oil shocks. Our estimates suggest that the scarcity of gas caused by the war was a key driver behind the surge in inflation in Europe in 2022, and that its repercussions are likely to be felt well into 2023.

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Sample	Observations	Mean	Std
2019-2022	874	0.175	5.783
2010-2018	939	0.007	1.996
Pooled	1813	0.088	4.264
Levene's statistic (absolute)	227.4		
Degrees of freedom	11811		
p-value	0		

Table 1: Test of equality of variances (Levene test). The test compares the volatility in the TTF growth rate across the samples 2010-18 and 2019-2022.

event date	*key headline*	%ΔTTF
14-Mar-2011	Japan boosts LNG demand to substitute nuclear energy after Fukushima disaster	5.6
03-Mar-2014	Tensions piling up between Russia and Ukraine	9.5
29-Aug-2014	Gazprom accuses Ukraine of stealing gas	15.9
28-Apr-2016	Gazprom hopes Nord Stream 2 avoids problems with Brussels faced by predecessor	-9.6
10-Sep-2019	EU court ruling against Gazprom on Opal Pipeline	17.7
29-Jun-2020	US threaten to sanction EU on NS2	15.6
03-Aug-2020	Tensions between Poland and Gazprom	12.9
05-Oct-2021	Putin declaration: "Gazprom will prioritize domestic market"	20.0
28-Oct-2021	Gazprom declares it can pump gas into EU storage	-10.9
29-Oct-2021	Gazprom reaches agreement with ENI and Moldova	-23.3
24-Feb-2022	Russia invades Ukraine	51.1
25-Feb-2022	Reassurances from Gazprom on gas flows	-30.7
02-Mar-2022	Yamal stops; Sanctions on EU-Russian gas joint-ventures	36.1
09-Mar-2022	Gazprom books Yamal transit	-27.3
10-Mar-2022	Regular Gazprom supply to EU	-18.9
23-Mar-2022	Gazprom will require payments in rubles	18.5
14-Jun-2022	Nord Stream 1 limited capacity due to turbine stuck in Canada	16.4
15-Jun-2022	Nord Stream 1 volumes drop further; implications of Freeport LNG Fire Continue to Grow	24.0
04-Jul-2022	Gazprom may ask for rubles payment also for LNG exports; Norway flows drop by 13% due to strike	10.3
25-Jul-2022	Gazprom announced Nord Stream flows cut due to renew dispute on Siemens turbine	10.5
26-Jul-2022	Nord Stream flows drop to 20% of capacity	13.2
22-Aug-2022	Three days stop to Nord Stream announced	13.2
25-Aug-2022	Gazprom states that turbines are not being repaired in Canada	10.0
29-Aug-2022	Flows to Ukraine increase; Yamal flows regularly	-19.6
02-Sep-2022	Data signals Nord Stream 1 flows to resume	-11.7
05-Sep-2022	New halt to Nord Stream1 flows	14.7

Table 2: Examples of natural gas supply events

Sample	TTF	Brent	Coal	Wheat	EuroStoxx	VStoxx	Euribor-3m	Geopol. Risk
2010-2022	25.2**	1.5	22.1**	2.6**	2.3**	1.7**	3.3	0.70**
2010-2019	14.3**	2.5	1.6	1.1	1.4	1.7	0.5	0.76
2020-2022	12.3**	0.6	10.7**	2.6**	2.0**	1.4	1.4	0.59**

Table 3: Volatilities on shock and no-shock dates. For each indicator the table reports the ratio between the volatility observed on days that are characterized by shocks to gas supply and the volatility on the remaining dates in the sample. The ratios are computed over the full sample as well as the 2010-2019 and 2020-2022 subsamples. ** denote a ratio statistically different from 1 at the 1% level; * at the 5% level.

	Correlation	PValue	Observations
Kanzig (2021) oil supply shocks	-0.03	0.70	156
Kanzig (2022) carbon policy shocks	0.13	0.14	120
Baumeister and Hamilton (2019) oil supply shocks	-0.03	0.68	156
Baumeister and Hamilton (2019) demand shocks	0.07	0.34	156
Caldara and Iacoviello (2022) GPR global - AR(1) residual	0.07	0.37	156
Caldara and Iacoviello (2022) GPR Russia - AR(1) residual	0.09	0.22	156

Table 4: Correlation with other shocks in the literature.

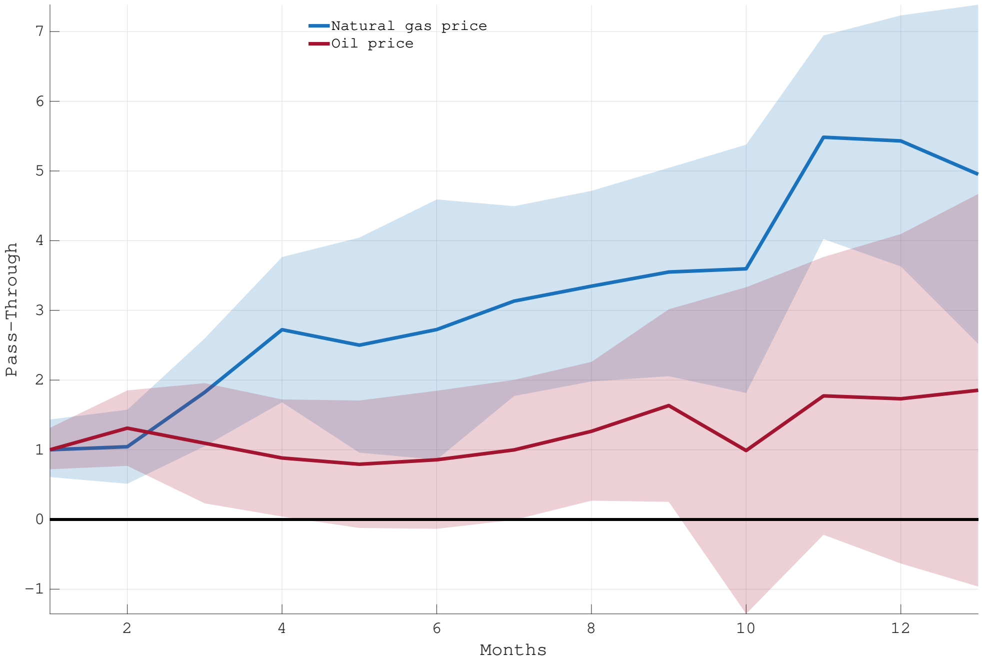

Figure 1: Pass-through from gas and oil prices to consumer energy prices. The figure shows the estimated β^h coefficients from a local projection of the form $Y_{t+h} = \alpha^h + \beta^h p_t + \theta^{h\prime} X_{t-1} + \epsilon_{t,t+h}$, where Y is the energy component of the Euro Area consumer price index, p is the wholesale gas or oil price and X includes four lags of Y and p (all in logarithms). The sample runs from January 2012 to November 2022.

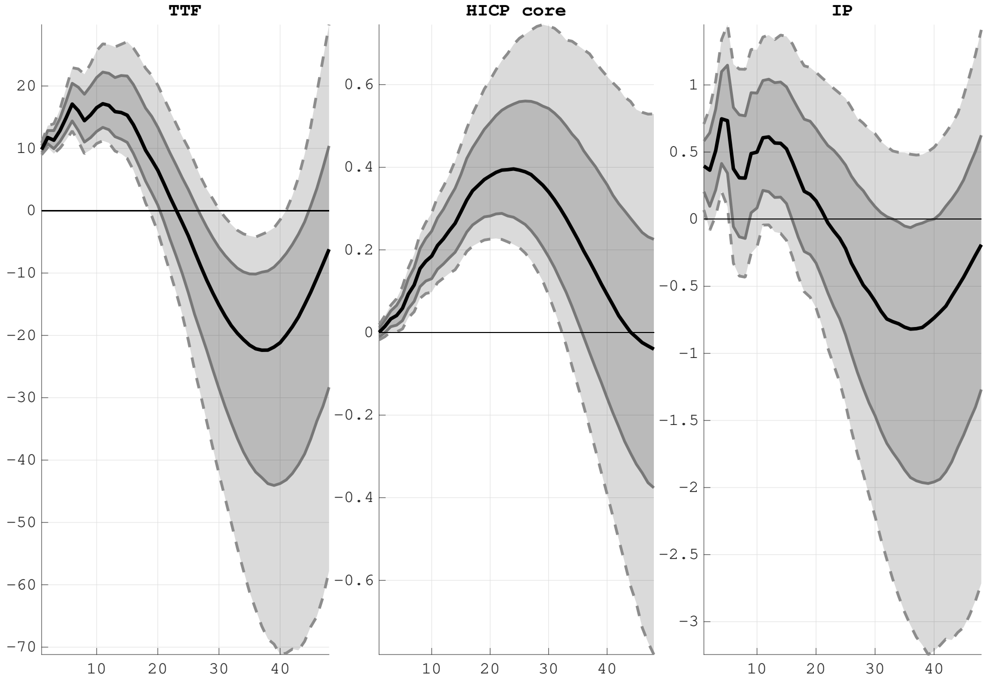

Figure 2: Impact of gas supply shocks under a naive Cholesky identification

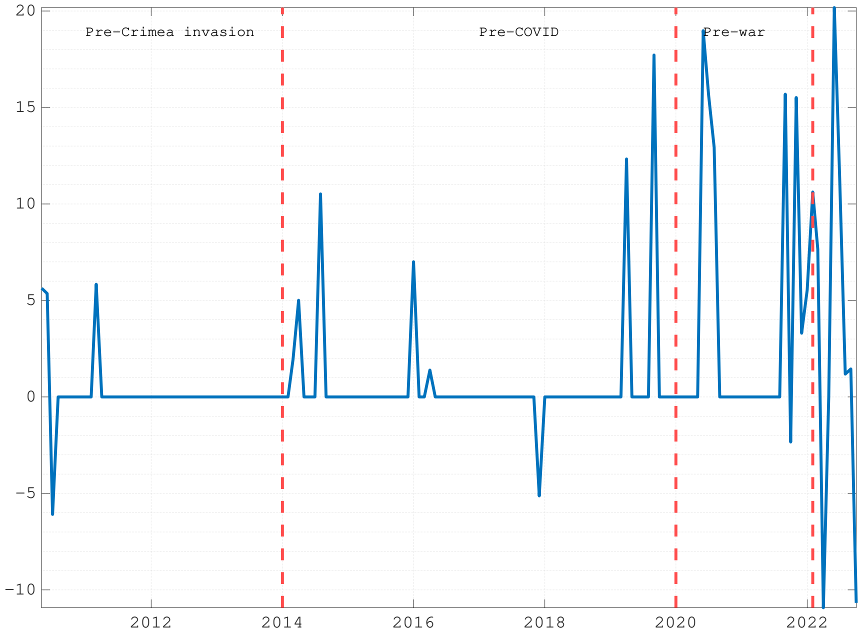

Figure 3: Monthly instrument. The figure shows the monthly average of the gas supply shocks obtained through narrative identification. Each monthly observation is obtained by averaging the daily changes in one-month futures on natural gas observed on the dates that are characterized by restrictions to gas supply. The dates are identified auditing a large daily news dataset obtained from Refinitiv (see Table 2).

