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UNVEILING NATURAL GAS CONSUMPTION SECTORAL PRICE ELASTICITIES

by Simone Emiliozzi* and Filippo Favero**

Abstract

This paper analyzes how natural gas consumption in Italy responded to supply-driven Title Transfer Facility (TTF) price shocks from 2012 to 2023. Leveraging a granular monthly dataset that captures sectoral and provincial gas consumption, and applying a panel local projections methodology, we find significant rigidity in short-run consumption, constrained by contractual and technological factors. In the medium term, gas consumption declines by 13% two years after a price doubling caused by supply disruptions. Sectoral differences are pronounced: gas-intensive industries, such as chemicals and metallurgy, exhibit lower elasticity due to limited substitutability, while electricity generation and non-gas-intensive sectors show greater responsiveness. The 2021-2022 European energy crisis amplified these effects, further increasing sectoral sensitivity to price changes. These findings highlight the importance of temporary targeted policy measures to mitigate the adverse effects of gas supply disruptions.

JEL Classification: C33, E32, L95, Q41, Q43.

Keywords: natural gas, panel local projections, narrative identification, 2021-2022 European energy crisis, dynamic elasticity.

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1 Introduction[1]

The dramatic surge in natural gas prices, driven by escalating geopolitical tensions between Russia and Europe in 2021 and culminating in the Russian invasion of Ukraine in February 2022, exposed the vulnerabilities of energy-dependent economies. This crisis emphasized the urgent need for policies to address energy security and commodity price volatility, particularly in Europe, where natural gas plays a crucial role in industrial production, electricity generation, and household energy consumption (Borin *et al.*, 2022; Albrizio *et al.*, 2022; Ferriani and Gazzani, 2023a; Di Bella *et al.*, 2024). Policies such as the *Next Generation EU (NGEU)* have become critical tools for strengthening European energy resilience and addressing structural challenges (Draghi, 2024; Letta, 2024). Recent research has documented the significant macroeconomic implications of energy price shocks, including output losses, inflationary pressures, and an unequal distribution of the economic burden across households and firms (Bachmann *et al.*, 2024; Alessandri and Gazzani, 2023; Pieroni, 2023; Ruhnau *et al.*, 2023; Rubaszek *et al.*, 2021; Adolfsen *et al.*, 2024; De Santis, 2024; Casoli *et al.*, 2024; Güntner *et al.*, 2024; Chan *et al.*, 2024).

This paper analyzes the response of natural gas consumption to price shocks arising from exogenous supply disruptions in the European gas market, focusing on sectoral dynamics and geographical heterogeneity. It offers two main contributions. First, it provides a comprehensive analysis of dynamic gas demand elasticity, leveraging a granular provincial and sectoral dataset that includes the 2021-2022 European energy crisis. This bridges the gap between micro-level and macroeconomic studies. Second, we document significant heterogeneity in how different sectors adjust to gas supply shocks before and after the 2021-2022 European energy crisis, with implications for policy design.

These findings are crucial for designing effective policy interventions to counter such cyclical shocks, informing the debate on whether fiscal responses should be general or sector-targeted given the widespread use of broad, untargeted measures

[1]We would like to thank Piergiorgio Alessandri and Andrea Gazzani for sharing their narrative natural gas supply shock time series. This paper has benefited from comments by Umberto Berzero, Dario Caldara, Riccardo Cristadoro, Ivan Faiella, Fabrizio Ferriani, Davide Furceri, Andrea Gazzani, Domenico Giannone, Andrew Harvey, Oscar Jordà, Silvia Miranda-Agrippino, Valerio Nispi Landi, Marco Taboga and Giovanni Veronese. Snam is gratefully acknowledged for its assistance, expertise, and for providing the billing and distribution datasets. All errors are our own. The views expressed in this paper do not reflect those of the Bank of Italy or Snam. Emails: simone.emiliozzi@bancaditalia.it; filippo.favero@snam.it.

during the 2021-2022 crisis (Sgaravatti *et al.*, 2022; Ari *et al.*, 2023; Checherita-Westphal and Dorrucci, 2023; Emiliozzi *et al.*, 2024a), which risked inefficient resource allocation. Recent contributions emphasize the role of sectoral heterogeneity in demand elasticities for the efficient allocation of fiscal resources when facing temporary disruptions (Gnocato, 2025; Auclert *et al.*, 2023; Bartocci *et al.*, 2024; Fornaro and M. Wolf, 2023; Gustafsson *et al.*, 2025; Pieroni, 2023; Chan *et al.*, 2024).[2]

Our empirical strategy employs panel local projections to estimate both short-term and medium-term dynamic elasticities over a three year horizon (Jordà, 2005; Jordà, 2023; Ramey and Zubairy, 2018). This approach improves upon static price elasticity estimates by capturing both initial rigidity and subsequent adjustments in gas demand that unfold over time. We analyze two distinct periods — the pre-COVID-19 phase (January 2012 to December 2019) and the full sample (January 2012 to December 2023) — to distinguish between effects during market stability and the heightened turbulence of the 2021-2022 European energy crisis.

The analysis leverages a unique dataset from Snam (*Società Nazionale Metanodotti*)[3], covering monthly gas consumption for more than 60 industrial sectors at the ATECO-2-digit[4] level and 102 Italian provinces.

This paper occupies a position between macroeconomic studies like Rubaszek *et al.*, (2021), Alessandri and Gazzani (2023), Ruhnau *et al.*, (2023), and De Santis (2024) and micro-level analyses based on individual households and firms panel data (Labandeira *et al.*, 2017; Faiella and Lavecchia, 2021; Faiella *et al.*, 2022;

[2]It is important to note from the outset that the policy considerations flowing from our analysis primarily address responses to such temporary supply shocks, rather than the broader fiscal strategies required for long-term structural transformations like the green transition. Further our findings align with the sectoral heterogeneity in gas demand elasticities documented in earlier studies where fostering adaptation via sector-specific interventions such as targeted subsidies or tax discounts can mitigate the adverse effects of energy price shocks (Davis and Muehlegger, 2010; Rubin and Auffhammer, 2024; Labandeira *et al.*, 2017; Huntington *et al.*, 2019).

[3]Snam operates the majority of Italy's natural gas transportation and dispatching, owning nearly 94% of the transportation infrastructure, which includes over 32,600 km of pipelines. The network is managed via 8 districts, 48 maintenance centers, 13 compression stations, and a newly renovated dispatching unit. Gas is injected at nine entry points, including the TAP pipeline and LNG regasification terminals, and then transported to local distribution networks, regional redelivery points, or large end users. For further details see this link `https://reports.snam.it/2020/annual-report/directors-report/business-segment-operating-performance/natural-gas-transportation/snam-s-presence-in-transmission-in-italy.html`.

[4]The ATECO classification is the Italian adaptation of the European NACE statistical classification of economic activities. At the 2-digit level, it categorizes almost 80 economic sectors across industries like manufacturing, services, construction, and agriculture, providing a standardized framework for aggregate economic analysis and reporting.

Favero and Grossi, 2023; Rubin and Auffhammer, 2024; Alpino *et al.*, 2024). Unlike macroeconomic studies that rely on national time-series data, our dataset offers a granular perspective, capturing sectoral and provincial variations while maintaining aggregate representativeness by encompassing almost the entire Italian natural gas market. The data allow us to estimate sector-specific elasticities with improved precision, leveraging provincial and sectoral fixed effects to control for unobserved heterogeneity.

Micro-level studies that estimate natural gas price elasticities with household- or firm-level panel data are particularly effective in capturing heterogeneous behavioral responses and compositional effects within a given sector. However, they often abstract from the broader interdependencies between sectors or the economy-wide impacts of supply shocks, which are critical for understanding aggregate dynamics.[5] While micro-level studies frequently identify larger short-run elasticities due to the immediate responses of firms and households, our findings demonstrate smaller short-run and more pronounced medium-run elasticities, consistent with delayed adjustments arising from contractual and technological constraints at our level of aggregation.

Using the narrative gas supply shock series constructed by Alessandri and Gazzani (2023) (AG henceforth), which is derived from movements in the deflated Title Transfer Facility (TTF) price caused by exogenous gas supply disturbances, we trace how these disruptions propagate through the economy and examine the heterogeneity in sectoral responses. This approach allows us to isolate the causal impact of supply-side shocks on gas consumption dynamics, providing a unique perspective on the role of macroeconomic disruptions in shaping gas demand across different sectors.

Our findings reveal significant variations in dynamic elasticities across both horizon (short vs medium), time (pre-COVID-19 vs full sample) and sectors. In the short-run, gas consumption exhibits low elasticity in response to supply-shock-driven price increases both in the pre-COVID-19 and the full sample, consistent with technological and contractual rigidities documented in previous theoretical (Pindyck and Rotemberg, 1983; Atkeson and Kehoe, 1999; Hassler *et al.*, 2022) and empirical research (Asche *et al.*, 2008; Labandeira *et al.*, 2017; Huntington *et al.*, 2019; Kumar and Wesselbaum, 2024).

[5] Our framework partially internalizes system-wide interactions, as sectoral relations and aggregate supply constraints create propagation mechanisms where shocks in one sector can affect others, amplifying or dampening aggregate dynamics (C. K. Wolf, 2023; Huber, 2023).

Medium-term responses are more pronounced, particularly in the full sample that includes the 2021-2022 European energy crisis. Looking at the estimated elasticities, we find that Italy's total gas consumption is unresponsive to price shocks in the first year, with elasticity peaking at -0.13 after two years (and -0.07 pre-COVID-19) with clear sectoral differences. Past studies on static natural gas consumption price elasticity, such as Asche *et al.*, (2008), Labandeira *et al.*, (2017), and Huntington *et al.*, (2019), report static elasticities between -0.05 and -0.38. Our estimates, therefore, fall at the lower end of the elasticity range found in the literature, consistent with the idea that sectoral data capture an average response across heterogeneous firms that are subject to different rigidities, both technological and contractual. This pattern underscores the heightened sensitivity of gas consumption to price shocks in the aftermath of the 2021-2022 energy crisis and supports previous findings on the slow but yet significant propagation of natural gas supply disturbances (Ruhnau *et al.*, 2023; Alessandri and Gazzani, 2023; Rubaszek *et al.*, 2021; Adolfsen *et al.*, 2024; De Santis, 2024; Casoli *et al.*, 2024; Güntner *et al.*, 2024).

Over a three-year horizon, Italy's cumulative elasticity for total gas consumption remains persistently negative at -0.04, indicating sustained demand reduction. In contrast, the pre-pandemic period showed weaker responses, with cumulative elasticities approaching zero, reflecting absence of medium-term demand destruction.

The heterogeneity across sectors highlights significant differences in their ability to adapt to gas supply shocks. Local distribution consumption (LDC) — comprising primarily households and small businesses that do not rely on gas as a major production input — adjusts relatively quickly since aggregate gas supply shocks are transmitted rapidly to final consumers. This segment, accounting for around 45% of Italy's gas consumption, displays a distinct response compared to industrial sectors. Sectoral heterogeneity plays a key role in shaping overall elasticity, consistent with findings from studies on residential gas demand in Europe (Asche *et al.*, 2008; Labandeira *et al.*, 2017) and on Californian households (Rubin and Auffhammer, 2024). While household-focused studies using micro-level data, such as Favero and Grossi (2023), typically find more negative elasticity estimates, our broader analysis captures the distinct consumption patterns and constraints across industrial and commercial sectors. The lower short-run elasticity we observe reflects how structural factors cause firms and industries to adjust more slowly than households to price increases.

Gas-intensive industries, such as chemicals and metallurgy, exhibit low elasticity due to the substantial costs of adapting their production processes. For these industries natural gas is a critical input and market disruptions could generate significant output losses. By contrast, sectors like electricity generation and services show greater flexibility, substituting away from gas more easily or adjusting consumption patterns with possible minimal disruption to their operations.

In gas-intensive manufacturing sectors such as chemicals and ceramics, the elasticity of -0.11 after two years reflects limited substitution options in the short run, compounded by the staggered expiration of contracts, consistently with predictions by putty-clay models, where the adjustment process to a shock is sluggish. Instead, in gas-non-intensive sectors, such as services, firms exhibit greater flexibility to adapt, either through energy efficiency measures or by substituting gas with alternative fuels. This flexibility translates into higher cumulative elasticities over the same horizon, consistently with theoretical predictions by putty-putty models, where the adjustment process to a shock is faster.

A key theoretical mechanism that explains the stronger reaction in terms of dynamic price elasticities of natural gas consumption during the full sample (2012–2023) compared to the pre-COVID-19 period (2012–2019) is the role of expectations. Our findings can be interpreted within the framework proposed by Eichenbaum *et al.*, (2024), which emphasizes how the perceived persistence of a crisis amplifies economic responses of households and firms.[6]. During the 2021–2022 European energy crisis, expectations of persistently elevated supply-driven increases in gas prices led firms and households to react more decisively, accelerating adjustments such as energy substitution, efficiency improvements, and demand reductions. In contrast, during the pre-2020 period, supply-driven price shocks were perceived as transitory, resulting in weaker and more delayed responses.

Contractual rigidities further influenced these dynamics. Fixed-price contracts, particularly common in industrial sectors, initially shielded consumers from price shocks. However, as these contracts expired during the crisis, firms and households faced the full extent of price increases, which magnified the scale and speed of their adjustments.

The forecast error variance decomposition analysis underscores the growing

[6] In Eichenbaum *et al.*, (2024), during the COVID-19 pandemic, individuals reduced consumption in response to perceived high mortality risks, which were initially overestimated. As they updated their expectations based on observed data, consumption patterns gradually recovered.

importance of supply-side shocks persistence in driving gas consumption volatility, especially after the 2021-2022 energy crisis. This has significant implications for monetary policy, as persistent shocks to natural gas prices can transmit to inflation through direct increases in energy costs and indirect effects on production and transportation costs across the economy. If households and firms start to perceive supply gas shocks as persistent, this could come at the cost of dis-anchoring inflation expectations, prompting firms and workers to adjust prices and wages in ways that could sustain inflationary pressures. In such cases, central banks must act decisively to stabilize prices and prevent further spirals.[7]

Related literature. Our paper bridges the gap between micro-level studies on firms and household energy consumption and macroeconomic analyses of aggregate gas demand. Among the most relevant contributions, Faiella and Lavecchia (2021) and Faiella *et al.*, (2022) analyze the energy demand of Italian households and firms using granular panel data for periods up to 2018. While their work focuses on static short-run elasticities, our study advances the literature by estimating dynamic elasticities over both the short- and medium-run, capturing adjustments across multiple sectors. Additionally, our analysis incorporates the 2021–2022 European energy crisis — a major macroeconomic episode excluded from their sample — providing insights into how gas consumption reacts to large, persistent disruptions.

Likewise, Alpino *et al.*, (2024) examine the effect of the 2021-2022 energy crisis on Italian firms' energy demand. They focus on short-run responses, identifying elasticities close to zero at the onset of the crisis and a delayed adjustment in the latter half of 2022. Their identification strategy leverages micro-level variation arising from the staggered expiration of fixed-price energy contracts. Conversely, our study utilizes a macroeconomic instrument—the narrative shock series developed by AG, which captures supply-driven price increases in the real TTF market caused by natural gas supply disruptions. This alternative source of variation enables us to capture broader aggregate dynamics and estimate dynamic elasticities exploiting variation at both the provincial and sectoral levels.

Overview. The remainder of the paper is structured as follows. Section 2 presents

[7] If the gas supply shocks are considered temporary, the central bank should optimally choose a *look-through* approach to avoid over-tightening (Hazell *et al.*, 2022; Beaudry *et al.*, 2023; Drechsel *et al.*, 2024). The 2021-2022 energy crisis underscores the dual challenge for monetary policy: assessing the persistence of the natural gas supply shock in real time and intervening effectively to maintain price stability without excessively slowing down economic activity.

the sectoral gas data and describes the main events of the 2021-2022 European energy crisis. Section 3 details the econometric methodology, where we use a panel local projection approach to estimate IRFs, FEVDs, and dynamic elasticities. Section 4 discusses the baseline results. Section 5 provides robustness checks, while Section 6 briefly touches upon possible policy interventions following a natural gas supply shock. Section 7 concludes with broader implications for energy policy and future research directions.