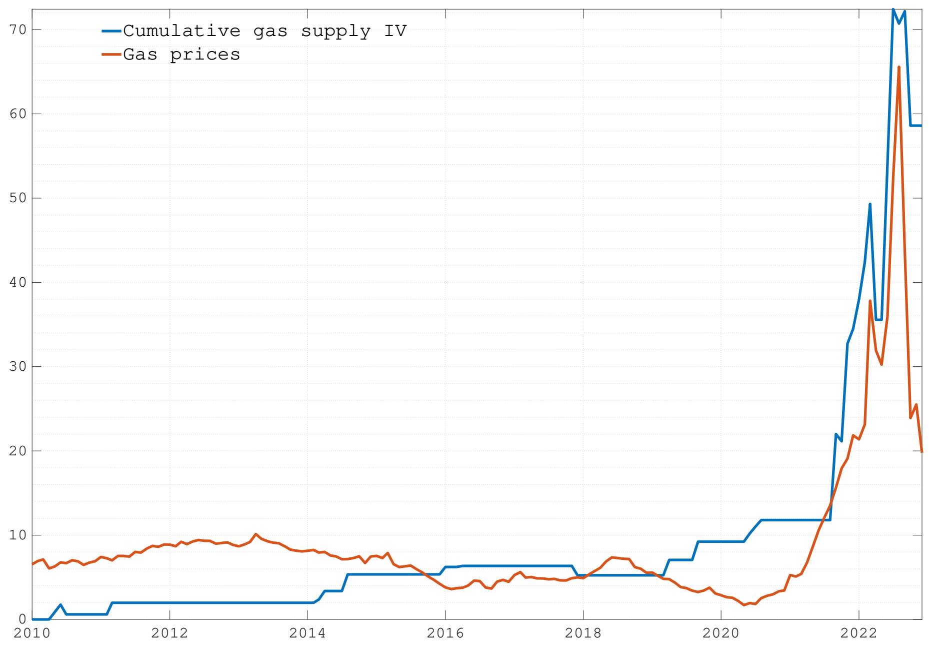

Figure 4: Gas prices and cumulative gas supply IV. The chart compares the price of natural gas on the main European market (the Dutch *Title Transfer Facility* or *TTF*, orange line) to the cumulative effect of shocks to the supply of natural gas to Europe obtained through a narrative identification.