2 Data

This section explores the data used for this work. Subsection 2.1 presents the Snam dataset, some characteristics of the gas demand in Italy and briefly describes the impact of the 2021-2022 European energy crisis; Subsection 2.2 introduces the natural gas supply shock series of AG; Subsection 2.3 deals with the construction of the temperature surprise series of Heating (HDD) and Cooling degree days (CDD) used in the study to control for temperatures; finally Subsection 2.4 introduces the Terna electricity consumption data that are available at the regional level.

2.1 Snam gas dataset

In this study, we utilize a comprehensive dataset provided by Snam. The dataset captures monthly gas consumption, measured in Gigajoules, over the period from January 2012 to December 2023. The data are sourced from Snam and primarily pertain to users connected to the high-pressure network, which typically includes large industrial consumers with intensive natural gas requirements. In contrast, the residential sector and small to medium-sized enterprises in the industrial and tertiary sectors are typically served by distribution networks. For these categories, the dataset offers only aggregated consumption data without detailed classification by ATECO codes, categorizing them under Local Distribution Consumption (LDC). As Snam is the principal natural gas Transmission System Operator (TSO) in Italy, the sample is representative of almost the entirety of Italian natural gas demand[8],

[8]Snam manages the primary Italian pipelines and entry points. It is the principal Transmission System Operator (TSO) with a 94% market share in Italy, though it is not the sole operator. The other smaller transporters or Distribution System Operators (DSOs) are mainly connected to the Snam network, hence the analyzed sample represents almost the total amount of Italian methane consumption.

providing insights into 60 Italian ATECO sectors in 102 provinces divided into four macro-categories: 1) LDC; 2) electricity via natural gas; 3) manufacturing divided in gas-intensive and non-gas-intensive ATECOs and 4) services.

- *Local Distribution Consumption (LDC)*: This refers to the consumption of natural gas by residential, industries and commercial users within a local distribution network. It includes gas used by households for heating, cooking, and hot water, as well as small-scale industrial and commercial applications. From Eurostat Energy Balances, residential and commercial services are about the 80%-90% of consumption of LDCs while the remaining part is gas used from small and medium-sized enterprises.

- *Electricity Generation via natural gas*: This sector refers to power plants that use natural gas to generate electricity.

- *Manufacturing*: This sector includes industries that use natural gas as an energy source or raw material for producing goods. Natural gas can be used for heating, powering machinery, or in chemical processes such as in the production of chemicals, glass, steel, and other materials. This sector is divided in gas-intensive and non-gas-intensive ATECOs according to the average annual natural gas consumption measured in average bcm/year (see Table 1 and Figure 4 for greater detail in the distinction between gas-intensive- and non-gas-intensive- classification).

- *Services*: This category includes large-scale commercial businesses and public services that utilize natural gas primarily for heating. Unlike the small commercial users under LDC, this category includes larger entities such as hospitals, schools, retail chains, and large office buildings.

Figure 1 shows annual gas consumption in billions of cubic meters per year (bcm/year), from January 2012 to December 2023. Notably, the period from 2012 to 2013 exhibits a marked reduction in gas usage. This decline coincides with the aftermath of the European sovereign debt crisis, which constrained economic activity across Italy (Bassanetti *et al.*, 2014; Neri and Ropele, 2015), and an unusually warm autumn-winter season. Panel (a) in Figure A.4 illustrates this with a strong and persistent negative anomaly in the Heating Degree Days surprise series.[9]

A subsequent recovery in gas consumption is observed from 2014 onward, aligning with the broader economic rebound. However, by 2018, a marked slowdown becomes evident, likely tied to the deceleration of the business cycle and downturns in key industrial sectors, such as the German automotive industry, which also affected the automotive supply chain in Italy slowing down industrial production and gas consumption (Leal *et al.*, 2019; Mistretta, Forthcoming).

While 2020 experienced a decline in gas consumption, coinciding with reduced industrial activity and mobility due to the COVID-19 pandemic, 2021 brought a swift recovery as economic activity resumed (S. Marchetti *et al.*, 2022; Conteduca and Borin, 2022; Emiliozzi *et al.*, 2024b).

The 2021-2022 European gas energy crisis. From 2022 onward, the gas data indicate a new phase of contraction in gas consumption. This period coincides with supply constraints caused by geopolitical tensions and rising natural gas prices, particularly after the issues surrounding Nord Stream 1 between Germany and Russia started in the summer of 2021. The situation further deteriorated following the Russian invasion of Ukraine in February 2022, which led to a sharp reduction in Russian gas supplies, drastically altering the european energy landscape. The effects of this unprecedented geopolitical shock is clearly reflected in the declining gas consumption in 2022 and 2023 (Borin *et al.*, 2022; Albrizio *et al.*, 2022; Bachmann *et al.*, 2024; Emiliozzi *et al.*, 2024a; Di Bella *et al.*, 2024).[10] The reduction of flows through key pipelines, including the complete shutdown of Nord Stream 1, caused wholesale gas prices to peak at over 300 euros per megawatt-hour in August 2022.[11]

Figure 2 illustrates the annual gas consumption shares by macro sector in Italy from 2012 to 2023, revealing a remarkably stable pattern throughout the period. Local Distribution Consumption (LDC) and gas usage for electricity generation consistently dominate as the largest consumers. The first macro sector accounts for approximately 44-46% of total gas usage, while the second has a share of around

[9]Temperature is a crucial driver of natural gas consumption, especially due to its impact on heating demand during colder months (Soldo, 2012).

[10]Italy's heavy reliance on natural gas imports, accounting for 93% of total consumption in 2020, made it particularly vulnerable to the 2021-2022 European energy crisis. Before the crisis, Russia supplied 43% of Italy's imported gas, underscoring the country's dependence on a single geopolitical partner.

[11]Natural gas also played a significant role in Italy's electricity production, accounting for about half of its domestic power generation. Given the structure of the day-ahead power market, shocks to the price of natural gas had a direct impact on electricity prices in Italy (Uribe *et al.*, 2022; Zakeri *et al.*, 2023).

24-26%. The industry and construction sector follows as the third-largest consumer, utilizing about 20-25% of the Italian gas supply. Services and smaller sectors such as agriculture account for a smaller share (around 6-11%).[12]

Figure 3 shows the annual distribution of gas consumption across Italian regions in the period January 2012 - December 2023, measured in billion cubic meters per year (bcm/year). Lombardia stands out as the region with the highest gas consumption, with a median consumption well above other regions. Emilia-Romagna and Piemonte follow with lower consumption levels. The distribution within each region also highlights variability in gas consumption.

Figure 4 shows the distribution of yearly gas consumption (bcm/year) across ATECO-2 digit sectors. Two sectors dominate: sector 35.22 (*Local Distribution Consumption, LDC*) and sector 35.11 (*Electricity generation via gas*), both characterized by higher means — approximately 33 bcm/year and 26 bcm/year, respectively — and substantial variability due for example to temperatures and business cycle fluctuations. These two sectors account for a significant share of aggregate gas demand. Within the *Manufacturing* category, gas-intensive sectors include *Manufacture of other non-metallic mineral products* (23), *Chemicals* (20), *Metallurgy* (24), *Paper and paper products* (17), *Coke and refined petroleum products* (19), and *Food industries* (10).[13] These gas-intensive sectors are identified as those with annual average gas consumption between 3 and 1 bcm/year, while non-gas-intensive sectors fall below the 1 bcm/year threshold. The remaining sectors display much lower gas consumption levels and are categorized as non-gas-intensive.[14]

Cleaning steps. We applied several data cleaning steps to ensure the quality and reliability of the dataset. First, we trimmed the bottom and top 1% of the dataset for each province-ATECO-2 digit pair to eliminate extreme negative (almost zero-gas-consumption) and positive outliers. Second, we excluded ATECO sectors present in fewer than three provinces to avoid including highly specialized sectors

[12]Despite minor annual fluctuations, the overall distribution of gas consumption across the five macroeconomic sectors has remained largely stable, with no significant shifts or trends in any sector's relative consumption. This stability indicates a consistent pattern of gas utilization within the Italian economy over the observed period, suggesting no major structural changes in the way different macroeconomic sectors consume natural gas.

[13]This classification based on the average annual gas consumption aligns with Corsello *et al.*, (2023) and Alpino *et al.*, (2024).

[14]The classification into gas-intensive and non-gas-intensive sectors is based on annual average gas consumption computed over the entire sample period (2012–2022). This classification remains unchanged if annual averages are taken over the sample 2012-2019, before the crisis. Further analysis on regional and macro-sector gas consumption can be found in Subsection A.1 of the Appendix.

concentrated in only a few locations. This step had a minimal impact on the results, as it removed only a small number of ATECO sectors with a significant amount of missing observations. Finally, we retained only those province-ATECO pairs with at least 30% of the total possible observations (January 2012 to December 2023), allowing for non-consecutive observations. This threshold was chosen to ensure sufficient data coverage for estimating impulse response functions (IRFs), forecast error variance decompositions (FEVDs), and dynamic elasticities over a medium-term horizon of 36 months.[15]

We then performed a seasonal adjustment of the monthly time series: Panel (a) of Figure A.2 in Appendix A.2 shows the raw time series of the LDC in each Italian province from January 2012 to December 2023. Panel (b) displays the seasonally adjusted series processed using the TRAMO-SEATS algorithm (Maravall, 2006).

2.2 Natural gas supply shocks

In our empirical strategy, we employ the gas supply shock series developed by AG ($AGshock_t$) to investigate the elasticity of gas consumption for the short (1-year) and medium run (3-year). Panel (a) of Figure 5 plots the monthly Title Transfer Facility (TTF) spot price that is the benchmark price in the European Union, while panel (b) displays the $AGshock_t$ gas supply shock series that captures unexpected fluctuations in gas supply that are unrelated to broader economic conditions or demand factors.

By focusing on supply-side disturbances, the measure allows us to isolate the causal effects of gas supply changes on consumption patterns. The shock series is constructed using a narrative approach, which identifies specific events, or policy changes that directly affect gas supply, such as unexpected pipeline disruptions, geopolitical tensions affecting major gas-producing regions, or sudden changes in extraction capabilities.

2.3 Temperature data

In our analysis, we utilize monthly temperature data for Italy from Eurostat. This dataset provides crucial information on temperature variations across European regions, which is essential for understanding gas consumption patterns.

[15]We started with a dataset of 158,928 data points. After the cleaning steps, we retained 137,601 observations.

Heating Degree Days (HDD) and Cooling Degree Days (CDD) are metrics used to quantify the demand for energy needed to heat or cool buildings. HDD is calculated as the number of degrees that a day's average temperature falls below a base temperature, typically 18°C.

The dataset is organized at the NUTS 3 level, which corresponds to Italian provinces. This granular level of data allows us to control for temperature variations across different geographic areas, accounting for local climate conditions that can significantly influence gas and energy consumption patterns.

Bringing in the analysis temperature variations is crucial when estimating gas price elasticity. Temperature is a key determinant of natural gas demand, particularly for residential and commercial heating (LDC sector) and it is highly heterogeneous at local level. Failing to control for temperature effects could lead to biased estimates of price elasticity (Deschênes and Greenstone, 2007; Dell *et al.*, 2009; Dell *et al.*, 2014; Deryugina and Hsiang, 2014; Colacito *et al.*, 2019; Ruhnau *et al.*, 2023; Nath *et al.*, 2024).

Figure A.3 displays the raw HDD data in panel (a) (raw CDD time series depicted in panel (b)). Since these data are characterized by an elevated seasonality, following the literature we compute a surprise measure of HDD (CDD) defined as the deviation between the realized HDDs (CDDs) for a given month and province, and a 10-year moving average of HDDs (CDDs) for the corresponding month in prior years.[16]

Surprises for HDD and CDD across various Italian provinces over the period from January 2012 to December 2023 are shown in panel (a) and (b) of Figure A.4 in the Appendix. The plots highlight the substantial heterogeneity in both HDD and CDD surprises across Italian provinces.

2.4 Electricity Data

Regional electricity consumption is a widely used high-frequency proxy for local economic activity, as it captures fluctuations in industrial production, commercial operations, and household demand in near real-time. Because electricity and gas are often jointly used in production processes, lagged electricity consumption also helps capture dynamic complementarities that influence gas demand (Asche *et al.*, 2008; Alberini *et al.*, 2011; Miller and Alberini, 2016; Alberini *et al.*, 2020). Including

[16] See also works by Burke *et al.*, (2015) and Gourio and Fries (2020).

regional electricity consumption as a control variable therefore helps account for time-varying confounders related to economic conditions and energy usage patterns (D. J. Marchetti and Parigi, 2000; Galdi *et al.*, 2023; Fezzi and Fanghella, 2021; Baumeister *et al.*, 2024; Lewis *et al.*, 2022; Delle Monache *et al.*, 2020). For the empirical part that follows we use the monthly values of total regional electricity consumption from January 2012 to December 2023.[17]

3 Econometric methodology

This section presents the econometric methodology, detailing the tools used to analyze the dynamic impact of natural gas supply shocks on consumption patterns in Italy. IRFs are estimated using the panel local projection method, following the framework established by Jordà (2005) and Jordà (2023). IRFs trace how gas consumption adjusts to unexpected supply disruptions. They capture the evolution of quantities over time and the persistence and magnitude of the shock effects. This is crucial for understanding the time-varying nature of demand adjustments in response to supply-side changes.

The forecast error variance decomposition (FEVD) is computed using the panel local projections method developed by Gorodnichenko and Lee (2020). The FEVD quantifies the proportion of total variation in gas consumption that can be attributed to the identified supply shocks, offering insights into their relative importance compared to other shocks influencing demand. This is particularly valuable in disentangling the dominant drivers of gas consumption volatility during periods of heightened market stress.

We estimate dynamic elasticities using a one-step instrumental variable method as proposed by Ramey and Zubairy (2018), Fieldhouse *et al.*, (2018), Bernardini and Peersman (2018), and Auer *et al.*, (2021), leveraging the narrative shocks identified by AG. These elasticities measure the cumulative responsiveness of gas demand to changes in prices triggered by supply disruptions, providing a direct assessment of the sensitivity of gas consumption across sectors, time horizons and state dependence (reaction in the 2012-2019 and 2012-2023 samples).

[17] Figure A.5 in the Appendix displays the logarithm of the annual values of electricity consumption (in terawatt-hours, TWh) for Italian regions. The figure highlights regional heterogeneity in electricity use as well as the impact of major events, such as the sharp decline during the COVID-19 pandemic in 2020.

3.1 Impulse responses

We estimate the short- (impact and 1-year) and medium-term (3-years) elasticities of gas demand for six key aggregates: (i) local Distribution Consumption (LDC); (ii) gas for electricity generation; (iii) gas-intensive manufacturing sectors; (iv) non-gas-intensive manufacturing sectors; (v) services; and (vi) total gas consumption in Italy. Furthermore, we document for the first time how these elasticities evolved after the 2022 energy crisis, which was triggered by the Russian invasion of Ukraine.

The baseline estimating panel local projection specification is in equation (1):

$$\begin{aligned} y_{ijt+h} = \alpha_{ij}^h + \sum_{k=0}^{12} \beta_k^h AGshock_{t-k} + \sum_{k=1}^{12} \gamma_k^h y_{ijt-k} + \ldots + \sum_{k=1}^{12} \delta_k^h ttf_{t-k} + \ldots \\ + \sum_{k=0}^{3} \eta_1^h HDDSurprise_{jt-k} + \sum_{k=0}^{3} \eta_2^h CDDSurprise_{jt-k} + \varepsilon_{ijt+h} \end{aligned} \tag{1}$$

where $h = 0, \ldots, 36$

Equation (1) describes the evolution of the logarithm of gas consumption in ATECO i in province j (y_{ijt}) between month $t-1$ and h with $h = 0, \ldots, 36$.[18]. The parameters of interests are the sequence of β_k^h for $h = 0, \ldots, 36$ months in equation 1) that is the percentage change of gas consumption h period ahead after an unexpected gas supply shock.[19] The model includes fixed effects α_{ij}^h for each combination of ATECO-2-digit/province combination to account for time-invariant confounders. The variable $AGshock_{t-k}$ is the time series of the natural gas supply shocks identified in AG together with twelve lags and we treat the natural gas supply shock as observed (Ramey and Zubairy, 2018; Fieldhouse *et al.*, 2018; Bernardini and Peersman, 2018; Auer *et al.*, 2021).[20]

[18] y_{ijt} represent the natural logarithm of gas consumption in ATECO i, Province j and time t adjusted for seasonality before running the panel local projections using TRAMO-SEATS. See Section A.2 in Appendix for details.

[19] We also tried a specification including monthly COVID-19 dummies for the whole sample specifications. Results are unchanged with respect to those presented in the baseline specification since the COVID-19 had not a major impact on gas consumption in Italy as can be seen both in Figure 1 and in Figure A.2 in subsection A.2 in the Appendix.

[20] We also estimated the IRFs not only via OLS but also using panel LP-IV local projections. Results are available upon request to the authors. We did not report them in the paper since we are mostly interested in the dynamic elasticities that are estimated following Ramey and Zubairy (2018).

We add as controls twelve lags of both the log-level of gas consumption at the ATECO-2-digit/province level and the log-level of the real TTF price day-ahead future deflated with the Italian HICP.[21]

We add monthly dummies for the years 2020 and 2021 to account for the sharp decline and subsequent rebound in economic activity during the COVID-19 pandemic.[22]

Since weather shocks are a key driver for gas consumption dynamics, especially in the LDC sector we also add to the baseline specification surprises in cooling ($CDDsurprises_{jt}$) and heating degree days ($HDDsurprises_{jt}$); see Subsection A.2 in the Appendix for details about the construction of the data. [23]

As a robustness check in Section 5, for the manufacturing sector we enrich the baseline equation (1) including lagged log-levels of the corresponding ATECO-2 digit industrial production index ($ipateco_{it-k}$) as controls. Further, to isolate business cycle dynamics and address time-varying confounders, we also include regional electricity consumption ($electricity_{jt-k}$) and province-level linear trends.[24]

3.2 Forecast error variance decomposition (FEVD)

The forecast error variance decomposition (FEVD) provides insights into the contribution of the narrative natural gas supply shock to the variation in gas consumption. At each forecast horizon h, the FEVD quantifies the share of the forecast error variance in gas consumption that can be attributed to this exogenous natural gas supply shock, relative to others sources of variation.

Based on the panel local projection model presented in Equation (1) - following Gorodnichenko and Lee (2020) - the FEVD for a given horizon h for the natural gas supply shock $AGshock_t$ can be expressed as:

$$\text{FEVD}_h = \frac{\sum_{k=0}^{h} \left(\beta_0^h\right)^2 \sigma^2_{AGshock_t}}{\text{Var}(y_{ijt+h})} \text{ where } h = 0, \ldots, 36 \tag{2}$$

[21]As a robustness we also deflated the nominal TTF price using the HICP excluding-energy index. Results are unchanged.

[22]We also tested specifications that exclude these 24 dummies from the full sample, and the results remain robust to their omission.

[23]We include the contemporaneous values and 3 monthly lags for both $HDDSurprise_{jt-k}$ and $CDDSurprise_{jt-k}$ because these variables capture unanticipated climate fluctuations, which tend to persist over a typical seasonal cycle lasting of approximately three months.

[24]Since monthly indices that track value added for services are unavailable, we rely on provincial linear trends and regional electricity consumption to control for business cycle fluctuations.

with $\sigma^2_{AGshock_t}$ - the variance of the narrative natural gas supply shocks provided by AG - equal to one by construction. The coefficient β_0^h represents the impulse response coefficients of gas consumption to the shock at different lags and Var(y_{ijt+h}) is the total forecast error variance of gas consumption at horizon h.[25]

3.3 Natural Gas Dynamic Elasticity at the National and Sectoral level

In this section we present the methodology put forward by Ramey and Zubairy (2018), Fieldhouse *et al.*, (2018), and J. H. Stock and Watson (2018) to estimate the dynamic elasticity of natural gas consumption in Italy, both at the national and sectoral levels in our panel local projection framework.

The dynamic elasticity measures the cumulative response of gas consumption to the cumulative changes in real TTF prices following a supply disruption.

To address the endogeneity of TTF prices and isolate the supply contribution of the price movements from all the other possible causes such as demand, geopolitical events, weather, storage levels, and macroeconomic conditions, we use the natural gas supply shock identified by AG as an instrument.

This approach helps mitigate the two-way causality between gas consumption and TTF prices.[26] There may also be omitted variables that are correlated with both gas consumption and TTF prices, such as unobserved shocks to energy demand or broader economic trends. These unobserved factors introduce further endogeneity concerns, as they can lead to spurious correlations between TTF prices and gas consumption that we tackle with this IV strategy.

The elasticity of gas consumption to a natural gas supply shock is estimated with a 2SLS approach using equation (3):

$$\frac{\sum_{j=0}^{h}(Y_{ijt+j} - Y_{ijt-1})}{Y_{ijt-1}} = \alpha_{ij}^h + \beta_0^{h,cumul} \frac{\sum_{j=0}^{h}(TTF_{t+h} - TTF_{t-1})}{TTF_{t-1}} + \gamma^h X_{ijt} + \varepsilon_{ijt+h} \tag{3}$$

where $h = 0, \ldots, 36$

[25]We computed the FEVD standard errors using the delta method. A detailed explanation is provided in Section C in the Appendix.

[26]The reverse causality from gas consumption to TTF prices is a minor concern since the TTF price is the European benchmark and reflects European and global factors. It is possible that the supply and demand shocks of the Italian local natural gas market has a limited impact of the European TTF prices.

where $\frac{\sum_{j=0}^{h}(Y_{ijt+j}-Y_{ijt-1})}{Y_{ijt-1}}$ represents the cumulative percentage change in gas consumption for ATECO i, province j from time t to $\frac{\sum_{j=0}^{h}(TTF_{t+h}-TTF_{t-1})}{TTF_{t-1}}$ is the cumulative percentage change in the real TTF price from t to $t+h$, X_{ijt} includes control variables such as twelve lags of gas consumption, past values of the real TTF; weather-related surprises (HDDs and CDDs surprises) and ε_{ijt+h} is the error term.

$\beta_0^{h,cumul}$ is the parameter of interest, indicating the elasticity of gas consumption at horizon h: this dynamic elasticity represents quantifies the cumulative change of gas consumption in a given sector to a surprise increase in real TTF prices over horizon h.

First Stage. Equation (4) estimates the first stage regression where the endogenous variable $\frac{\sum_{j=0}^{h}(ttf_{t+h}-ttf_{t-1})}{ttf_{t-1}}$ is regressed on the exogenous natural gas supply shock $AGshock_t$, along with exogenous controls included in X_{ijt} described for equation (3):

$$\frac{\sum_{j=0}^{h} TTF_{t+h} - TTF_{t-1}}{TTF_{t-1}} = \pi_0^h + \sum_{k=0}^{12} \pi_k^h AGshock_{t-k} + X_{ijt}\gamma^h + \nu_{ijt+h} \tag{4}$$

where $h = 0, \ldots, 36$

Second Stage. The endogenous term $\frac{\sum_{j=0}^{h}(TTF_{t+h}-TTF_{t-1})}{TTF_{t-1}}$ in equation (3) is replaced with its fitted values from the first stage regression (4). This two-stage least squares (2SLS) approach enables us to obtain consistent estimates of $\beta_0^{h,cumul}$ and calculate robust standard errors, as described in Ramey and Zubairy (2018). Since the model incorporates fixed effects in a panel setting, we compute heteroskedasticity-robust standard errors clustered at the ATECO-province level to correct for potential serial and spatial correlation in the error terms.

4 Baseline results

This section presents the baseline results on the transmission of a natural gas supply shock in Italy, focusing on impulse responses, forecast error variance decompositions, and the dynamic price elasticity of gas consumption. Specifically, we analyze the effect of a 10% increase in real TTF prices, induced by unanticipated supply disruptions identified in the narrative shock by AG, on total gas consumption in Italy and of the various sectors of the economy over a three-year horizon. The analysis spans different periods and market conditions, with particular attention to the differences between the pre-COVID era (January 2012 to December 2019) and the full sample (January 2012 to December 2023), which includes both the COVID-19 pandemic and the 2021-2022 European energy crisis following the Russian invasion of Ukraine. 95% significance level confidence intervals are shown as shaded areas.

4.1 Real TTF response to a unexpected gas supply shock

Impulse responses. Panel (a) of Figure 6 illustrates the response of the real TTF price after a 10% increase due to a gas supply disruption. The blue line represents the full sample response , while the red line captures the response during the pre-COVID period. Both samples exhibit a sharp increase in TTF prices, with the full sample showing a stronger and more prolonged effect, with real prices rising by 25% after one year. In contrast, in the sample 2012-2019, real TTF prices increase by around 20% and revert to baseline more quickly, with less persistence. These findings align with Alessandri and Gazzani (2023), Adolfsen *et al.*, (2024), De Santis (2024), and Casoli *et al.*, (2024), which emphasize the lasting effects of unexpected supply disruptions on European natural gas prices.

Forecast error variance decomposition. Panel (b) shows that the shock accounts for around 50% of price changes on impact in the full sample, compared to 40% in the pre-COVID-19 period, aligning with findings by AG. By the 12-month horizon, the shock still explains 40% of price movements in the full sample and 20% in the pre-COVID-19 period. The growing role of supply shocks post-2021 reflects heightened geopolitical tensions and market uncertainties that generated vulnerabilities in European energy supply. Similarly, at a three-year horizon, the shock explains 40% of price variation in the full sample but only 15% pre-COVID-19.

4.2 Total Natural Gas Consumption in Italy

Impulse responses. Panel (a) of Figure 7 shows the response of total Italian natural gas consumption. Comparing the full sample with the pre-COVID-19 period reveals a gradual decline in consumption over time, with no immediate response but a stronger decline in the full sample, reflecting the amplifying effects of the 2021-2022 European energy crisis.

The consumption response peaks around two years after the shock, with a decrease of over 2% in the full sample versus 1.5% in the pre-COVID-19 period. This delayed, hump-shaped pattern reflects several rigidities in the gas market (Rubaszek *et al.*, 2021; Ruhnau *et al.*, 2023; Alessandri and Gazzani, 2023; Corsello *et al.*, 2023; Adolfsen *et al.*, 2024; De Santis, 2024; Casoli *et al.*, 2024; Güntner *et al.*, 2024). A key source of rigidity is the prevalence of fixed-price contracts, particularly among large industrial consumers.[27]

This contractual structure creates a staggered adjustment pattern, where some firms face immediate price exposure while others remain temporarily shielded by the fixed-price contracts negotiated before the gas supply disruption. Our sectoral estimates average across these heterogeneous exposures, explaining the delayed and attenuated aggregate response compared to micro-level studies. The averaging effect contributes to the observed inelastic short-run response, where firms primarily adjust through price pass-through or margin compression rather than consumption changes (Corsello *et al.*, 2023; Alpino *et al.*, 2024).

After three years, both sub-samples show signs of recovery, though the full sample exhibits a more gradual adjustment than the pre-COVID-19 period's faster rebound. This divergence likely reflects the persistent market disruptions from the 2021–2022 European energy crisis.

These findings indicate a negligible response in the short run, followed by a delayed adjustment in gas consumption during the medium term. Both consumers and firms appear to adopt a "wait-and-see" strategy before making substantial changes to natural gas consumption. This behavior aligns with the predictions of "putty-clay" models, as outlined by Pindyck and Rotemberg (1983), Atkeson and Kehoe (1999), and Hassler *et al.*, (2022).

Forecast error variance decomposition. Panel (b) reveals the increasing role of supply shocks in explaining gas consumption volatility. The post-COVID-19 period shows heightened sensitivity to supply disruptions, with these shocks accounting for approximately 2% of total variation at their two-year peak, compared to about 1% pre-pandemic (Bastianin *et al.*, 2019; Rubaszek *et al.*, 2021; Ruhnau *et al.*, 2023; Güntner *et al.*, 2024).

Dynamic elasticity. Panel (c) illustrates the dynamic elasticity associated with

[27]While we do not observe the specific contract duration since they are confidential data, firm-level surveys analyzed by Neumann and Von Hirschhausen (2015), Alpino *et al.*, (2024), and Kumar and Wesselbaum (2024) document substantial heterogeneity in firms' exposure to price increases based on contract expiration timing.

a 10% increase in the real TTF price resulting from an unanticipated supply shock. This dynamic elasticity is calculated as the ratio of cumulative percentage changes in natural gas consumption versus real TTF prices.[28]

The elasticity remains near zero in the first year for both periods, reflecting significant constraints on adjustment. In the residential sector, essential uses such as heating and cooking are inherently inelastic (Bentzen and Engsted, 1993), while industrial users face technical limitations and capacity constraints in switching energy sources (Kilian, 2008; Labandeira *et al.*, 2017). Furthermore, fixed-price contracts shield households and firms from immediate price increases by locking in pre-shock energy prices for a limited period. These contracts provide short-term protection but come at a cost, particularly during major gas supply shocks, and their duration is finite, typically lasting one to two years.[29]

By the second year, as fixed-price contracts begin to expire and firms and households are forced to renegotiate, cumulative elasticity declines to -0.13 in the full sample (-0.07 pre-2019). This implies that a doubling of TTF prices reduces consumption by 13% (7% in the pre-COVID-19 sample). The delayed peak in the dynamic elasticity, occurring approximately two years after the shock, aligns with the timing of contract renegotiation, suggesting that contractual rigidities are an important driver of the sluggish adjustment (Alberini *et al.*, 2011; Miller and Alberini, 2016; Labandeira *et al.*, 2017; Rubin and Auffhammer, 2024; Favero and Grossi, 2023). However, these rigidities alone cannot fully account for the observed patterns. Behavioral factors also play a role, as consumers and firms may adopt a "wait-and-see" strategy, delaying adjustments until price shocks persist. Notably, by the end of 2023 — two years after the onset of the European energy crisis — Italy's annual gas consumption had declined by 19% compared to 2021 levels. This observed reduction is close to our estimated -13% decrease resulting from a 100% increase in real TTF due to a gas supply shock, highlighting the significant impact of supply disruptions on consumption patterns.[30]

[28] Panel (c) of Figure 7 shows the 2SLS estimate of $\beta_0^{h,cumul}$ in equation (3). As Ramey and Zubairy (2018) explains, this can also be computed as the ratio between cumulative IRFs of consumption and real TTF price response. Section B details the strong instrument validity based on Kleibergen-Paap Wald F-statistics.

[29] Although precise data on natural gas and energy contracts expiration for households and firms are confidential and unavailable to us, industry experts indicate that fixed-price contracts for firms and households generally last no more than two years before renegotiation is required.

[30] It's important to note that the actual -19% reduction is unconditional, reflecting a combination of supply and demand shocks, whereas our -13% estimate specifically isolates the effect of supply disruptions after a doubling in real European gas prices.

Beyond the third year, elasticity starts to revert towards zero in the pre-COVID-19 sample but stabilizes at -0.06 in the full sample. This sustained reduction in demand likely reflects structural adjustments, such as the adoption of energy-efficient technologies and shifts in consumption patterns (Reiss and White, 2005; Knittel, 2011; Favero and Grossi, 2023).[31] These findings highlight the interplay between contractual protections, behavioral responses, and longer-term structural changes, emphasizing the importance of both contractual and non-contractual factors in shaping gas consumption dynamics.