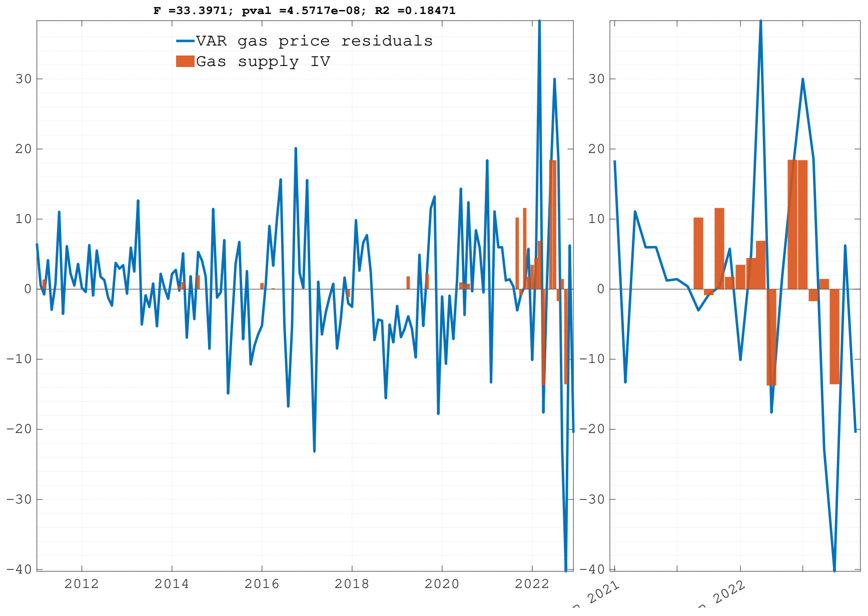

Figure 5: Instrument strength

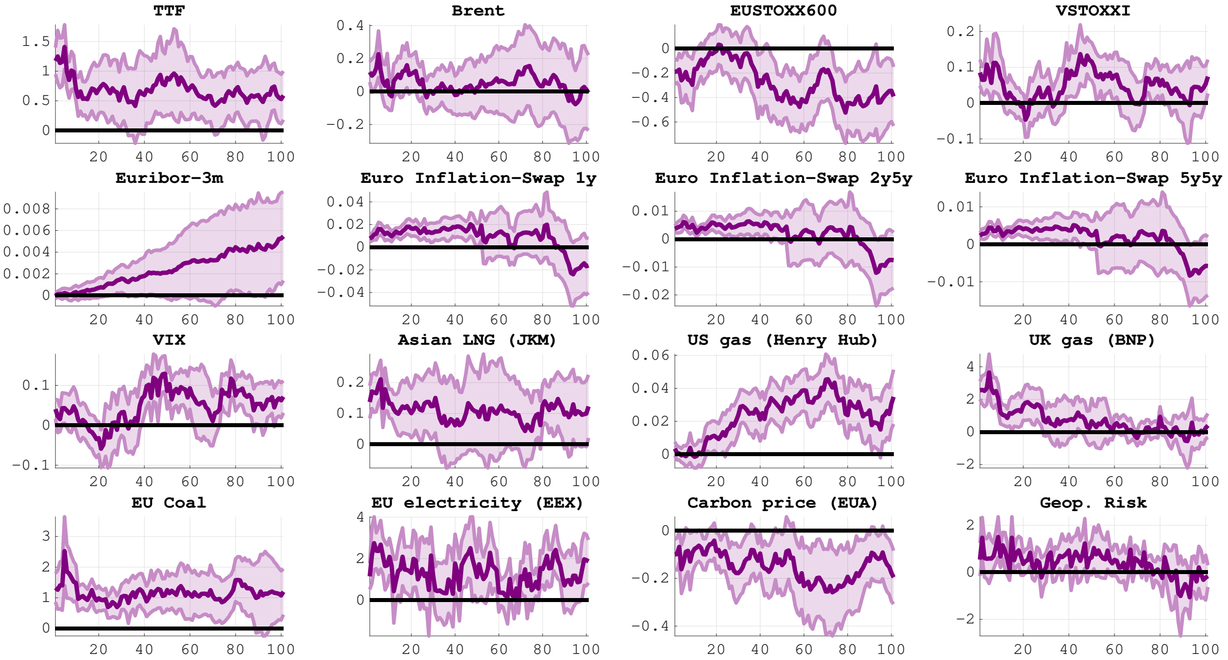

Figure 6: Daily IRFs - LPIV

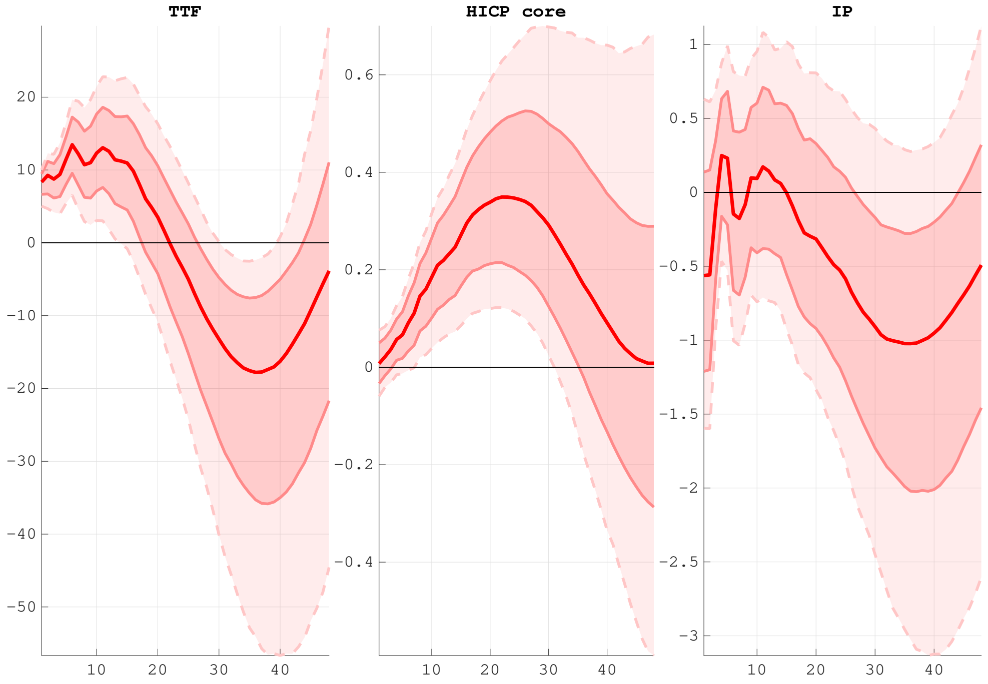

Figure 7: Impact of gas supply shocks - baseline VAR model

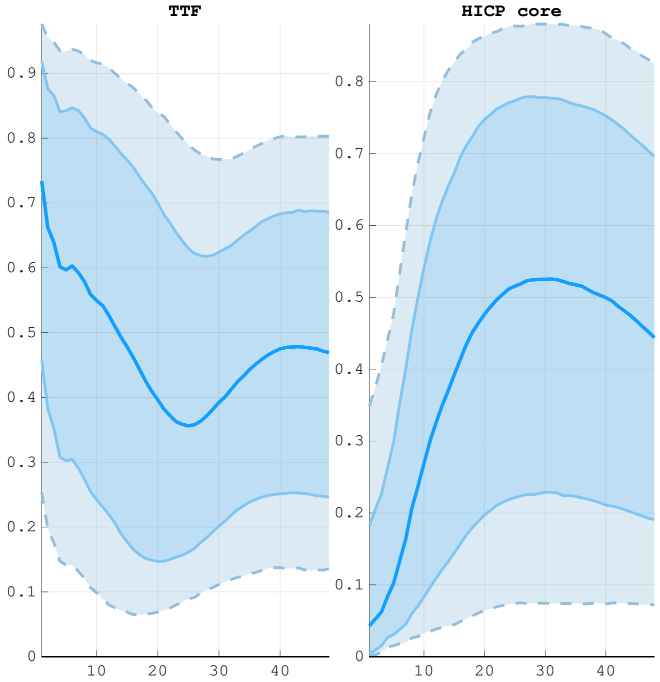

Figure 8: Forecast Error Variance Decomposition - baseline VAR model

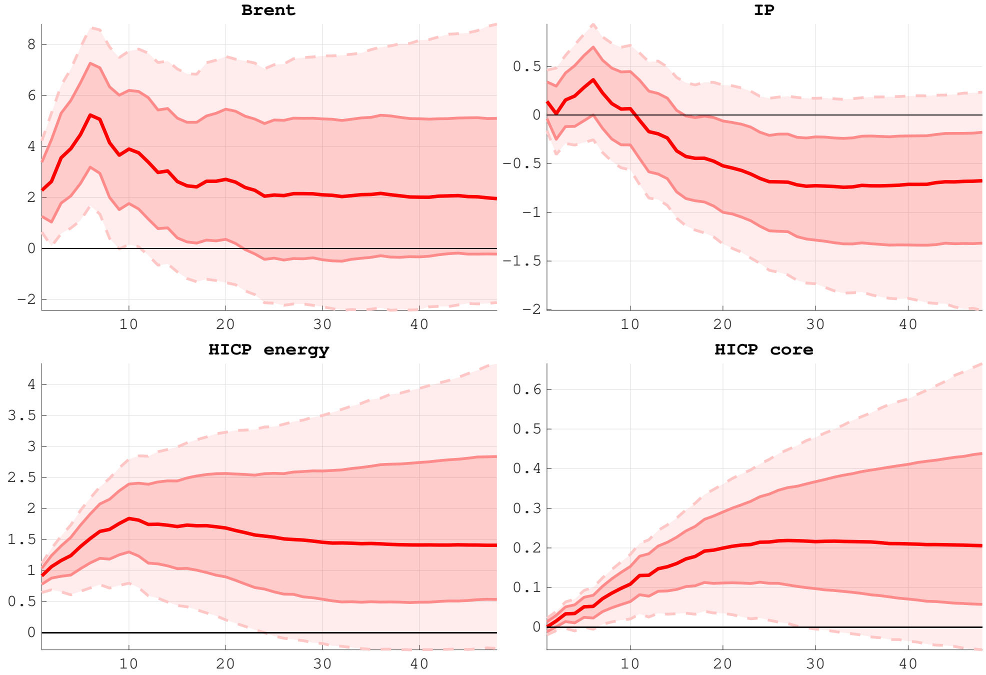

Figure 9: Impact of oil supply shocks in the FAVAR model

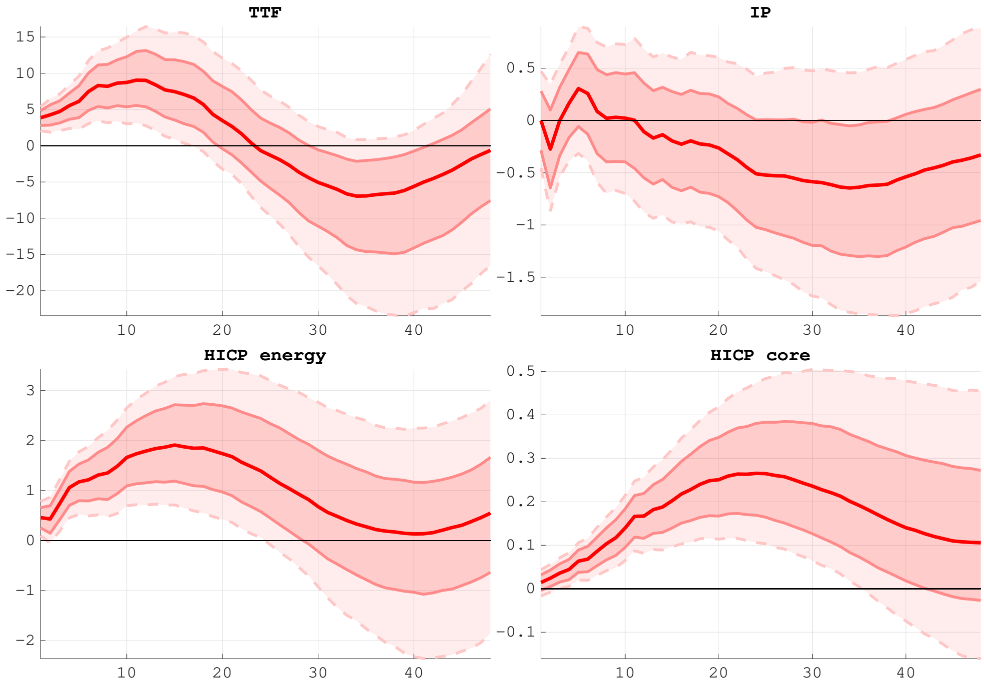

Figure 10: Impact of gas supply shocks in the FAVAR model

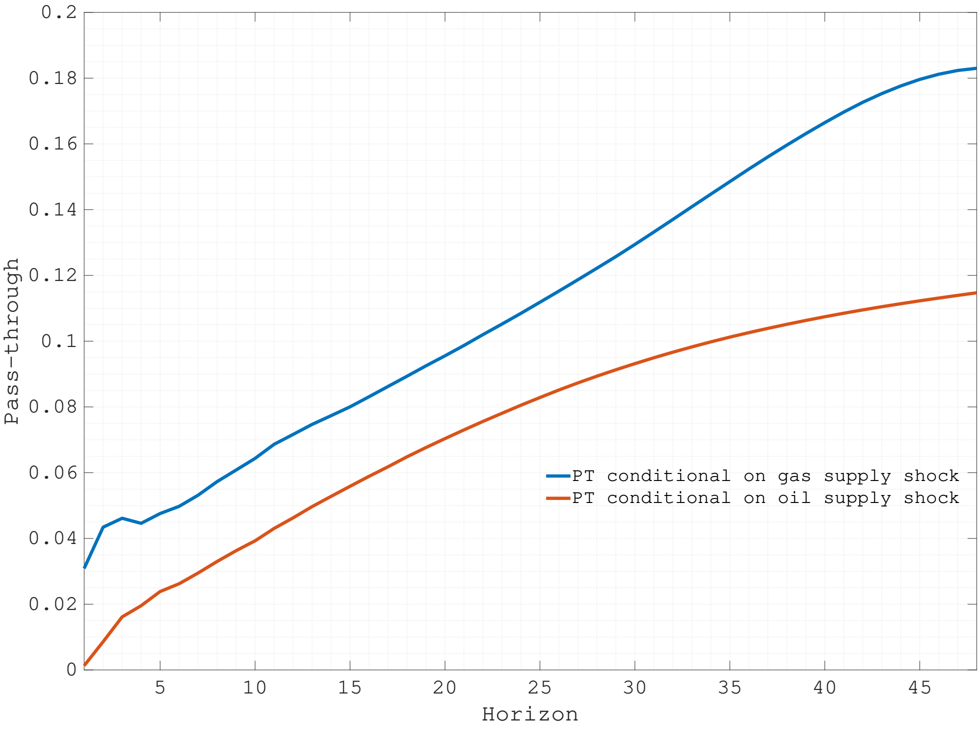

Figure 11: Pass-through of oil and gas shocks in the FAVAR model

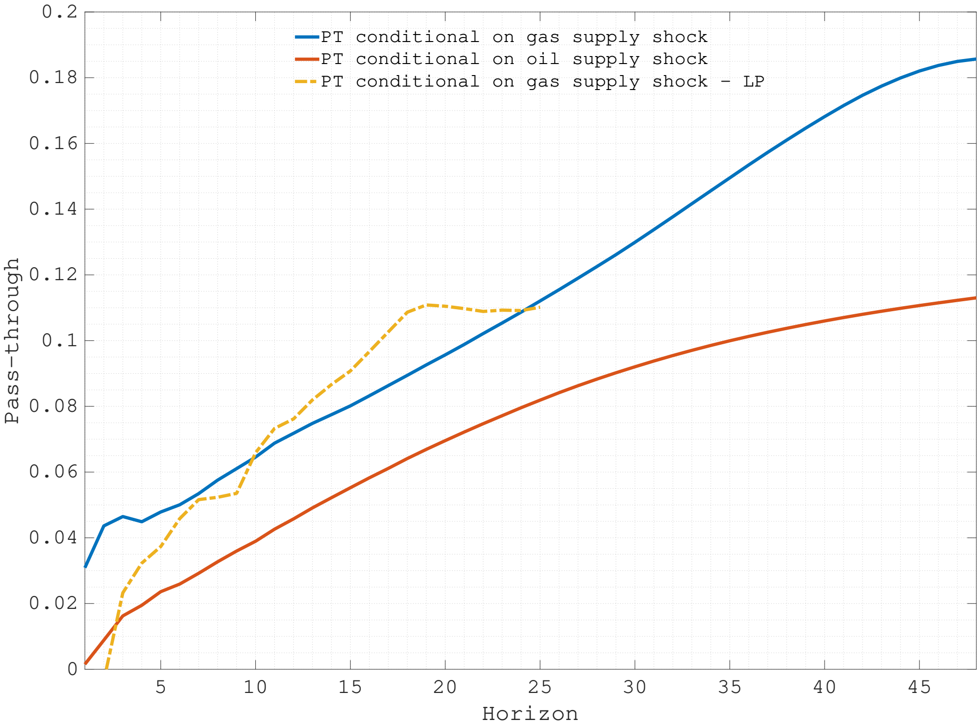

Figure 12: Pass-through of oil and gas shocks: FAVAR *versus* Local Projections

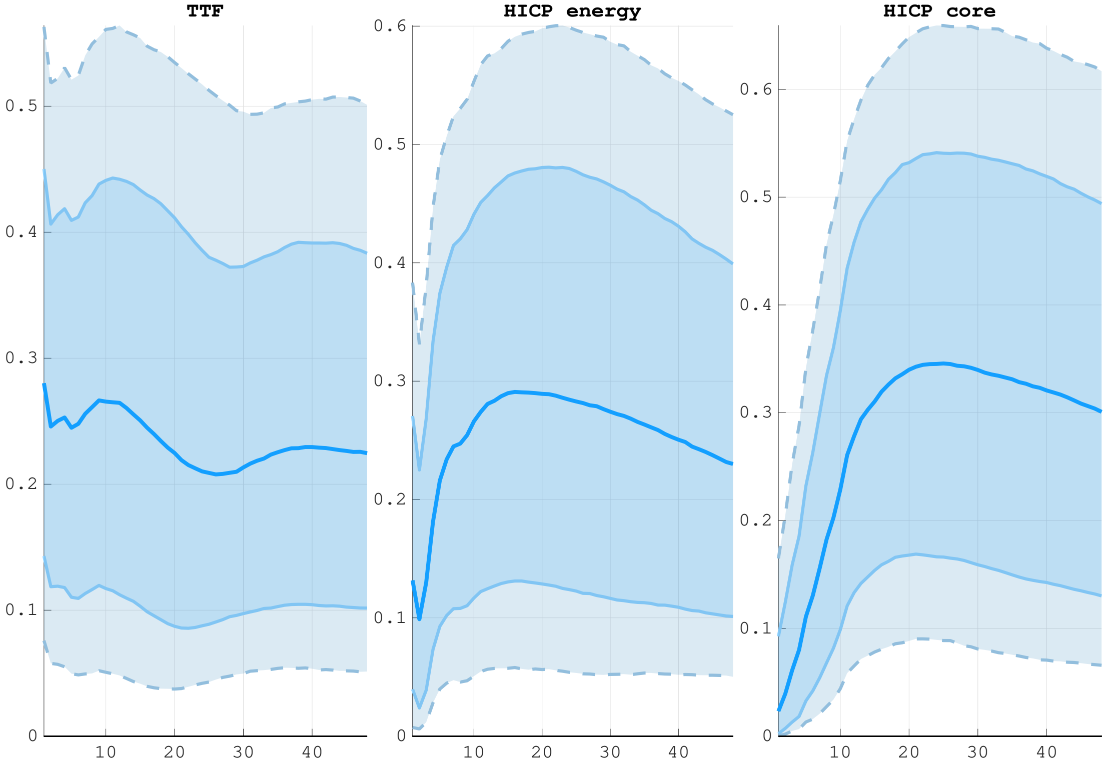

Figure 13: FEVD for gas supply shocks in the FAVAR model

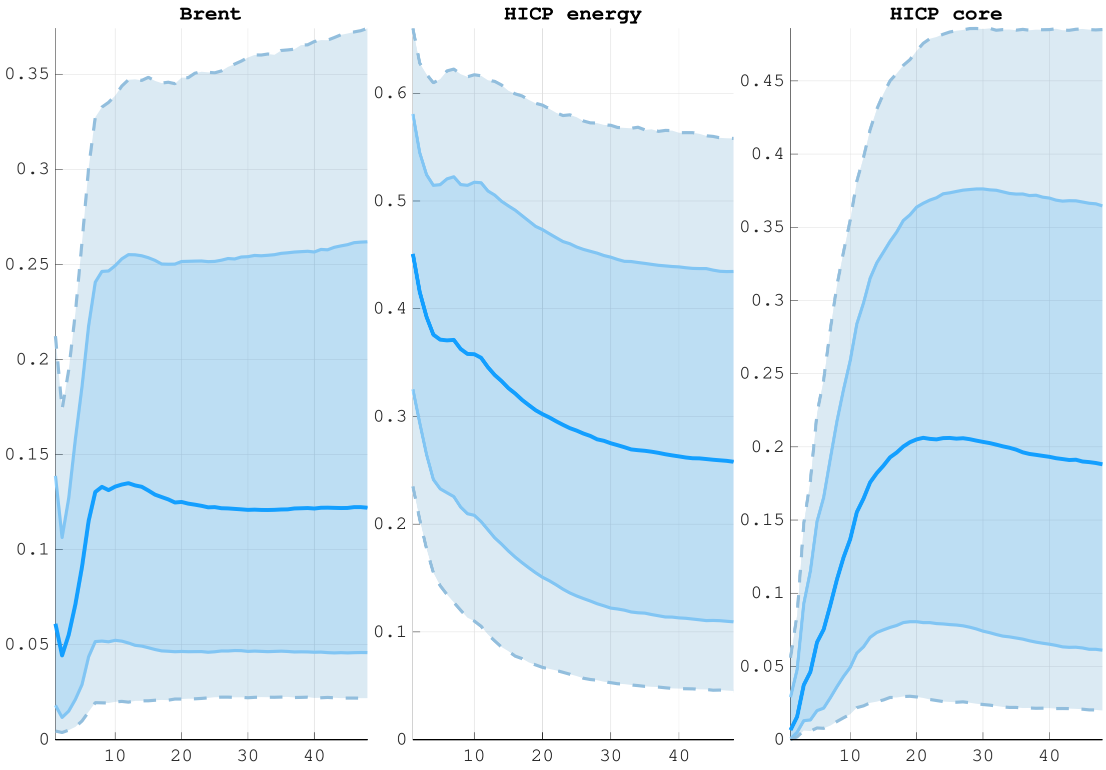

Figure 14: FEVD for oil supply shock in the FAVAR model

Figure 15: Historical decomposition, role of gas supply shocks in the FAVAR model

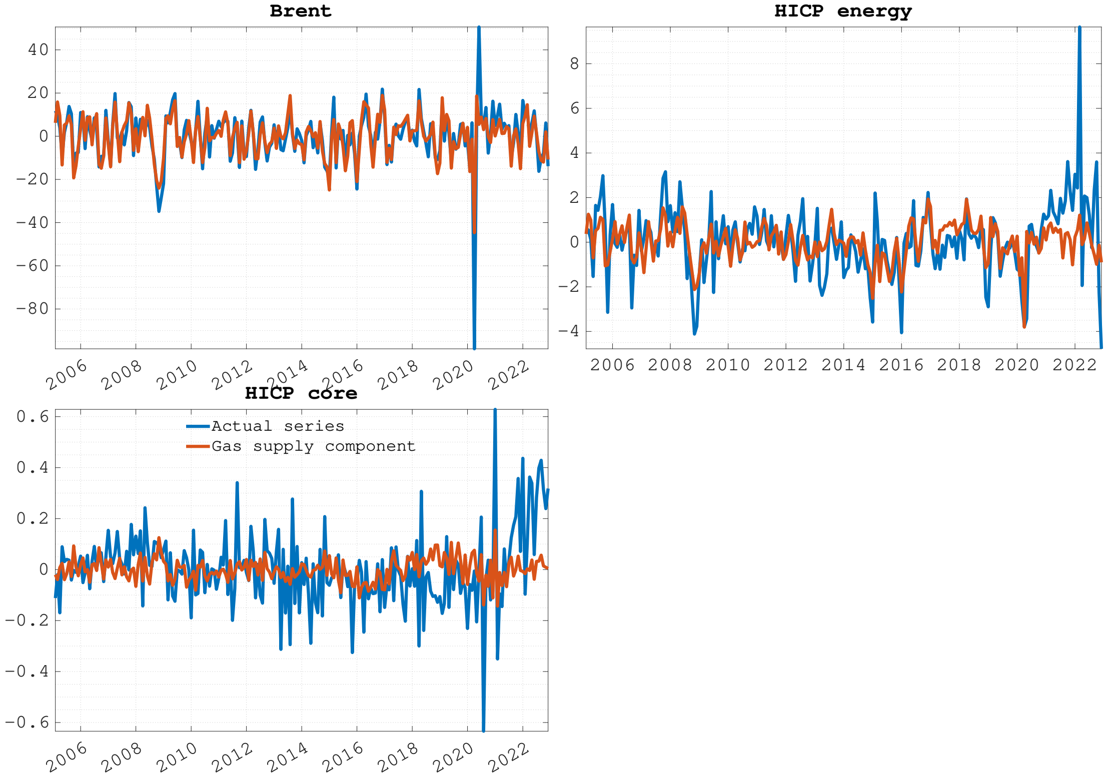

Figure 16: Historical decomposition, role of oil supply shocks in the FAVAR model

Appendix

Table A1: Main data source

Mnemonic	Description	Source
	Commodity and asset prices	
ETMCS00	TTF - front contract	Refinitiv
ETMC.01	TTF - 1m ahead	Refinitiv
ETMC.02	TTF - 2m ahead	Refinitiv
ETMC.03	TTF - 3m ahead	Refinitiv
ETYC.01	TTF - 1y ahead	Refinitiv