These findings highlight the importance of structural sectoral characteristics, sectoral contractual dynamics and expectations in shaping sectoral responses to supply natural gas price shocks. The systematic increase in dynamic elasticities between the pre-COVID-19 and full-sample periods suggests that the perception of a prolonged crisis significantly influenced consumption behavior. Similar to the expectation channel identified during the COVID-19 pandemic by Eichenbaum *et al.*, (2024)[32], where individuals reduced consumption sharply due to perceived high mortality risks and gradually adjusted as they updated their beliefs, the 2021–2022 European energy crisis saw firms and households reacting strongly to the anticipation of persistently higher gas prices.

The expectation of a prolonged disruption significantly influenced behavioral adjustments. During the 2021–2022 European energy crisis, the heightened belief in sustained high gas prices led to a faster adoption of energy-efficient measures, a shift away from natural gas, and more aggressive reductions in consumption. This contrasts with the pre-2020 period, when price shocks were perceived as temporary and triggered weaker, more delayed adjustments.

Past studies on natural gas consumption price elasticity, such as Asche *et al.*, (2008), Labandeira *et al.*, (2017), and Huntington *et al.*, (2019), report static short-run elasticities between -0.05 and -0.38 as reported in Table 2.[33] This places our peak response estimates at the bottom of the elasticity range found in the literature, consistent with the idea that that sectoral data capture an average response across

[31] These estimates are smaller than the long-run elasticities reported in studies like Rubin and Auffhammer (2024), Labandeira *et al.*, (2017), and Huntington *et al.*, (2019), possibly due to differences in data aggregation, sectoral composition, and time horizons.

[32] During the COVID-19 pandemic, the overestimation of case-fatality rates prompted immediate precautionary consumption cuts, which eased as updated information lowered perceived risks by consumers.

[33] Several papers estimate static elasticities of natural gas demand to gas prices, while our approach yields dynamic elasticities. Hence, we compare the peak responses.

heterogeneous firms that are subject to different rigidities, both technological and contractual.

4.3 Local Distribution Consumption (LDC)

Figure 8 illustrates results for the local distribution consumption (LDC).

Impulse responses. Panel (a) in Figure 8 displays the null response of LDC consumption during the first three months following the shock. This is primarily attributable to the ARERA (Autorità di Regolazione per Energia Reti e Ambiente) pricing mechanism, which transmits changes in the wholesale natural gas market price (TTF) to final households and small firms - those that do not heavily rely on natural gas for production - with a three-month lag.[34]

After the fourth month, LDC gas consumption decreases in both samples, with a steeper gradient in the full sample, reaching a peak of -2% after two years (approximately -1.2% in the pre-Covid-19 period). It subsequently recovers, bringing LDC gas consumption back toward zero after three years, indicating the slow transmission of natural gas shocks to gas quantities. As in the previous subsection, the stronger response is in the full sample that contains natural gas consumption patterns influenced by the 2021-2022 European energy crisis. A fraction of this difference could also be driven by other factors such as the energy savings mechanisms put in place by the Italian Government in October 2022 in order to compress natural gas consumption and address supply constraints during the early phases of the energy crisis.[35]

[34] However, this pricing mechanism changed in July 2022, some months after the Russian invasion of Ukraine. During this period, gas prices skyrocketed, prompting ARERA to revise its pricing policy. ARERA shortened the adjustment period for reflecting TTF price increases in consumer bills from three months to one month. This change aimed to more promptly pass on the price increases to consumers, thereby encouraging quicker adjustments in consumption behavior in response to market conditions. The legislative act that formalized this change is the *ARERA Resolution 374/2022/R/gas*, which was implemented to address the extraordinary circumstances of the energy crisis.

[35] With the decree Decree 383 of June 10, 2022 available at this link `https://www.mase.gov.it/sites/default/files/Archivio_Energia/Archivio_Normativa/dm_383_06_10_2022_riduzione_riscaldamento.pdf` the Italian Government introduced normative restrictions and recommendations that complicate the task of distinguishing the pure price-elasticity effects driven by supply shocks. The measures included: i) Reduction of 1° of the temperature allowed in environments (both public and private offices and in homes) which goes from 20° to 19° (+2° tolerance). For buildings used for industrial activities, the maximum permitted temperature is 17° (+2° tolerance); ii) Reduction of 1 hour of the maximum time allowed up to now for the daily switching on of the systems; iii) Reduction of the heating season time frame: the heating period has been reduced by a total of 15 day. Due to the brief period since their implementation, it is unfeasible to isolate the impact of these measures on decreasing LDC gas consumption in Italy.

Forecast error variance decomposition. Panel (b) results for LDC consumption are similar to previous section findings; however, the 2-year horizon is crucial, with the variance explained by the natural gas supply shock peaking at 6% of LDC gas consumption (compared to around 3% pre-COVID-19). This highlights the increased significance of natural gas supply shocks in shaping LDC gas consumption dynamics post-COVID-19 and following the 2022 energy crisis.

Dynamic elasticity. Panel (c) presents results for LDC consumption, which closely align with those discussed in the previous subsection due to the significant contribution of LDC consumption to Italy's total gas demand. In the short term, cumulative elasticity remains close to zero for both samples. This reflects the typical capacity constraints in the energy market, where short-term energy demand is highly inelastic due to rigid gas-dependent infrastructure and technologies, as highlighted by Reiss and White (2005) and Favero and Grossi (2023).

Cumulative elasticity decreases more rapidly in the overall sample, peaking at -0.17 after two years (-0.15 in the pre-COVID-19 subsample). Over three years, cumulative elasticity in the full sample does not converge to zero, unlike the pre-pandemic period, remaining at -0.07. This indicates significant medium-term demand destruction, as noted in the previous Subsection.

4.4 Natural Gas Demand for Electricity Production

Impulse responses. Panel (a) of Figure 9 reveals distinct differences between the full sample and the pre-pandemic period. In the full sample, the response to a TTF price increase is muted for the first year, followed by a sharper decline, reaching a peak of -3% after two years. In contrast, the pre-COVID-19 period shows a smoother, milder decline, with the peak response at -2% after two years. These results underscore the evolving dynamics of the electricity sector's gas consumption, especially in response to the heightened market volatility during the 2021–2022 energy crisis.

Forecast error variance decomposition. Panel (b) echoes the previous findings about the increased volatility in European gas markets due to supply-side disruptions: in the full sample, supply shocks explain 5% of the variation over three years, compared to 2% in the pre-pandemic period. This highlights the growing relevance of supply shocks in driving fluctuations in gas demand for electricity production.

Dynamic elasticity. Panel (c) shows that the cumulative elasticity follows a similar path in both samples, peaking at -0.4 two years after the shock. Initially, the sector exhibits rigidity due to the challenges in rapidly altering its generation mix, which is heavily reliant on gas in the Italian context. Over the medium term, however, responsiveness increases due to the expansion of alternative generation capacity and greater import flexibility. The magnitude of the peak elasticity, the largest in absolute across all sectors, reflects the critical role of gas demand for electricity generation in Italy's overall energy landscape and is consistent with studies such as Labandeira *et al.*, (2017) and Faiella and Lavecchia (2021). After the three-year horizon, cumulative elasticity returns to zero in both samples, in contrast to the sustained reductions observed for total national gas consumption.

Natural gas for electricity production represents the second most significant component of Italian gas demand after local distribution consumption (LDC), underscoring its central role in shaping Italy's energy supply dynamics. The high responsiveness of gas demand for electricity production, particularly during the 2022 energy crisis, reflects its flexibility. Unlike other sectors, electricity producers can adjust their gas usage dynamically, switching to alternative fuels such as coal and oil or importing electricity when gas prices rise (Khan and Rapposelli, 2024; IEA, 2022b; IEA, 2022a; International Energy Agency IEA WEO, 2022; International Energy Agency IEA WEO, 2023; International Energy Agency (IEA), 2022).[36]

Specifically, Italian electricity producers have adapted by investing in renewable energy sources. Between 2023 and 2024, Italy added approximately 7.5 GW of new gross renewable capacity, of which 6.8 GW came from solar photovoltaic and 0.7 GW from wind power.[37] These alternatives characterized by lower variable costs enhance the sector's ability to substitute away from high-priced natural gas over a multi-year horizon. In addition, electricity imports—especially from French nuclear generation—can be increased when domestic gas prices surge. This combination of medium-term diversification and import flexibility explains the sector's greater

[36] See, for example, S&P Global's article titled *"Global gas-to-oil fuel switching to jump 80% as European, Asian gas prices soar"* (`https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/oil/090722-global-gas-to-oil-fuel-switching-to-jump-80-as-european-asian-gas-prices-soar`) and Politico's article *"Coal's on a comeback in energy-desperate Europe"* (`https://www.eenews.net/articles/coals-on-a-comeback-in-energy-desperate-europe/`).

[37] Terna data are available at this link `https://dati.terna.it/en/download-center`.

elasticity compared to manufacturing and services, and aligns with a "putty-putty" adjustment model, where input mixes can be adjusted substantially over time, complementing short-term mechanisms like switching to coal or oil during acute price spikes.

This adaptability was further supported by Italy's temporary reactivation of coal plants under Decree 14/2022, allowing the country to mitigate the impact of gas price shocks on electricity generation.[38]

This price sensitivity, exacerbated by the post-pandemic market environment and the energy crisis triggered by the Russia-Ukraine conflict, highlights the dynamic nature of gas demand for electricity production, contrasting sharply with the rigidity observed in other sectors (Albrizio *et al.*, 2022; Bachmann *et al.*, 2024; López *et al.*, 2024; Di Bella *et al.*, 2024).

4.5 Manufacturing: Gas-Intensive and Non-Gas-Intensive Sectors

The classification in gas-intensive and non-gas-intensive manufacturing sectors is reported in Table 1 (see Figure 4 for the gas consumption distribution in these sectors).

Gas-Intensive Manufacturing Sectors. Manufacturing sectors belonging to this class include: 1) *Other non-metallic mineral products* (ATECO 23); 2) *Chemical Products* (20); 3) *Metallurgy* (24); 4) *Paper and paper products* (17); 5) *Land transport and transport via pipelines* (49); 6) *Coke and refined petroleum products* (19); 7) *Food industries* (10) and 8) *Retail Trade (excluding motor vehicles and motorcycles)* (47).

Impulse responses. After a 10% increase in the real TTF price, the decline in gas consumption is more rapid in the overall sample reaching a peak reduction of -2% around 24 months, compared to a milder -1% peak response in the pre-COVID-19 period (see panel (a) of Figure 10).

This pattern aligns with research on input-output linkages in manufacturing, (Acemoglu *et al.*, 2016; Berger *et al.*, 2022; Luo and Villar, 2023; Baqaee and Farhi, 2019; Ganapati *et al.*, 2020; Bachmann *et al.*, 2024; Kilian and Zhou, 2022), which emphasizes significant short-term rigidities in industrial energy use. Italian manufac-

[38]The Decree 14/2022 allowed Italy to temporarily increase coal-fired power generation to reduce natural gas demand amid supply disruptions from the Russia-Ukraine conflict. The measure, active from April 2022 to August 2023, aimed to stabilize electricity supply during the energy crisis. The text of the decree is available at `https://www.gazzettaufficiale.it/eli/id/2022/04/13/22A02359/sg`.

turing firms, especially in gas and energy-intensive sectors, showed limited short-run flexibility in adjusting to the 2021-2022 European energy price shock. Rather than implementing immediate energy-saving measures or renegotiating contracts, these firms primarily responded through pricing strategies or profit margin adjustments.

Forecast error variance decomposition. Panel (b) shows that supply shocks' influence grows in the full sample, explaining nearly 2% of variance after two years, compared to limited influence pre-pandemic.

Dynamic elasticity. Cumulative elasticity (panel (c)) shows that in both samples, the short-run elasticity is near zero, declining to approximately -0.11 after two years in the full sample (-0.06 pre-COVID-19). The full sample shows a more persistent negative effect, with medium-run elasticity at -0.05 after three years. Gas-intensive manufacturing sectors display a medium-run demand destruction consistent with the total national and LDC natural gas consumption. The post-COVID increase in sensitivity to gas supply shocks suggests vulnerability in energy-intensive manufacturing sectors, necessitating targeted interventions to maintain energy security and industrial competitiveness (Newell *et al.*, 2019; Ferriani and Gazzani, 2023a; Ferriani and Gazzani, 2023b). For instance, in gas-intensive manufacturing sectors such as chemicals and ceramics, the elasticity of -0.11 after two years reflects limited substitution options in the short- and medium-run.

The temporal evolution of these responses raises important questions about the effectiveness of existing industrial hedging strategies. The delayed reduction suggests that while firms may have short-term protection against supply shocks, their long-term adaptation mechanisms might be insufficient or costly (Fabra, 2023). This is particularly relevant for designing industrial energy contracts and developing financial instruments for risk management in energy-intensive industries, as detailed in Draghi, 2024 and Letta, 2024.

Non-gas-intensive manufacturing sectors. These sectors show greater elasticity to supply shocks, with consumption declining by nearly -3% after two years, compared to -2% in gas-intensive sectors (see panel (a) Figure 11). This difference reflects lower adjustment costs and higher flexibility in non-gas-intensive industries, consistent with putty-clay models of energy use (Atkeson and Kehoe, 1999; Hassler *et al.*, 2022). The pre-COVID period shows a more moderate response for low-intensity sectors, suggesting that the pandemic and the 2022 energy crisis accelerated technological adaptation in less gas-dependent industries (Dechezleprêtre and Sato, 2017).

Forecast error variance decomposition. FEVD results in panel (b) support this pattern: low-intensity manufacturers show a delayed but stronger response to supply shocks, explaining nearly 2% of variance after two years, compared to 1% in gas-intensive sectors. This reinforces the "energy flexibility hypothesis" (Levinson, 2021), positing that sectors with lower baseline gas consumption are more adaptable to energy price shocks.

Dynamic elasticity. Cumulative elasticity analysis reveals heterogeneity in how gas supply shocks propagate across manufacturing sectors. Non-gas-intensive sectors exhibit a peak cumulative elasticity slightly higher (-0.13) compared to the to -0.1 for gas-intensive sectors two years after the shock. Over three years, elasticity in non-gas-intensive sectors remains negative at -0.03 (-0.05 for gas-intensive sectors), reflecting their higher adaptability to shocks. This pattern aligns with studies on the relationship between energy intensity and adjustment capabilities in manufacturing (Allcott and Greenstone, 2017).

4.6 Services

The services sector's response to natural gas supply shocks differs from both gas-intensive and non-gas-intensive manufacturing sectors (see Table 1).

Impulse responses. Panel (a) in Figure 12 shows an initial 2% drop in natural gas consumption within two years, followed by a gradual reversal when the full sample is considered. This pattern is more rapid and persistent than in manufacturing sectors, indicating the services sector's higher adaptability to supply-side shocks (Levinson, 2021). In contrast, responses estimated with data up until December 2019 exhibit a smoother and less pronounced response, suggesting more stable consumption patterns.

Forecast error variance decomposition. The FEVD in Panel (b) reveals that gas supply shocks have a relatively modest explanatory power for service sector consumption variance compared to manufacturing sectors. Services, with lower natural gas usage in production, adapt more quickly to supply disruptions. The importance of supply shocks increased after the COVID-19 pandemic and the 2022 energy crisis, consistent with other sectors.

Dynamic elasticity. Cumulative elasticity analysis (Panel (c)) provides further insight into the services sector's response. One year after the shock, cumulative elasticity is already at -0.05 in the full sample, peaking at approximately -0.12 after two years. This pattern was not statistically significant in the pre-COVID-19 sample. Over three years, cumulative elasticity settles at -0.07, indicating long-term demand destruction and possible reallocation of natural gas inputs.

5 Robustness

In this Section, we provide evidence of the robustness of the baseline results discussed in Section 4.

Lag-length robustness. For the baseline results, the IRFs, FEVDs, and cumulative (dynamic) elasticities are computed using 12 lags for key regressors such as the natural gas supply shock ($AGshock_t$), lagged gas consumption, and the TTF (Title Transfer Facility) price, based on monthly data. Given the slow propagation of supply shocks on natural gas consumption at both national and sectoral levels, we also estimated models using 18-month lags. Figure D.1 in the Appendix compares the baseline results with this alternative specification. The results remained stable, with IRFs, FEVDs, and dynamic elasticities showing no significant deviations from the baseline.

Controlling for the European benchmark baseload price of electricity. To account for the possible confounding effects of European electricity prices, we control for the benchmark baseload price due to its strong correlation with natural gas prices in European markets.[39] Specifically, we include 12 lags of EEXBASE (measured in megawatt-hours) to capture any delayed effects of electricity prices on gas consumption.[40] This control ensures that the impact of natural gas supply shocks on gas consumption is not driven by electricity price fluctuations, which could influence substitution behavior across energy sectors.

The results (Figure D.2 in the Appendix) show no significant deviations from the baseline findings.

[39] In European electricity markets, electricity prices are often set by the most expensive generation source, typically gas-fired plants. This leads to a close link between electricity and gas prices (see Uribe *et al.*, (2022), Zakeri *et al.*, (2023), and Fabra (2023)).

[40] We also tested other European price variables, such as: i) EEXPEAK: the EU electricity baseload price specifically for peak hours (8:00 - 20:00) in the European Energy Exchange (EEX) market; ii) POWBASE: the EU electricity baseload price for the entire day in the Powernext market (POW); iii) POWPEAK: the EU electricity baseload for peak hours (8:00 - 20:00) in the POW market. Results using these different time-series for electricity prices are consistent (see Table 3).

Controlling for ATECO-2-digit industrial production indices, total regional electricity consumption and provincial sectoral trends. We address potential time-varying unobserved heterogeneity due to local, sectoral, or national business cycle fluctuations estimating equation (5) with additional controls: (i) industrial production indices at the ATECO-2-digit level (available for the manufacturing sector but not for services); (ii) regional electricity consumption; and (iii) a linear trend at the ATECO-2-digit/province level.

$$\begin{aligned} y_{ijt+h} = \alpha_{ij}^h &+ \sum_{k=0}^{12} \beta_k^h AGshock_{t-k} + \sum_{k=1}^{12} \gamma_k^h y_{ij,t-k} + \sum_{k=1}^{12} \delta_k^h ttf_{t-k} + \dots \\ &+ \sum_{k=1}^{12} \theta_k^h ipateco_{it-k} + \sum_{k=1}^{12} \theta_k^h electricity_{it-k} + \dots \\ &+ \eta_1^h lintrend_{jt} + \dots \\ &+ \sum_{k=0}^{3} \eta_3^h HDDSurprise_{jt-k} + \sum_{k=0}^{3} \eta_4^h CDDSurprise_{jt-k} + \varepsilon_{ijt+h} \end{aligned} \tag{5}$$

where $h = 0, \dots, 36$

Including the ATECO-2 digit industrial production indices for manufacturing sectors is important due to the variation in sectoral business cycles, potentially impacting gas consumption independently of natural gas supply shocks. Additionally, regional electricity consumption serves as a proxy for high-frequency economic activity, particularly in manufacturing. This indicator is a well-established measure of business activity at high-frequency, helping to control for short-term variations in energy demand driven by broader economic conditions rather than natural gas supply disruptions. Finally, a linear trend at the ATECO-2 digit/province level is included to account for long-term growth at this aggregation level. For the impulse responses, we estimate equation (5) and similarly incorporate these controls when estimating the forecast error variance decomposition and cumulative elasticity.

The robustness checks for gas-intensive, non-gas-intensive manufacturing sectors and services are reported in Figure D.3 , D.4 and D.5 respectively. The results align with those presented in the baseline specification in Section 4.

6 Policy Interventions after Natural Gas Supply Shock

During the 2021–2022 energy crisis, European countries often implemented broad, untargeted fiscal measures with limited differentiation based on sectoral energy demand elasticities (Sgaravatti *et al.*, 2022; Ari *et al.*, 2023; Checherita-Westphal and Dorrucci, 2023; Emiliozzi *et al.*, 2024a). According to Bruegel think tank data[41], from September 2021 to January 2023, €651 billion was allocated across European countries to shield consumers and firms from rising energy costs. Over half of these funds were untargeted, not specifically designed to make gas and energy prices more affordable for low-income households or the most-affected industries.[42]

While such untargeted measures offered short-term relief for both households and firms, they risked inefficiently allocating resources—benefiting sectors with greater substitutability and capacity to adapt, rather than those most vulnerable to disruption. Gas-intensive industries like chemicals, ceramics, and metallurgy, which face low short-run elasticities, required immediate and targeted support to prevent production losses and supply chain spillovers. In contrast, sectors such as electricity and services, with higher substitutability, were better positioned to respond through market signals or energy-efficiency incentives.

Our findings underscore that a uniform approach to fiscal support is suboptimal. Effective policy design should reflect sector-specific gas demand elasticities. For elastic sectors, market-based tools may suffice to encourage adjustment. For inelastic sectors, targeted fiscal transfers can buffer economic disruptions and reduce the risk of broader macroeconomic instability. This is consistent with evidence from Pieroni (2023), Auclert *et al.*, (2023), and Chan *et al.*, (2024), who highlight the efficiency of targeted interventions, especially for vulnerable households.

From a production standpoint, relief should prioritize sectors unable to quickly substitute away from gas, where supply shocks pose an immediate threat to output. Temporary instruments—such as targeted tax credits or subsidies—can stabilize these sectors, and should be gradually withdrawn as substitution capacity increases

[41]The dataset listing fiscal relief measures for several euro area countries is available at `https://www.bruegel.org/dataset/national-policies-shield-consumers-rising-energy-prices`.

[42]These measures reflected both the severity of the energy shock and the available fiscal space; see Bank of Italy (2023) and Marchese (2023) for a review.

over time through technological adaptation (Bachmann *et al.*, 2024; Bartocci *et al.*, 2024; Bayer *et al.*, 2023; Gustafsson *et al.*, 2025). Finally, neglecting the most vulnerable sectors during a temporary shock could result in lasting output losses, as highlighted by models incorporating hysteresis effects (Fornaro and M. Wolf, 2023; Airaudo *et al.*, 2023; Gnocato, 2025).

Our elasticity estimates provide a concrete framework for prioritizing support, helping maximize stabilization effects while containing fiscal costs. Freed resources can be redirected toward clean energy investments, aligning short-term stabilization with long-term climate goals. Crucially, the measures discussed here are tailored to temporary shocks and do not replace structural policies — such as the EU ETS, the PNRR, and "Piano Nazionale Industria 4.0"— which are essential for achieving lasting decarbonization. Prompt, targeted support is not only economically efficient but also critical to preserving the fiscal resources to invest in an ordered green transition.

7 Conclusion

This paper provides a comprehensive analysis of sectoral responses to natural gas price shocks, emphasizing the importance of considering both short- and medium-term dynamic elasticities using a comprehensive dataset on Italian gas consumption from 2012 to 2023, with a focus on the 2021-2022 European energy crisis culminated by the Russian invasion of Ukraine.

Using a panel local projection approach, the research estimates impulse response functions, forecast error variance decompositions and dynamic elasticities over a three-year horizon, revealing evidence of medium-term demand destruction. Notably, a 100% increase in real TTF price triggered by a supply disruption, as seen during the 2021-2022 energy crisis, results in a cumulative 13% reduction in total natural gas consumption in Italy over an horizon of two years. This figure stands in contrast to the 7% reduction observed in the pre-COVID-19 period. Furthermore, consumption remains 4% lower even after three years, whereas no demand destruction was evident in the pre-pandemic sample. This pattern of low short-term elasticity followed by medium-term demand destruction is consistent across sectors, though the magnitudes and the temporal profile of the dynamic elasticity varied across horizon reaching a peak after two years.

Natural gas consumption in electricity generation shows relatively higher elasticity compared to other sectors. This can be attributed to the sector's greater capacity for fuel switching. Faced with surging natural gas prices after the Russian invasion of Ukraine, some European countries reactivated coal-fired power plants to substitute for gas in a phenomenon known as "gas-to-coal switching". Additionally, several European nations adopted "gas-to-oil switching", turning to oil-based electricity generation to further mitigate cost pressures from the constrained gas supplies. This ability to switch between different energy sources for electricity production highlights the flexibility of this sector in adapting to energy price shocks and supply disruptions.

The services sector, although displaying a delayed response, exhibits the highest elasticity in the medium term. This can be attributed to the sector's inherently low gas intensity and its capacity to adapt to price fluctuations through operational and contractual adjustments and increased efficiency. Manufacturing, particularly gas-intensive industries, showed much lower elasticities, hampered by structural constraints and their dependence on natural gas as a critical input.

Our findings carry important implications for energy and fiscal policy. Targeted interventions—such as tax credits or subsidies—can help stabilize output in the most exposed sectors during the early phases of a shock. These measures should be temporary and phased out as firms adapt over time through technological substitution, efficiency gains, or contract renegotiation (Fabra, 2023).

Crucially, our results suggest that a one-size-fits-all fiscal response—like the untargeted measures adopted during the 2021–2022 crisis in many European countries—may misallocate public resources and fail to stabilize the sectors most vulnerable to gas price shocks (Sgaravatti *et al.*, 2022; Checherita-Westphal and Dorrucci, 2023). Instead, fiscal relief should prioritize sectors with the lowest short-term elasticities, where substitution is most difficult and the risk of production disruptions is highest.

This conclusion aligns with recent macroeconomic models advocating for short-lived, targeted policy responses to energy supply shocks to minimize long-term output losses and support the green transition (Bachmann *et al.*, 2024; Bartocci *et al.*, 2024; Bayer *et al.*, 2023; Gnocato, 2025). Moreover, complementary structural policies—such as the EU ETS, the National Recovery and Resilience Plan (PNRR), and "Piano Nazionale Industria 4.0"—remain essential for sustaining the energy transition and should not be confused with short-term stabilization tools.

Future research should examine how energy policy design can better integrate sectoral elasticities and long-run transition goals under fiscal constraints. In particular, further work is needed to explore the potential trade-offs between short-term economic stabilization and long-term decarbonization, especially in the context of persistent supply-side shocks (Airaudo *et al.*, 2023; Fornaro and M. Wolf, 2023).

We also plan to investigate potential non-linearities, such as asymmetric, shock-size, and state-dependent responses to natural gas supply disruptions, to better understand the economic implications at sectoral level of energy market volatility driven by supply disruptions (Auer *et al.*, 2021; Caravello and Martinez-Bruera, 2024).

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Figures and Tables

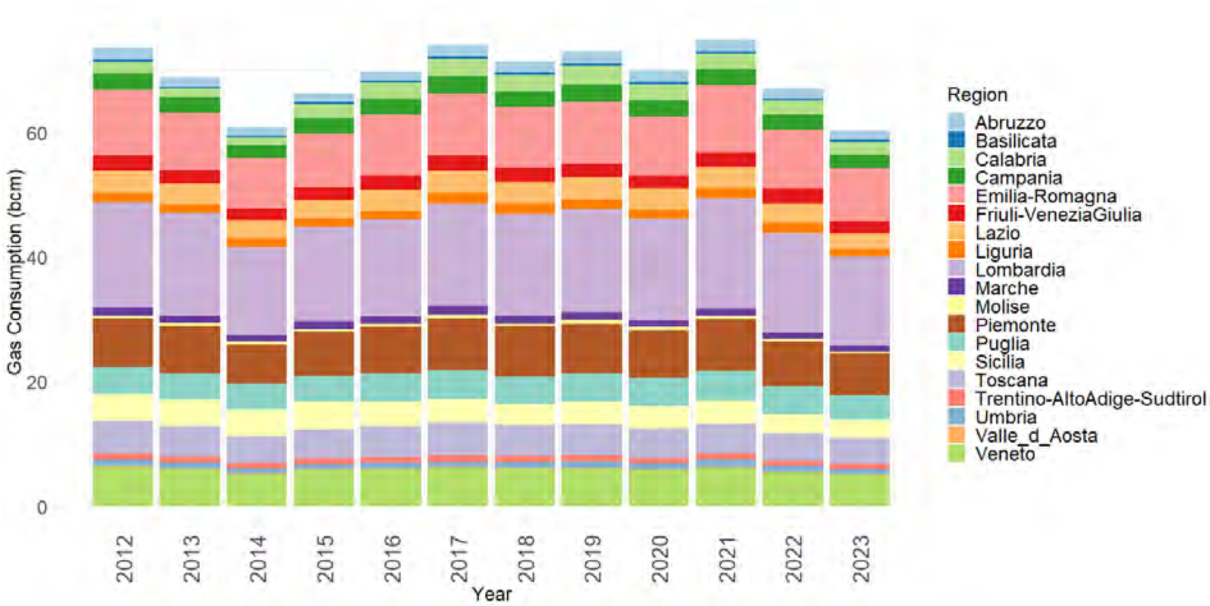


Figure 1: Annual gas consumption in billions of cubic meters (bcm) by region from 2012 until 2023

Note: The figure illustrates Italy's total gas consumption and the respective shares for each region (bcm/year).

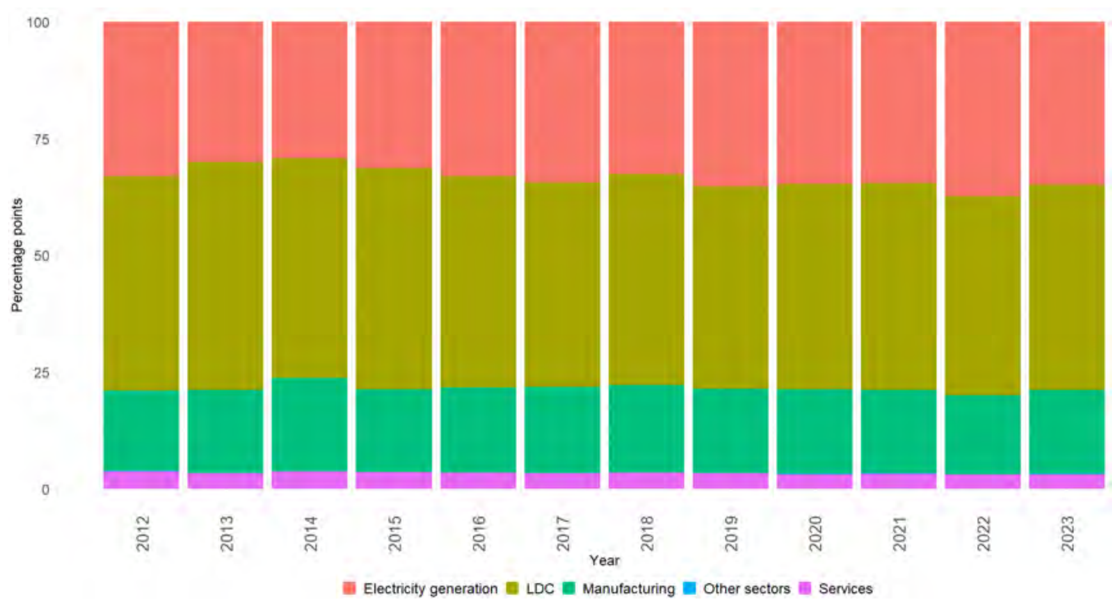


Figure 2: Annual gas consumption shares by macro sector in Italy from 2012 until 2023

Note: The Figure shows the shares of gas consumption in Italy for each macro sector (see also Table 1): i) Electricity generation, ii) Local distribution Consumption (LDC), iii) the Industrial and Construction sector, iv) Services and v) Other sectors. This macro classification is used by Snam and Eurostat.