TRNLTTD	TTF - spot	Refinitiv
Natural gas, Europe	European gas price	World Bank - Pinksheet
DJSTOXX	EuroStoxx600	Refinitiv
oilbrnp	Brent spot	Refinitiv
NHNCS00	Henry Hub US gas price	Refinitiv
NJKCS00	Asian LNG gas price	Refinitiv
TRGBNBD	BNP UK gas price	Refinitiv
VSTOXXI	VSTOXXI	Refinitiv
eexpeak	EU electricty price	Refinitiv
EIBOR3M	Euribor-3m	Refinitiv
MLB110L	MLB110L	Refinitiv
CBOEVIX	CBOEVIX	Refinitiv
LWHCS00	Wheat price	Refinitiv
LMCCS00	EU coal price	Refinitiv
JPEUEEN	NEER	Refinitiv
CBOEVIX	VIX	Refinitiv
EUSWI1 BGN Curncy	Euro inflation-swap 1-year	Bloomberg
EUSWI1 BGN Curncy	Euro inflation-swap 2-year	Bloomberg
EUSWI5 BGN Curncy	Euro inflation-swap 5-year	Bloomberg
EUSWI10 BGN Curncy	Euro inflation-swap 10-year	Bloomberg
	Macroeconomic variables - Euro Area 19	
EKCPCOREF	HICP core	Refinitiv
EKESCPENF	HICP energy	Refinitiv
EKCPHARMF	HICP all	Refinitiv
EKIPTOT.G	Industrial production - excluding construction	Refinitiv
EKESUNEMO	Unemployment rate	Refinitiv
EMECOIN.Q	EuroCoin	Refinitiv
EMPMIA..Q	PMI Output	Refinitiv
EMPMIS..Q	PMI Business Activity	Refinitiv
EMPMIANOQ	PMI New Orders	Refinitiv
NGTOTWP	EU Gas Storage	Refinitiv
Z8ESW40KP	EU Gas Imports	Refinitiv
U5ESZHCEP	EU Gas Consumption	Refinitiv
EKESTUNPO	Unemployment	Refinitiv
EKPROPRCF	PPI	Refinitiv
EKESPPCEF	PPI ex. energy	Refinitiv

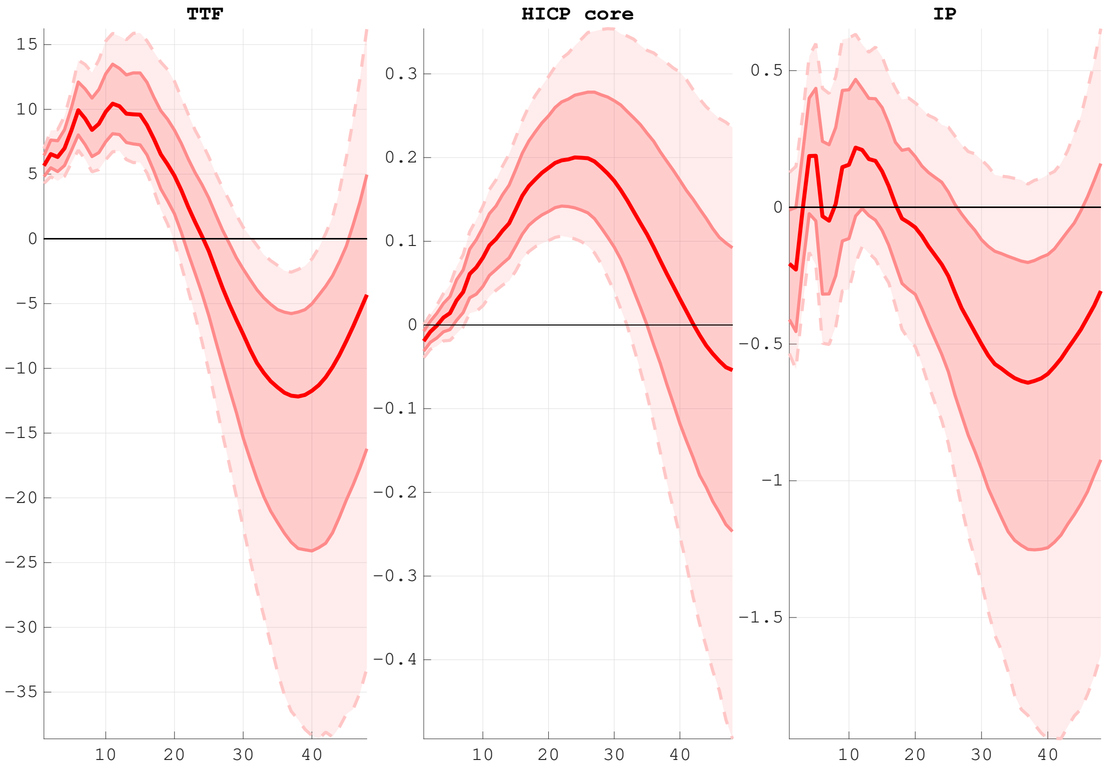

Figure A1: IRFs based on identification via heteroskedasticity

Figure A2: IRFs based on instrumented local projections (LP-IV)