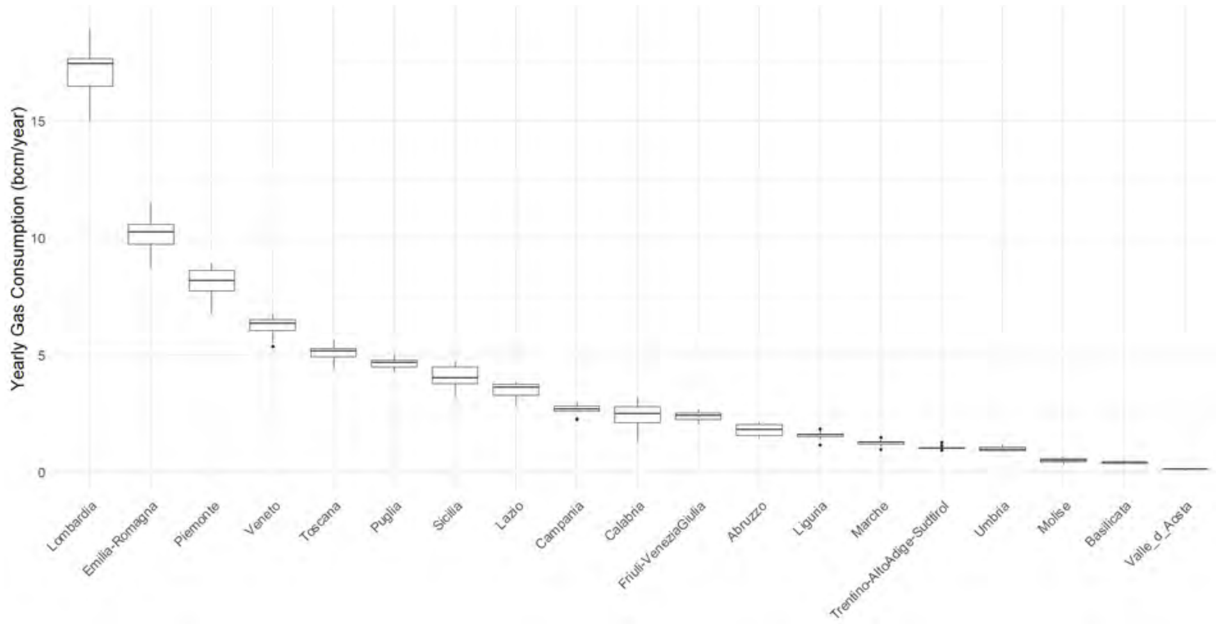


Figure 3: Distribution of Annual gas consumption by Region. Data from January 2012 until December 2023

Note: The figure presents box plots, displaying the median, the interquartile range of the distribution.

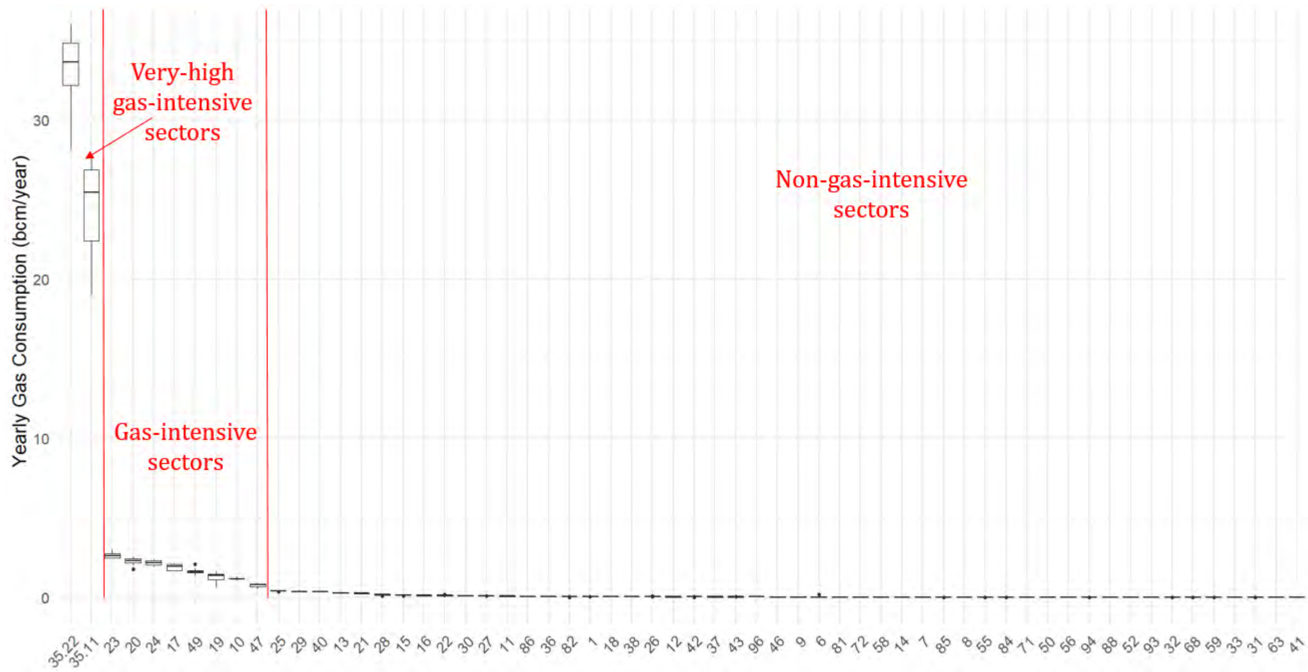
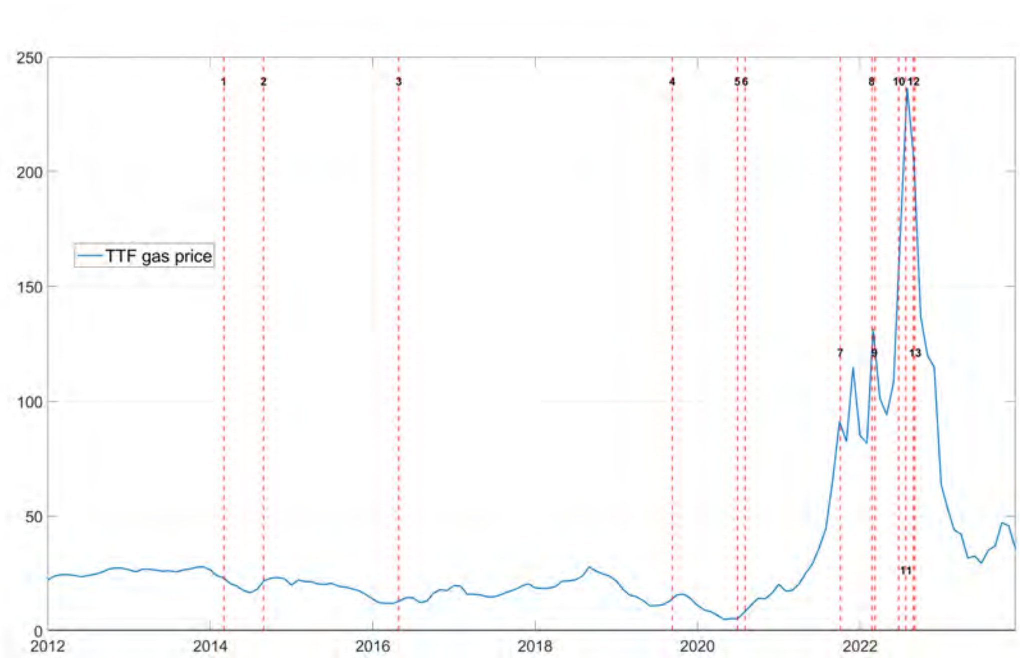


Figure 4: Distribution of Annual gas consumption by Ateco-2 digit. Data from January 2012 until December 2023

Note: The figure presents box plots, displaying the median, the interquartile range of the distribution.

Figure 5: TTF day-ahead futures series and gas supply shock series with notable events for the European gas market taken from Alessandri and Gazzani (2023)

(a) TTF spot price

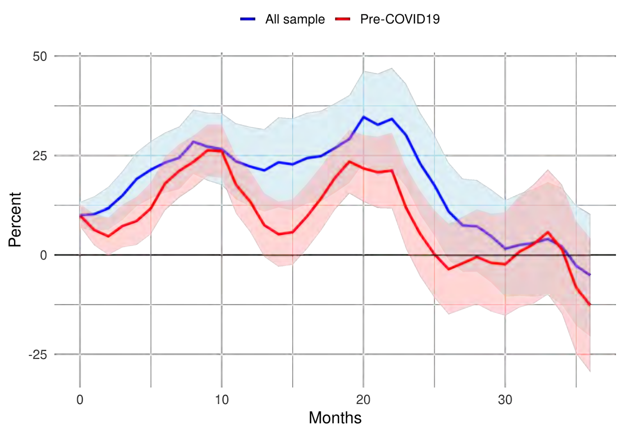


(b) Alessandri and Gazzani, 2023 identifies gas supply shocks

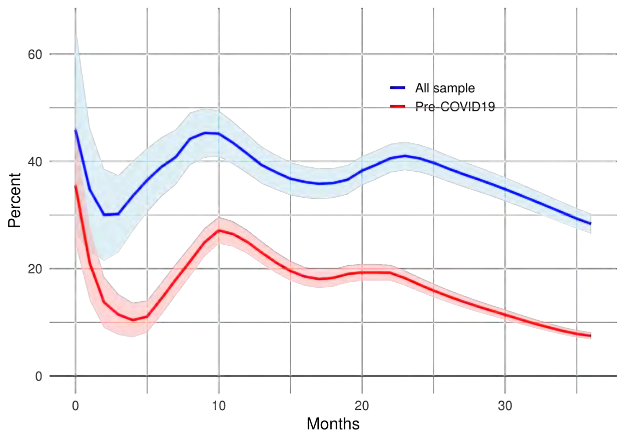
Note: Red vertical refer to a non exhaustive list of notable gas supply shocks identified in Alessandri and Gazzani, 2023: 1) Tensions piling up between Russia and Ukraine; 2) Gazprom accuses Ukraine of stealing gas; 3) Gazprom hopes Nord Stream 2 avoids problems with Brussels faced by predecessor; 4) EU court ruling against Gazprom on Opal Pipeline; 5) US threaten to sanction EU on Nord Stream 2; 6) Tensions between Poland and Gazprom; 7) Putin declaration: "Gazprom will prioritize domestic market"; 8) Russia invades Ukraine; 9) Gazprom books Yamal transit; 10) Nord Stream 1 limited capacity due to turbine stuck in Canada; 11) Nord Stream 1 flows drop to 20% of capacity; 12) Flows to Ukraine increase; Yamal flows regularly; 13) New halt to Nord Stream 1 flows.

Figure 6: Real TTF day-ahead future: Impulse response and forecast error variance decomposition for a real TTF price increase on impact of 10% due to a natural gas supply shock identified in Alessandri and Gazzani, 2023

(a) IRFs



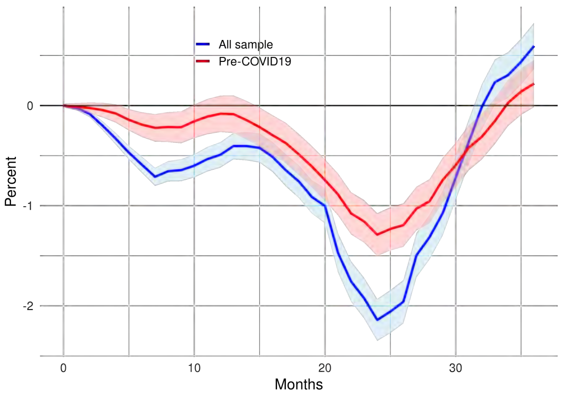
(b) FEVDs



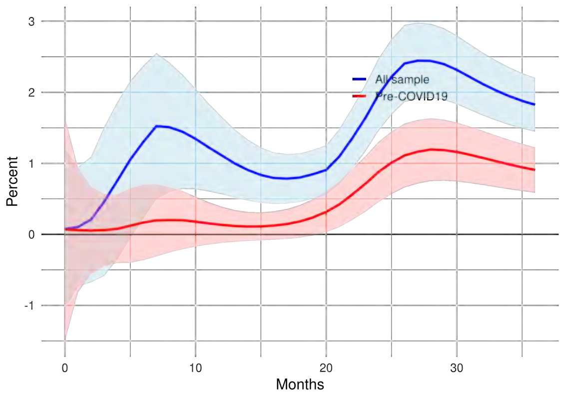
Note: Impulse responses are normalized so that the real TTF price increases by 10% on impact. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands.

Figure 7: Total gas consumption In Italy: Impulse responses, forecast error variance decomposition and cumulative elasticity to a natural gas supply shock that increases the real TTF price by 10% on impact

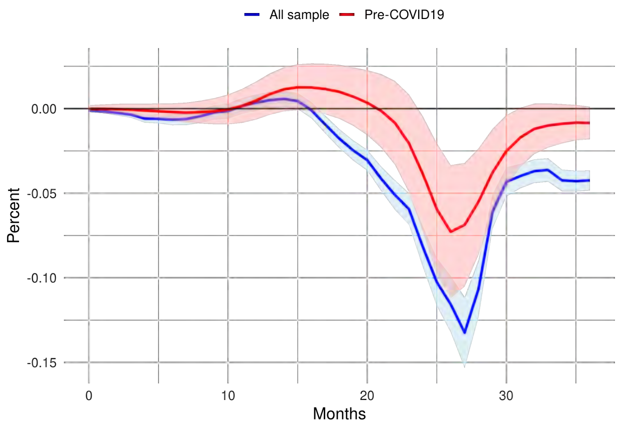
(a) IRFs



(b) FEVDs



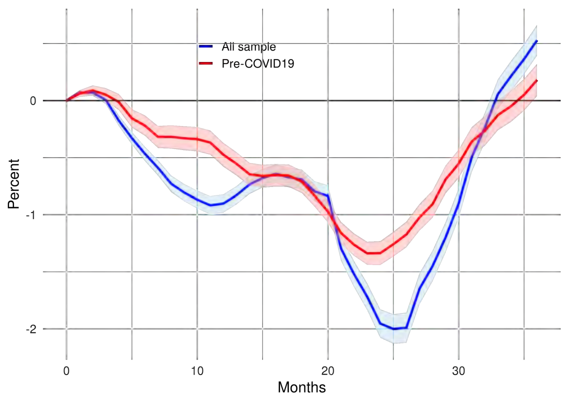
(c) Cumulative elasticity



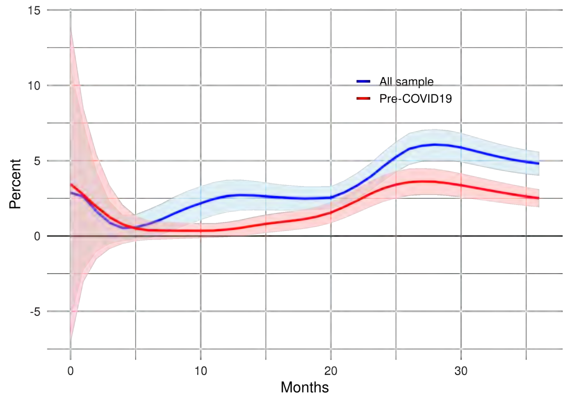
Note: Impulse responses (estimated via OLS) and cumulative elasticities (estimated via panel LP-IV) are normalized so that the real TTF price increases by 10% on impact. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the ATECO-2-digit / province level.