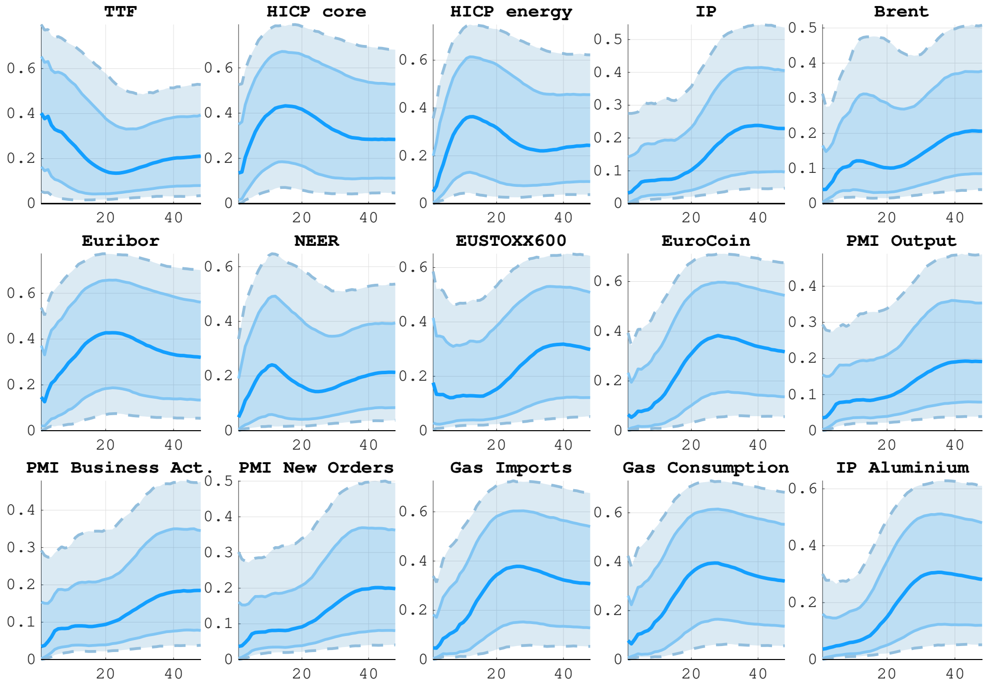

Figure A3: Forecast Error Variance Decomposition - FAVAR model

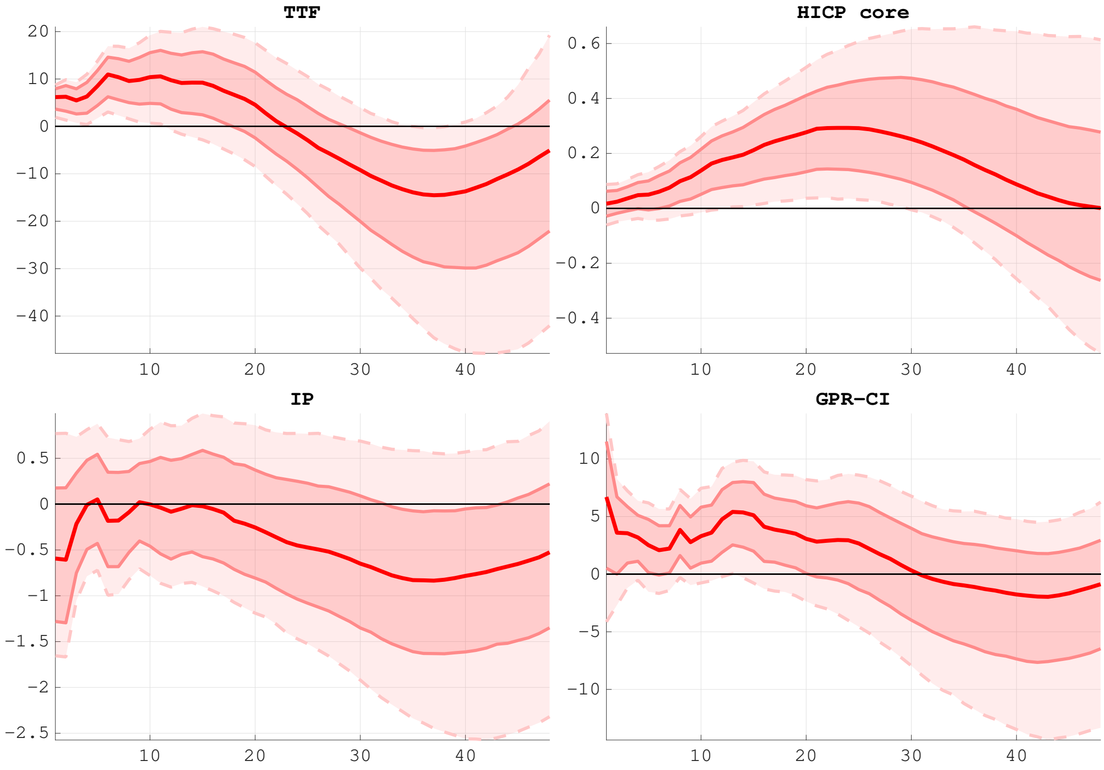

Figure A4: IRFs - VAR including GPRI

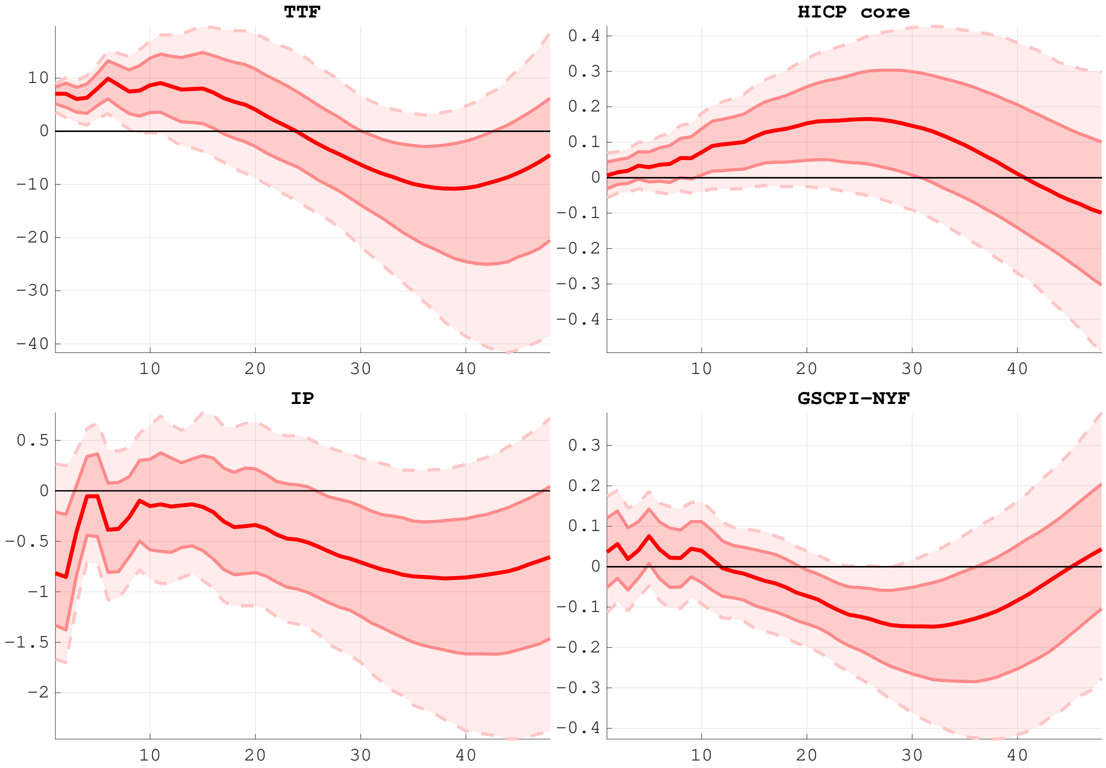

Figure A5: IRFs - VAR including NY Fed bottlenecks indicator (GSCPI)