Figure 8: Local Distribution Consumption (LDC): Impulse responses, forecast error variance decomposition and cumulative elasticity to a natural gas supply shock that increases the real TTF price by 10% on impact

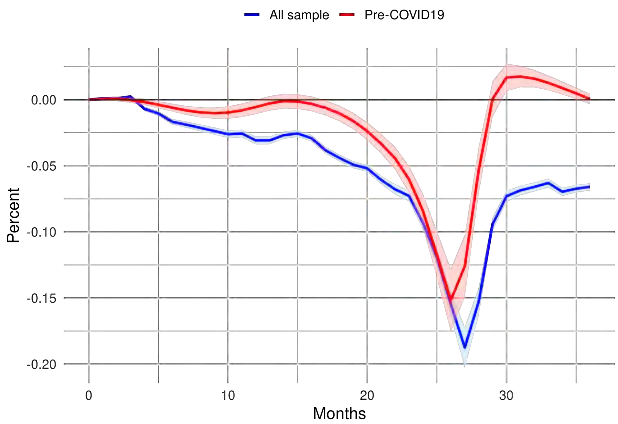
(a) IRFs



(b) FEVDs



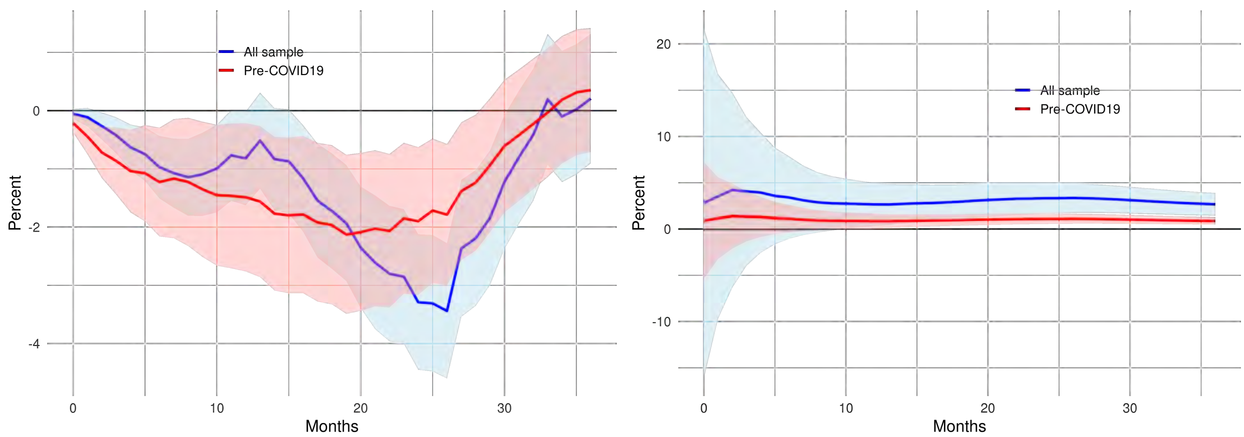
(c) Cumulative elasticity



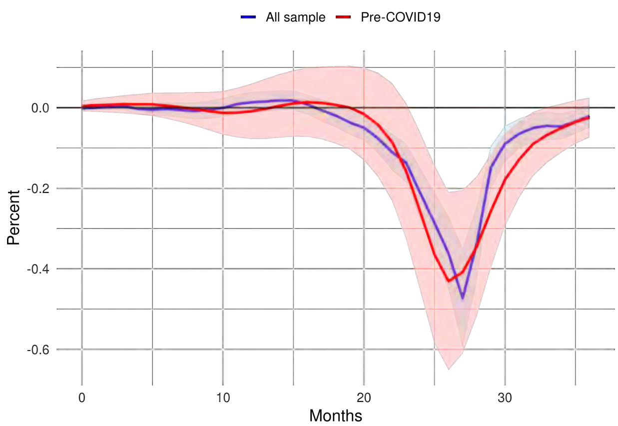
Note: Impulse responses (estimated via OLS) and cumulative elasticities (estimated via panel LP-IV) are normalized so that the real TTF price increases by 10% on impact. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the province level.

Figure 9: Gas consumption for electricity production: Impulse responses, forecast error variance decomposition and cumulative elasticity to a natural gas supply shock that increases the real TTF by 10% on impact

(a) IRFs (b) FEVDs



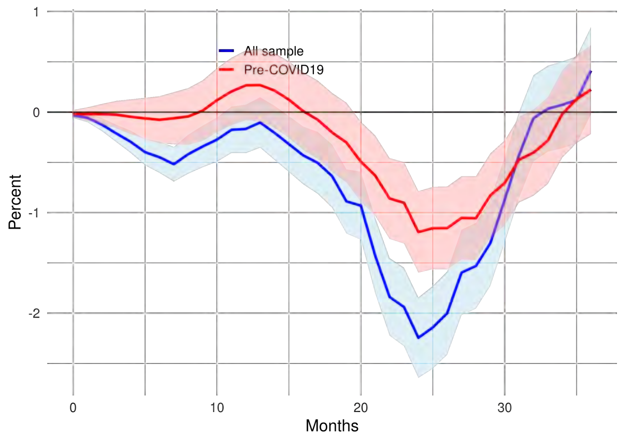
(c) Cumulative elasticity



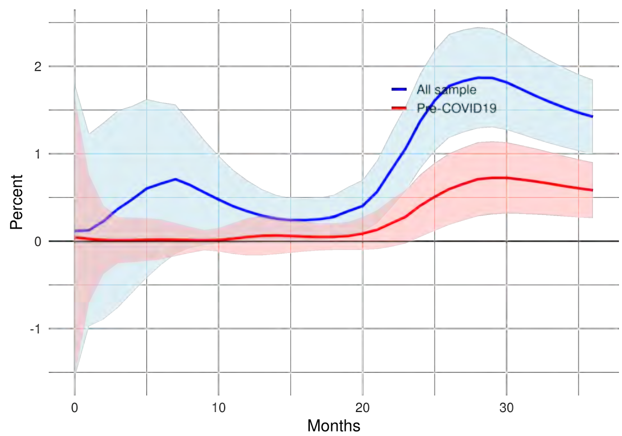
Note: Impulse responses (estimated via OLS) and cumulative elasticities (estimated via panel LP-IV) are normalized so that the real TTF price increases by 10% on impact. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the province level.

Figure 10: Gas-intensive manufacturing sectors gas consumption: Impulse responses, forecast error variance decomposition and cumulative elasticity to a natural gas supply shock that increases the real TTF by 10% on impact

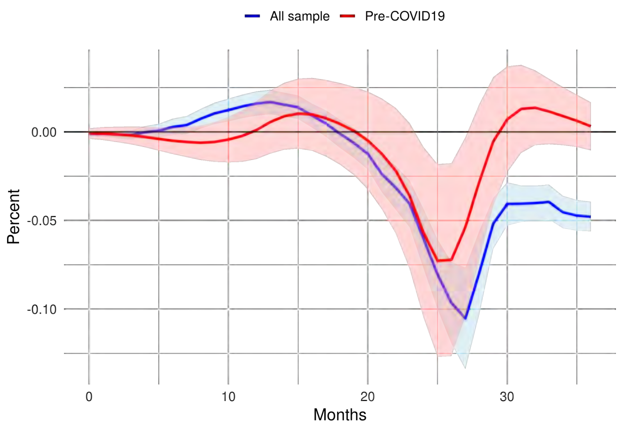
(a) IRFs



(b) FEVDs



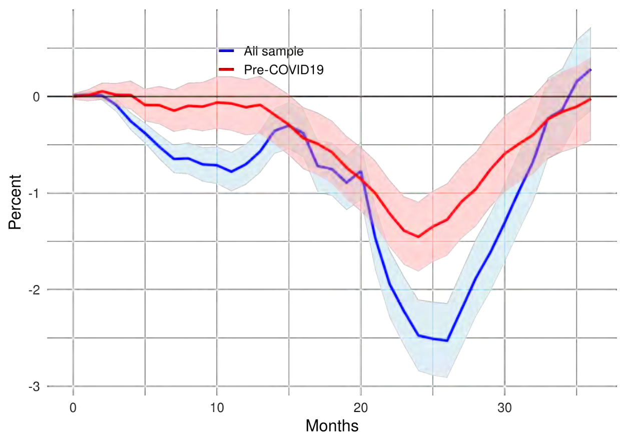
(c) Cumulative elasticity



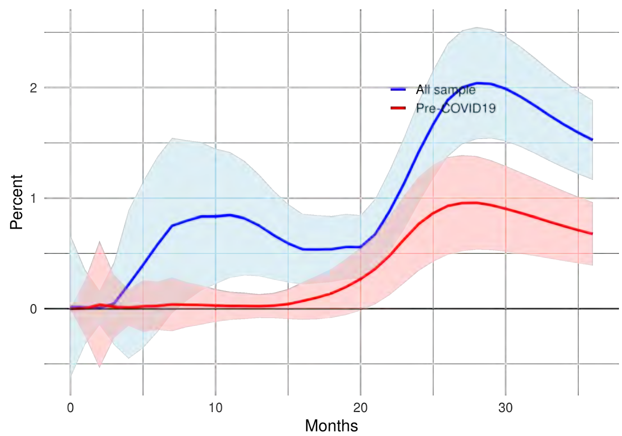
Note: Impulse responses (estimated via OLS) and cumulative elasticities (estimated via panel LP-IV) are normalized so that the real TTF price increases by 10% on impact. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the province / ATECO-2-digit level.

Figure 11: Non-gas-intensive manufacturing sectors gas consumption: Impulse responses, forecast error variance decomposition and cumulative elasticity to a natural gas supply shock that increases the real TTF by 10% on impact

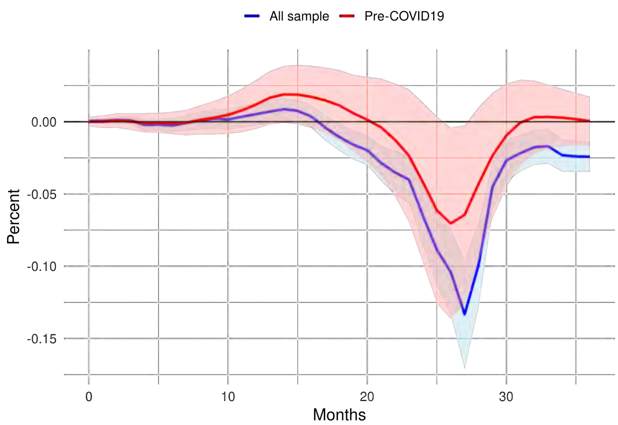
(a) IRFs



(b) FEVDs

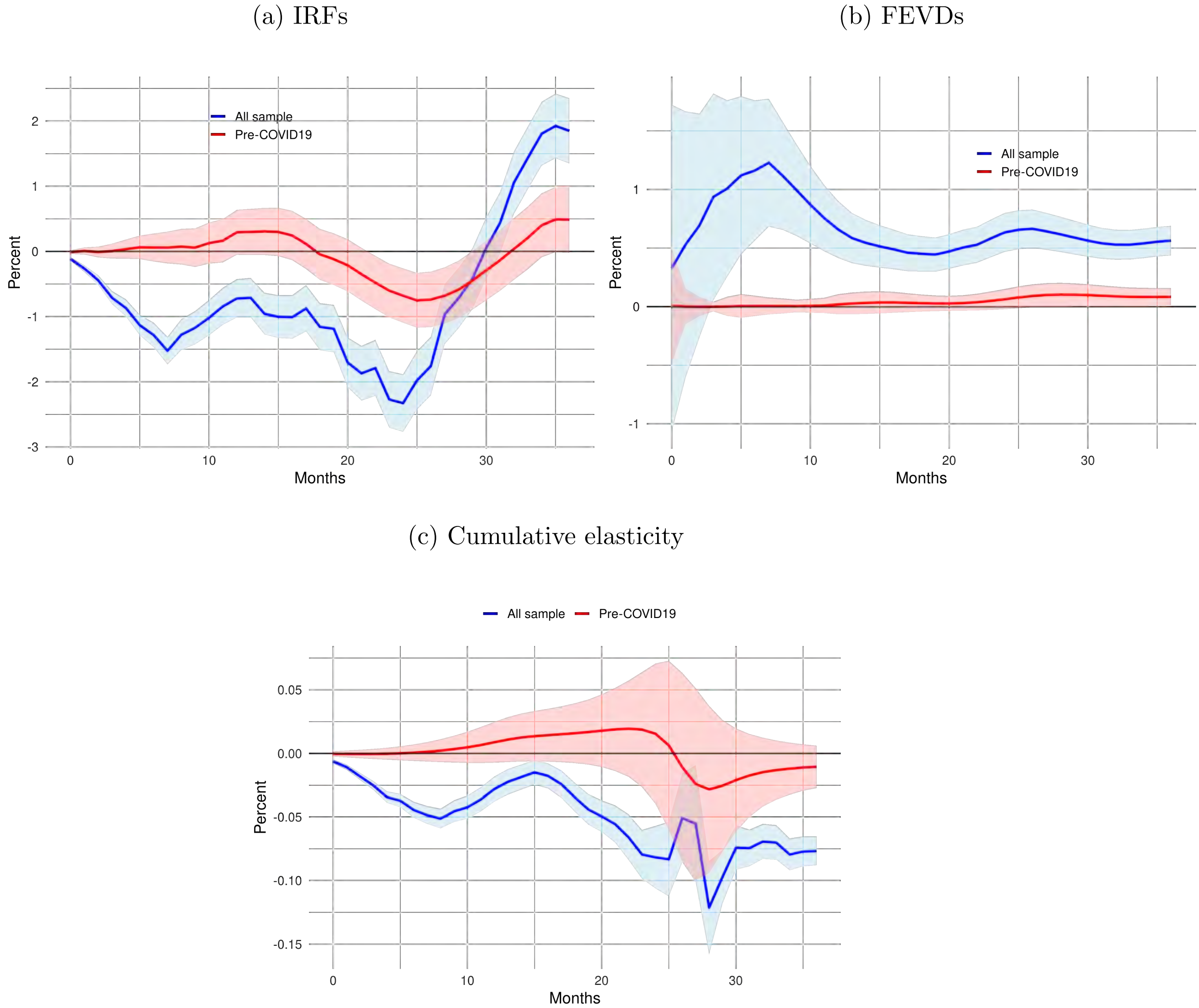


(c) Cumulative elasticity



Note: Impulse responses (estimated via OLS) and cumulative elasticities (estimated via panel LP-IV) are normalized so that the real TTF price increases by 10% on impact. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the province / ATECO-2-digit level.

Figure 12: Services gas consumption: Impulse responses, forecast error variance decomposition and cumulative elasticity to a gas supply shock that increases the real TTF by 10% on impact.



Note: Impulse responses (estimated via OLS) and cumulative elasticities (estimated via panel LP-IV) are normalized so that the real TTF price increases by 10% on impact. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the province / ATECO-2-digit level.