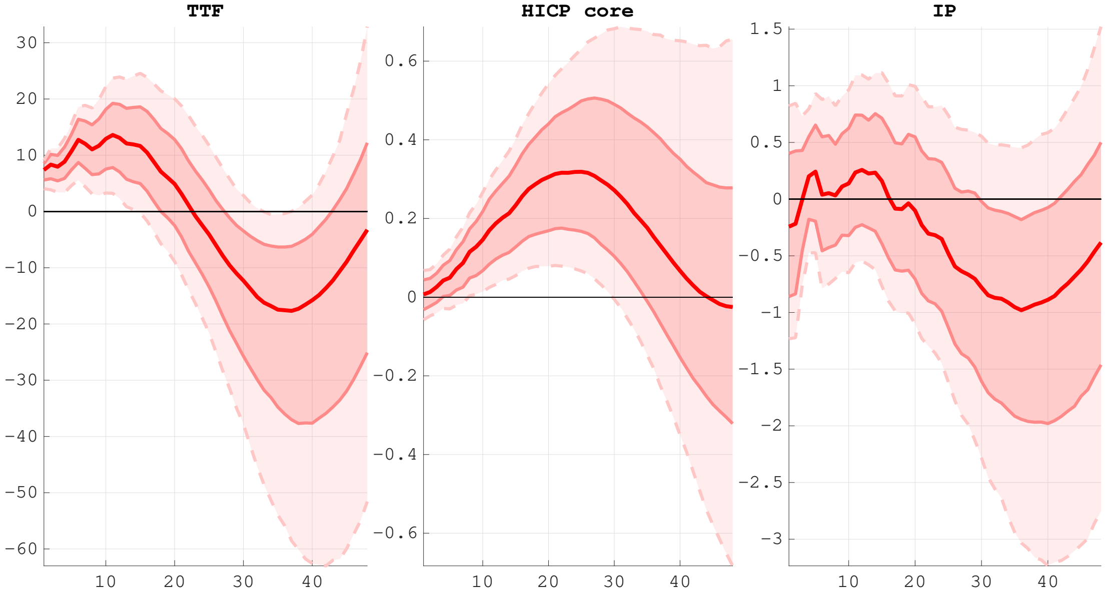

Figure A6: IRFs - VAR including Covid health variables

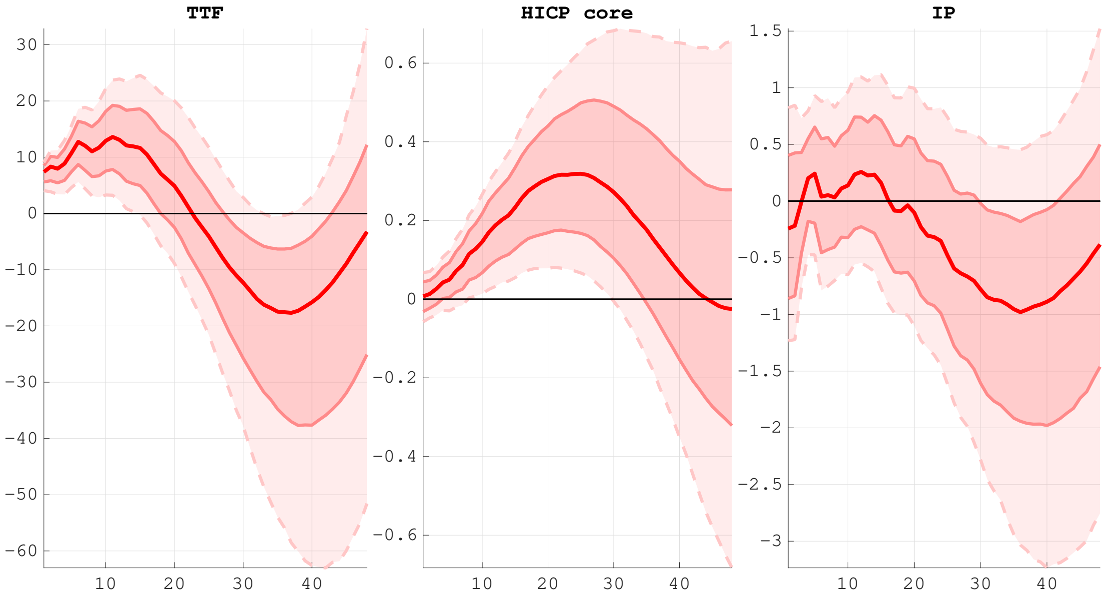

Figure A7: IRFs to a gas supply shock - sample until February 2022

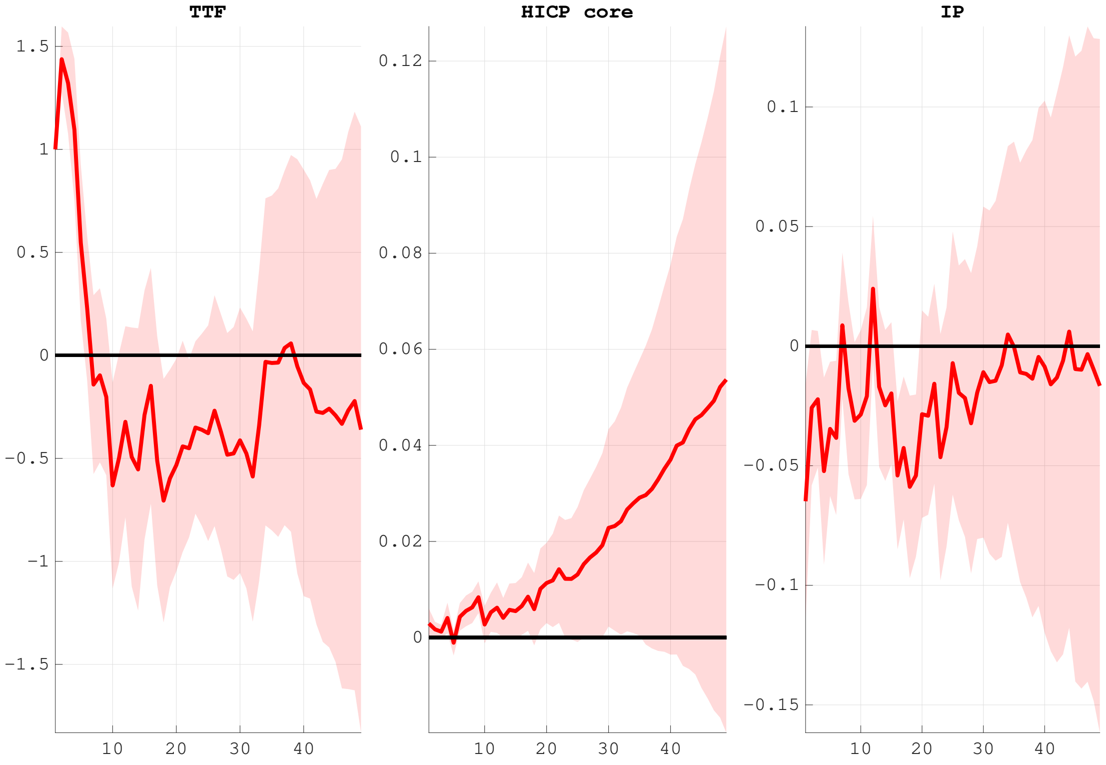

Figure A8: IRFs to a gas supply shock in the Pre-Covid sample

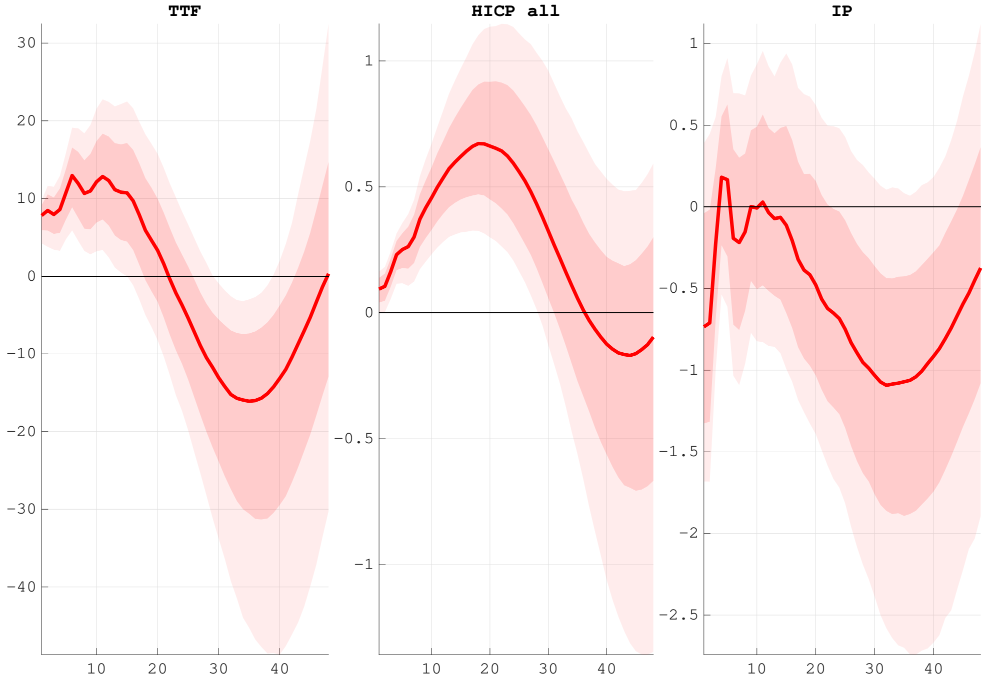

Figure A9: Impact of gas supply shocks. VAR including headline HICP

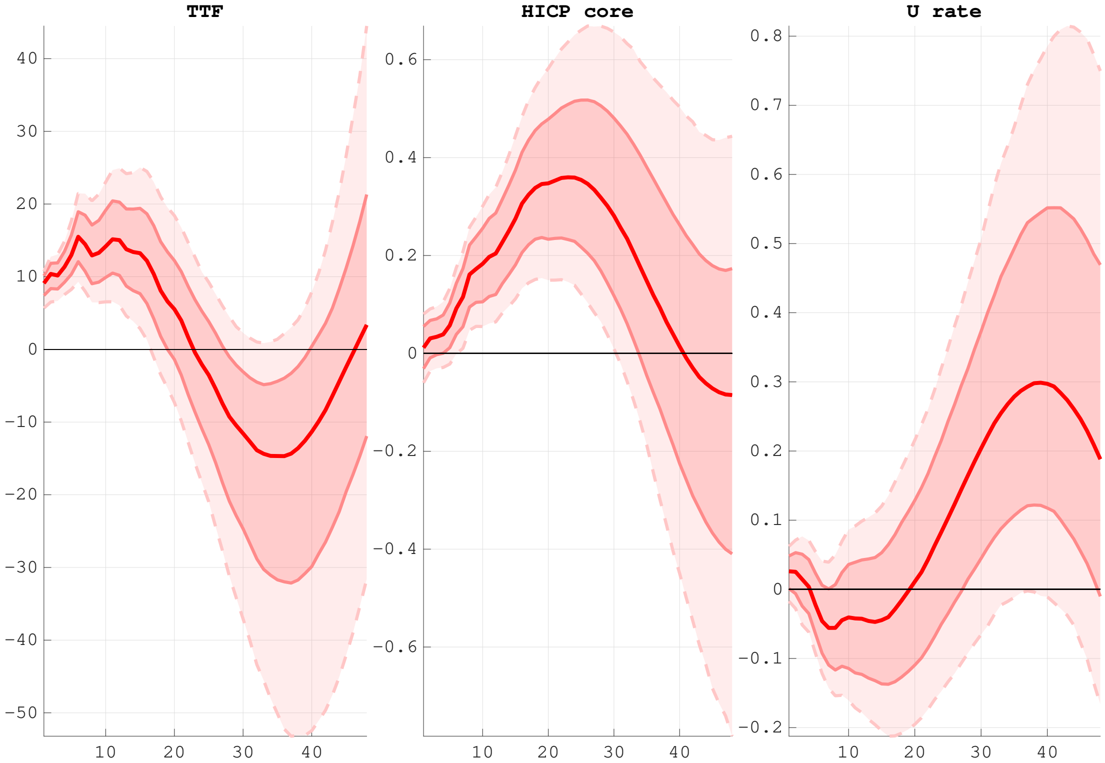

Figure A10: IRFs to a gas supply shock - VAR including unemployment rate

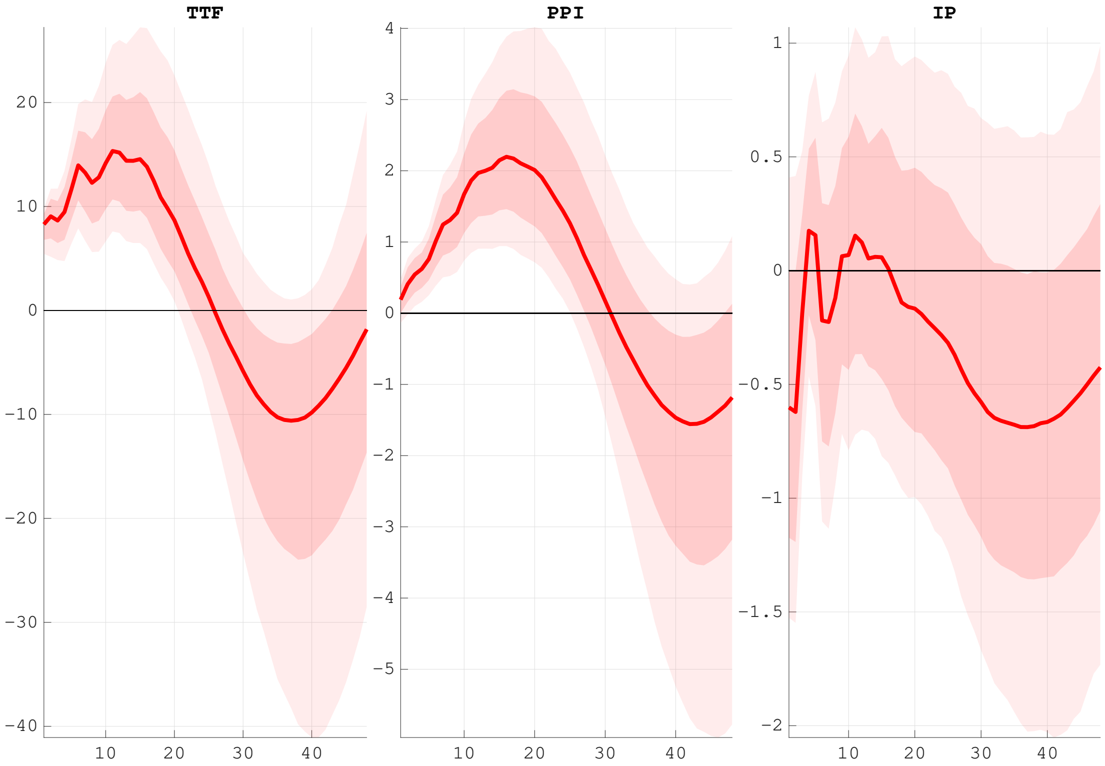

Figure A11: IRFs to a gas supply shock - VAR including PPI

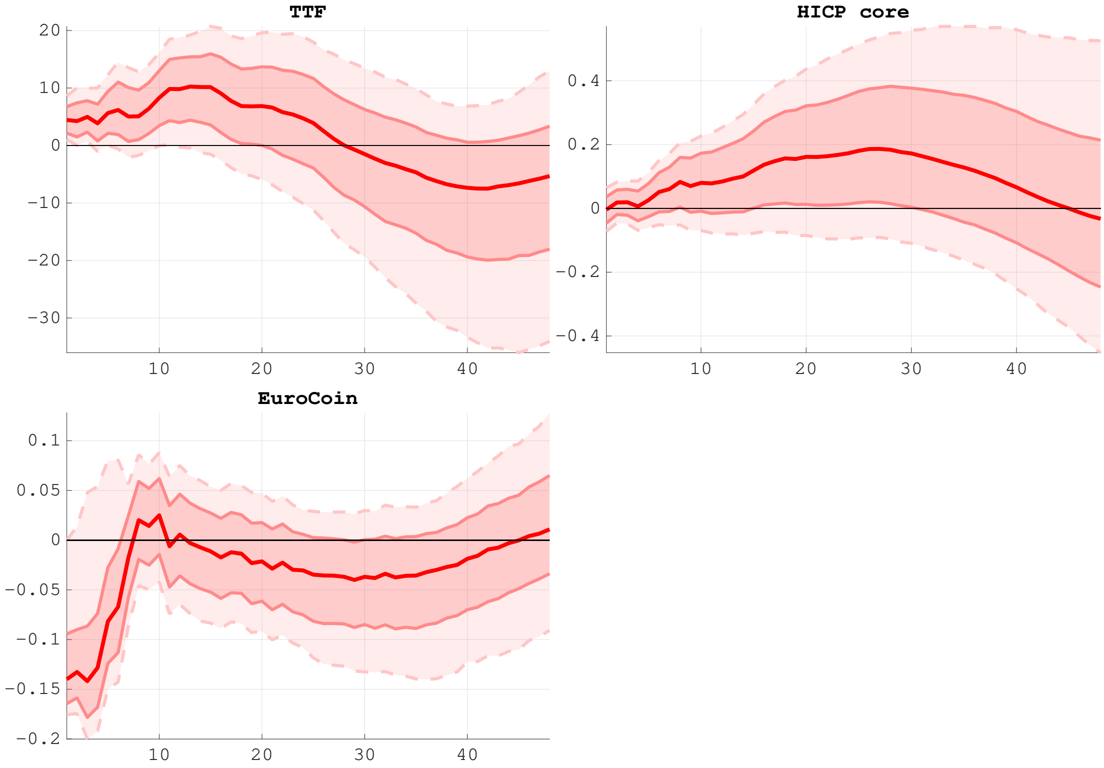

Figure A12: IRFs to a gas supply shock - VAR including EuroCoin

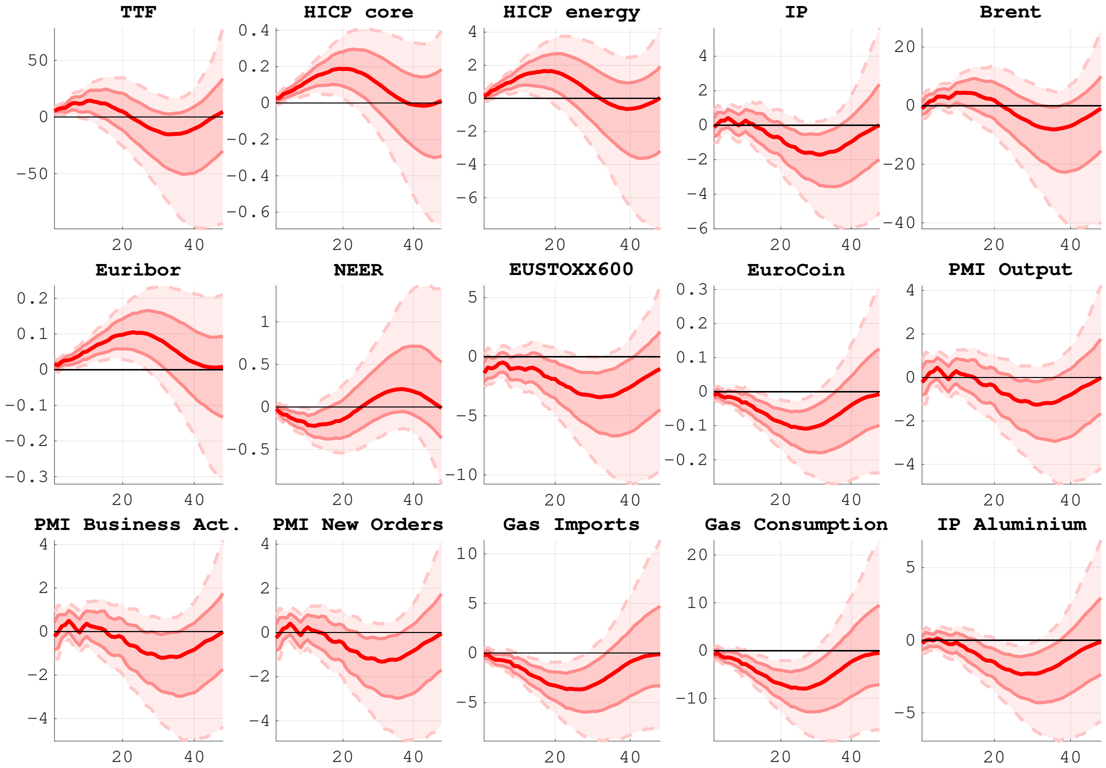

Figure A13: FAVAR IRFs

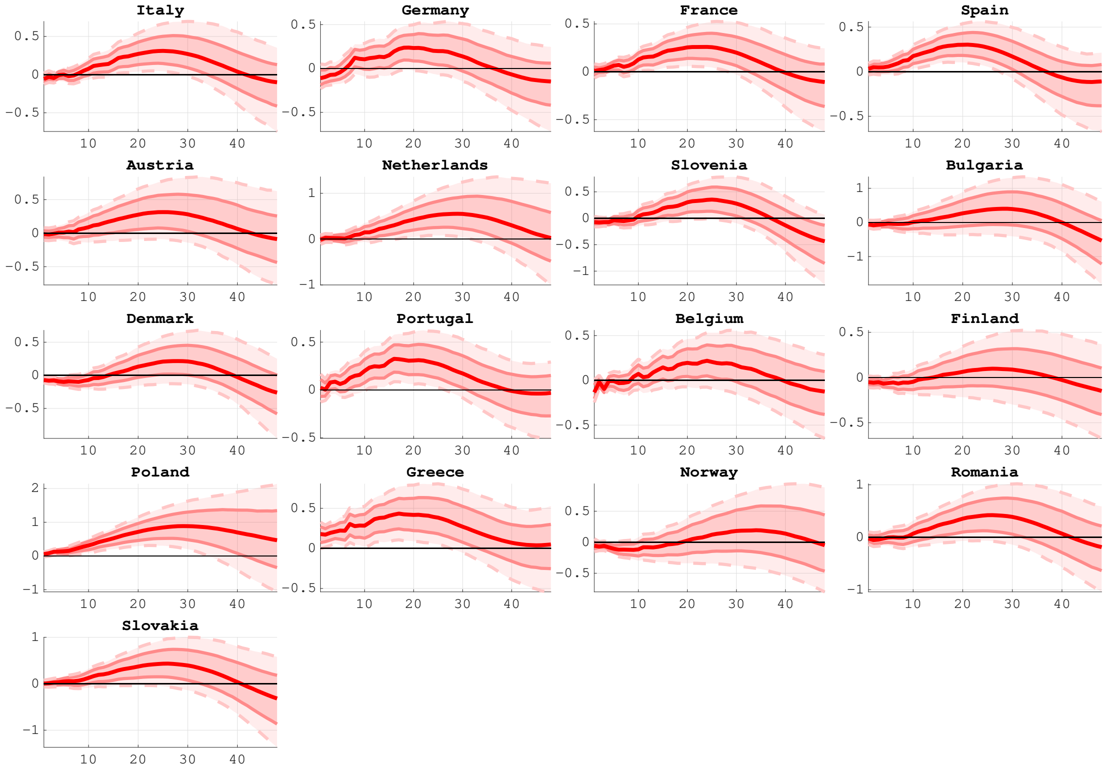

Figure A14: Country-level IRFs, consumer prices

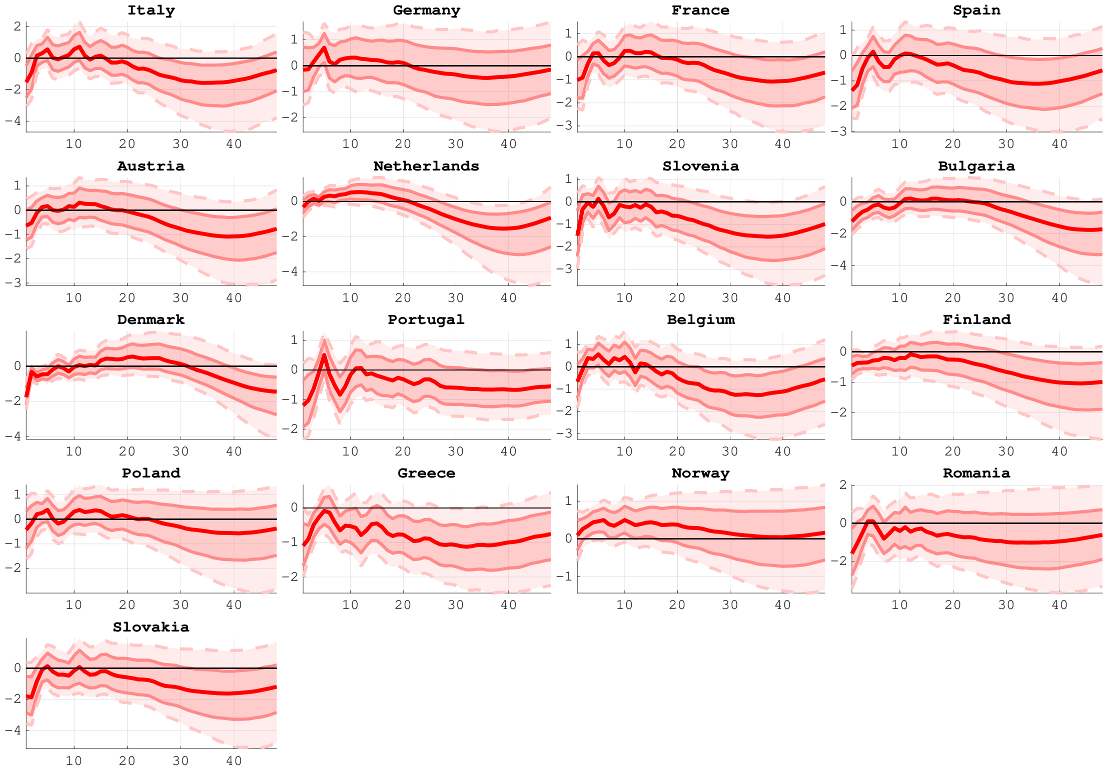

Figure A15: Country-level IRFs, industrial production

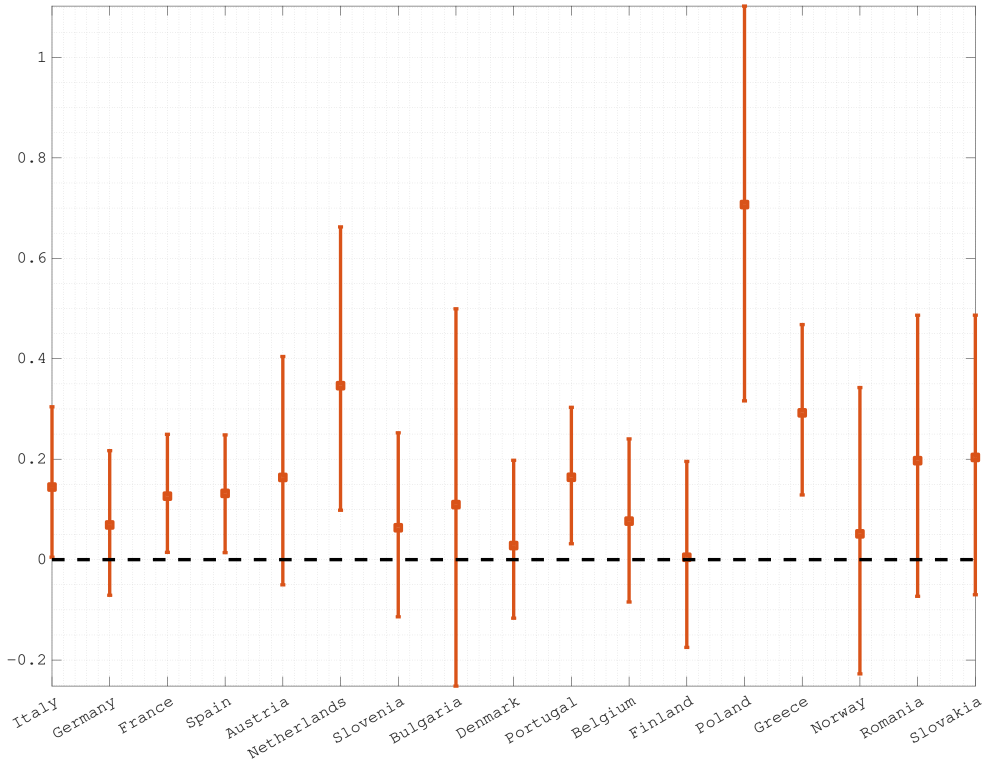

Figure A16: Country-level IRFs, consumer prices

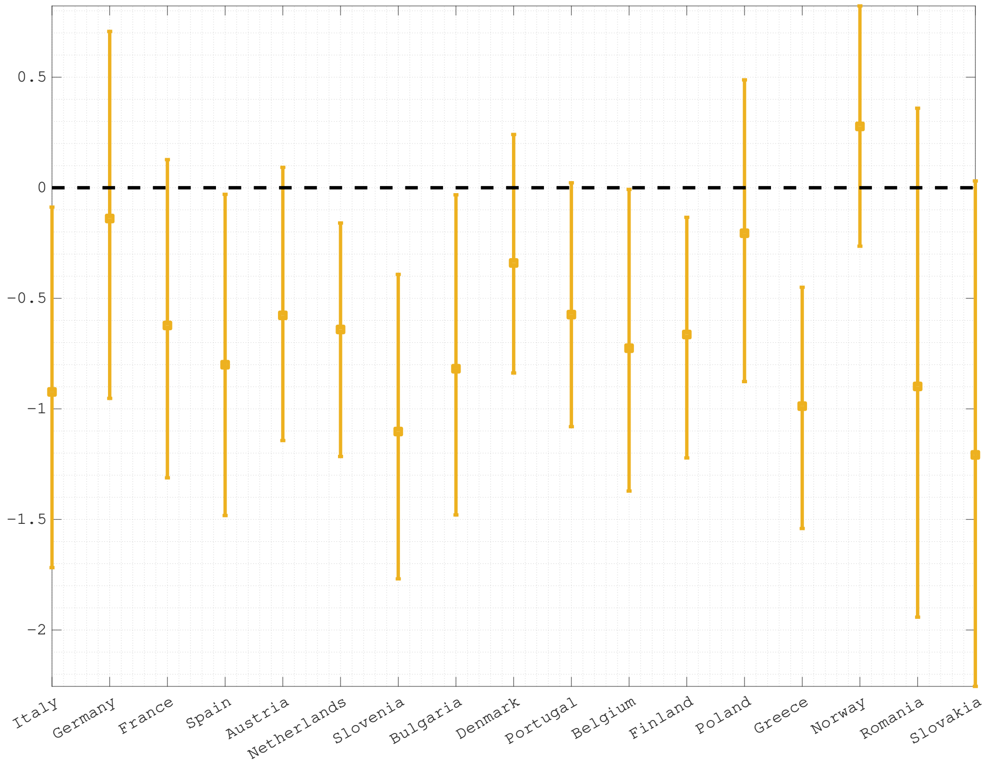

Figure A17: Country-level IRFs, industrial production

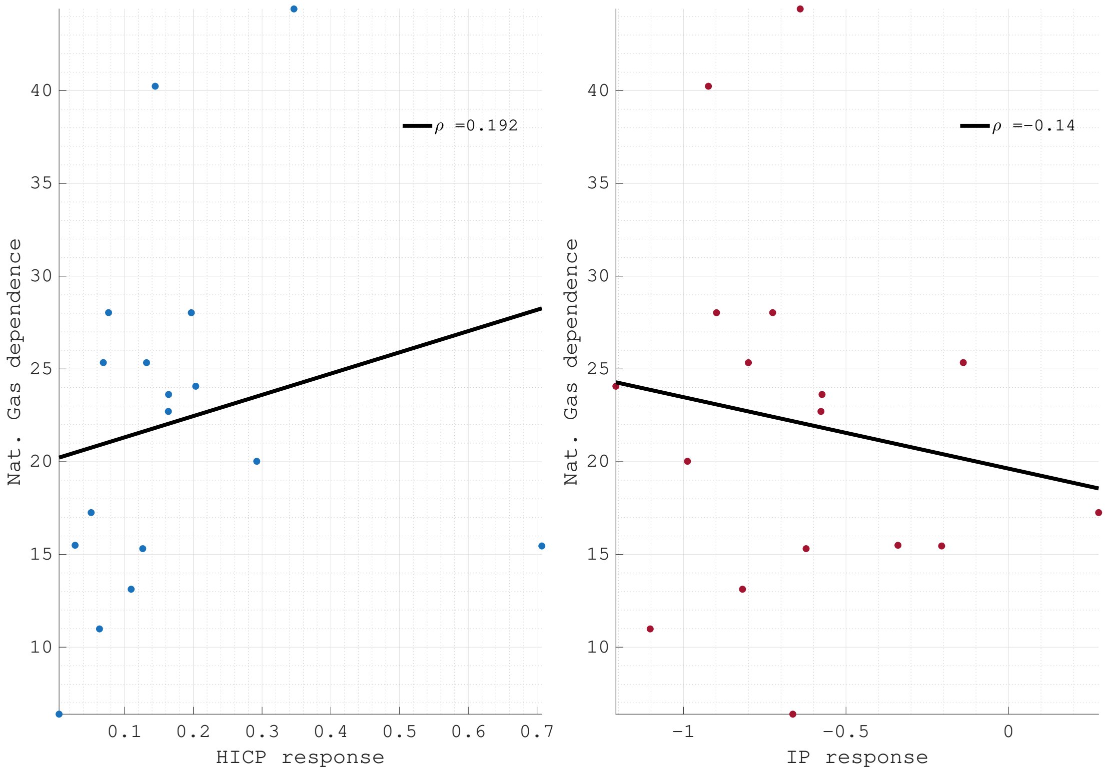

Figure A18: Country level responses and natural gas dependence

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