Table 1: ATECO-2 digit summary statistics on annual gas consumption (bcm/year)

ATECO-2digit	Macro sector	Sector name	Mean	Median	Std.Dev.	Min	Max	Obs.	Gas intensity
1	Other sectors	Crop and animal production, hunting, and related services	0.03	0.03	0.01	0.02	0.04	1936	Low
10	Manufacturing	Food industries	1.15	1.15	0.07	1.05	1.26	8860	High
11	Manufacturing	Beverage	0.06	0.06	0	0.05	0.06	2630	Low
12	Manufacturing	Tobacco industry	0.01	0.01	0.01	0	0.02	604	Low
13	Manufacturing	Textile industries	0.26	0.27	0.04	0.2	0.32	4173	Low
14	Manufacturing	Clothing and Leather/Fur	0.01	0.01	0.01	0	0.02	712	Low
15	Manufacturing	Leather and related products	0.13	0.14	0.02	0.08	0.16	2833	Low
16	Manufacturing	Wood and cork industry	0.1	0.11	0.03	0.05	0.14	1529	Low
17	Manufacturing	Paper and paper products	1.88	1.91	0.2	1.63	2.1	6300	High
18	Manufacturing	Printing and reproduction of recorded media	0.02	0.02	0	0.01	0.03	667	Low
19	Manufacturing	Coke and refined petroleum products	1.25	1.36	0.31	0.62	1.64	4705	High
20	Manufacturing	Chemicals	2.22	2.28	0.27	1.73	2.53	7679	High
21	Manufacturing	Basic pharmaceutical products	0.24	0.25	0.02	0.2	0.27	3699	Low
22	Manufacturing	Rubber and plastic products	0.1	0.1	0.01	0.09	0.12	2940	Low
23	Manufacturing	Other non-metallic mineral products	2.62	2.58	0.17	2.41	2.99	10260	High
24	Manufacturing	Metallurgy	2.15	2.14	0.16	1.89	2.36	7881	High
25	Manufacturing	Metal products (ex. machinery and equipment)	0.38	0.39	0.03	0.33	0.42	8121	Low
26	Manufacturing	Computers and oth. medical equipment	0.02	0.02	0.01	0.01	0.05	781	Low
27	Manufacturing	Electrical equipment and non-electrical household appliances	0.06	0.06	0.01	0.05	0.08	3701	Low
28	Manufacturing	Machinery and equipment	0.13	0.14	0.03	0.07	0.17	5043	Low
29	Manufacturing	Motor vehicles, trailers and semi-trailers	0.35	0.36	0.04	0.28	0.41	2769	Low
30	Manufacturing	Other transport equipment	0.07	0.08	0.01	0.06	0.08	2266	Low
32	Manufacturing	Other manufacturing industries	0.01	0.01	0.01	0	0.01	192	Low
35.11	Electricity generation	Electricity Production via gas	24.68	25.44	2.72	18.97	27.61	7817	Very high
35.22	LDC	Housholds and small firms	33.24	33.65	2.41	28.17	35.96	14688	Very high
37	Manufacturing	Sewage Network Management	0.01	0.01	0.00	0.00	0.01	417	Low
38	Manufacturing	Waste, materials recovery	0.03	0.02	0.02	0.01	0.06	1402	Low
42	Manufacturing	Civil Engineering	0.01	0.01	0	0.01	0.01	1315	Low
43	Manufacturing	Specialized construction activities	0.01	0.01	0.00	0.00	0.01	224	Low
46	Services	Wholesale trade (ex motor vehicles and motorcycles)	0.01	0.01	0.00	0.00	0.01	929	Low
47	Services	Retail trade (ex motor vehicles and motorcycles)	0.73	0.78	0.13	0.5	0.87	12972	High
49	Services	Land transport and transport via pipelines	1.62	1.58	0.18	1.37	2.05	2687	High
52	Services	Storage and Support Activities for Transportation	0.01	0.01	0	0.01	0.01	239	Low
55	Services	Accomodation	0.01	0.01	0.00	0.01	0.01	466	Low
56	Services	Restaurant Services Activities	0.01	0.01	0.00	0.01	0.01	329	Low
72	Services	Scientific Research and Development	0.01	0.01	0.00	0.01	0.01	491	Low
81	Services	Services to buildings and landscape activities	0.01	0.01	0.01	0.01	0.04	570	Low
82	Services	Office administrative ; office support and oth.	0.02	0.03	0.01	0.00	0.03	517	Low
84	Services	Public Administration and Defense; Compulsory Social Security	0.01	0.01	0.00	0.00	0.01	336	Low
85	Services	Education	0.01	0.01	0	0	0.01	355	Low
86	Services	Healthcare	0.04	0.04	0	0.03	0.04	576	Low
96	Services	Other personal service activities	0.01	0.01	0	0.01	0.01	990	Low
		Total Italian gas consumption	1.75	0.05	6.22	0.01	35.69	137601	

Note: Descriptive statistics on the ATECO-2 digit annual gas consumption on the cleaned dataset. Annual statistics computed on the January 2012 - December 2023 time span. See also Figure 4.

Table 2: Short-Run Natural Gas Elasticities estimates from the energy literature

Paper	Sample	Data Used	Sector	Short Run Natural Gas Elasticity Estimate and Range
Emiliozzi and Favero (2024)	Total gas consumption and different sectors of the Italian economy	Granular dataset of Italian natural gas consumption at the ATECO-2digit/province level from January 2012 to December 2023	1) Total Italy	Close to zero in the first year; -0.13 at peak after 2 years (-0.07 pre-COVID-19)
			2) LDC	Close to zero in the first year; -0.18 at peak after 2 years (-0.15 pre-COVID-19)
			3) Electricity generation via gas	Close to zero in the first year; -0.18 at peak after 2 years (-0.15 pre-COVID-19)
			4) gas-intensive-sectors in manufacturing	Close to zero in the first year; -0.11 at peak after 2 years (-0.08 pre-COVID-19)
			5) non-gas-intensive-sectors in manufacturing	Close to zero in the first year; -0.13at peak after 2 years (-0.06 pre-COVID-19)
			6) Services	Close to zero in the first year; -0.13at peak after 2 years (-0.08 pre-COVID-19) check
Labandeira *et al.*, 2017	230 studies on natural gas demand from the Dahl Energy Demand Database	Several estimates of short- and long-run natural gas price elasticities	**Several**	-0.18
Rubin and Auffhammer, 2024	Large panel of households in California	Large sample of household natural gas bills	Residential	-0.23 to -0.17
Favero and Grossi, 2023	51,177 end-users in Veneto, Italy	Monthly billing data of natural gas consumption	Residential	-0.23 to -0.51
Rubaszek *et al.*, 2021	U.S. natural gas market	Monthly data on natural gas prices, production, consumption, and inventory levels from January 1993 to June 2020	Macroeconomic	-0.42
Alpino *et al.*, 2024	Italian industrial firms	Survey data on energy expenditures and consumption, administrative data on energy consumption, and EU ETS data.	All Firms	No reaction in the first month of the shock
			All firms	-1.1 in the second half of 2022
			Firms for which gas is essential	-0.5 in the second half of 2022
			Gas-intensive firms	-0.03 in the second half of 2022
Huntington *et al.*, 2019	Macroeconomic responses to energy price shocks	A literature review of 66 studies on the macroeconomic response to energy price shocks, using a variety of different models and assumptions	Macroeconomic	Ranges from -0.05 to -0.38
Ruhnau *et al.*, 2023	German households and industrial consumers	Daily data on natural gas consumption from August 2021 to March 2022	Households and Industry	Implicitly estimated to be negative but no point estimate provided
Asche *et al.*, 2008	Residential natural gas demand in 12 European countries from 1978-2002	Annual data on residential natural gas consumption, prices, and income, as well as a heating degree days index	Residential	Ranges from -0.091 to -0.458
Davis and Muehlegger, 2010	U.S. natural gas sales and prices, 1991–2007	Monthly natural gas sales and prices from the U.S. Department of Energy, Energy Information Administration (EIA), "Natural Gas Navigator."	Residential	-0.28
			Commercial	-0.2
			Industrial	-0.71
			All Customer Classes	
Alberini *et al.*, 2020	Uzhhorod, Ukraine (household-level monthly consumption data from 2013 to 2017)	Monthly natural gas consumption data from households, 2SLS	Residential	-0.16
Trotta *et al.*, 2022	Denmark	Annual price and consumption data from 289 district heating utilities in Denmark from 2015 to 2019, combined with household-level socioeconomic and dwelling characteristics.	Residential DH	-0.53
Faiella and Lavecchia, 2021	Italian Households using a pseudo-panel approach with data 1997-2018	Italian Household Budget Survey (HBS) data from 1997 to 2018 combined with data on energy prices and energy use.	Households	-0.40 (LS) / -0.44 (IV)
Faiella *et al.*, 2022	Italy for the perdiod 1997-2018	Italian Household Budget Survey (HBS) data from 1997 to 2018 combined with data on energy prices and energy use.	Residential Heating	-0.4
			Construction	-0.6
			Agricolture	close to zero
			Industries	-0.2
			Services	less responsive than industries
			All Italian economy	-0.2
Alberini *et al.*, 2011	United States (Residential) 1997-2007	Energy utility data for over 69,000 single-family homes and duplexes in the 50 largest metropolitan areas in the US.	Residential	-0.69 to -0.57

Appendix

A Data sources

A.1 Distribution of regional and sectoral gas consumption

Figure A.1 highlights significant regional and sectoral differences in gas consumption across Italy, driven by industrial specialization. Gas consumption is concentrated in electricity generation and industrial processes, particularly in northern regions like Lombardia, Emilia Romagna, and Piemonte, reflecting their status as industrial and energy hubs.

Local distribution consumption (LDC), representing gas use by households and firms, shows relatively minor regional variation, with Lombardia, Emilia Romagna, and Piemonte having the highest values.

In contrast, *natural gas consumption for electricity generation* exhibits considerable regional variation, again led by Lombardia, Emilia Romagna, and Piemonte, underscoring their central role in Italy's energy production.

The *Industry and Construction* sector also displays regional specialization, with regions such as Lombardia, Emilia Romagna, Piemonte, Toscana and Veneto showing a pronounced reliance on gas for industrial activities since they have a higher concentration of manufacturing and construction industries, which are energy-intensive.

Gas use in *Services* and *Other sectors* is comparatively low and consistent across regions, reflecting the lower energy intensity of service activities, where gas is primarily used for heating rather than production.

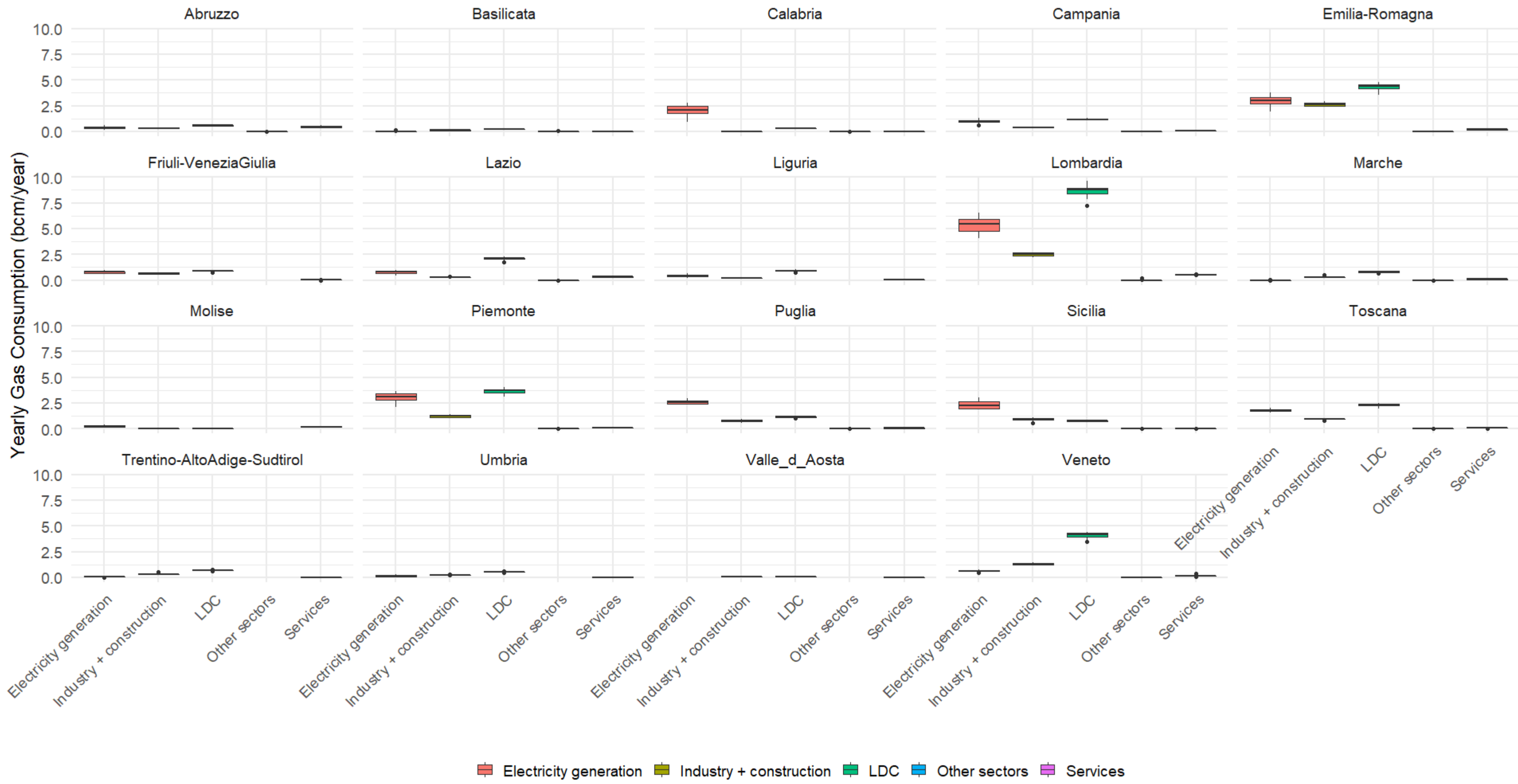


Figure A.1: Distribution of Annual gas consumption by Ateco-2 digit. Data from January 2012 until December 2023

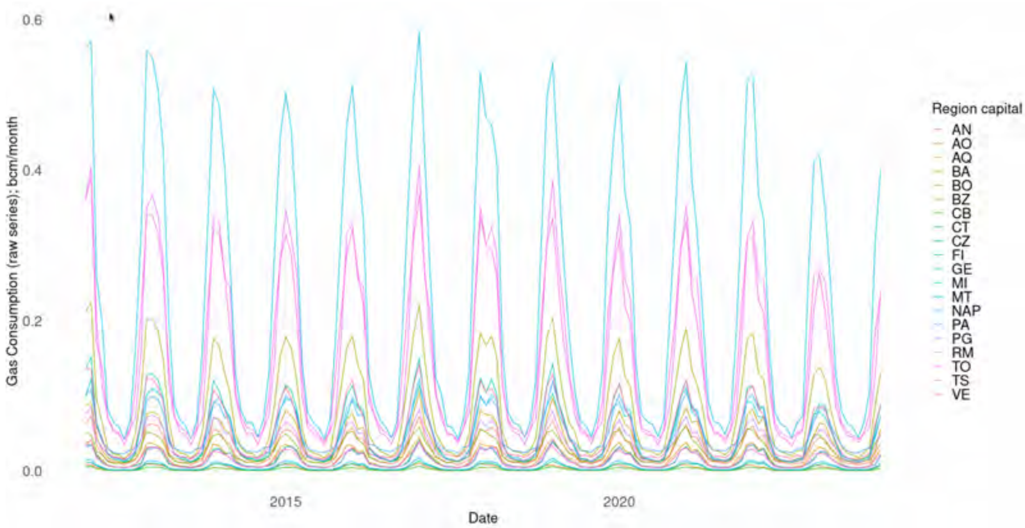
Note: The figure presents box plots, displaying the median, the interquartile range of the distribution.

A.2 Seasonal adjustment, HDD and CDD surprises and Regional electricity consumption

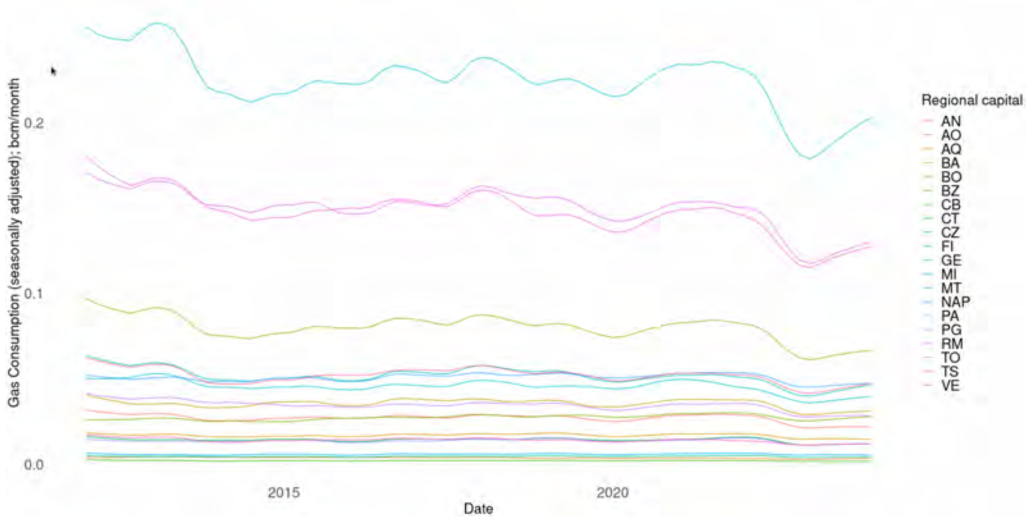
Panel (a) in Figure A.2 shows the raw time series of the Local Distribution Consumption (LDC) in each Italian region capital (data for all provinces are available) from January 2012 till December 2023; panel (b) displays the seasonally adjusted data via TRAMO-SEATS.

Figure A.2: Raw and seasonal adjusted series for Local Distribution Consumption (LDC) in each province

(a) LDC raw gas consumption series



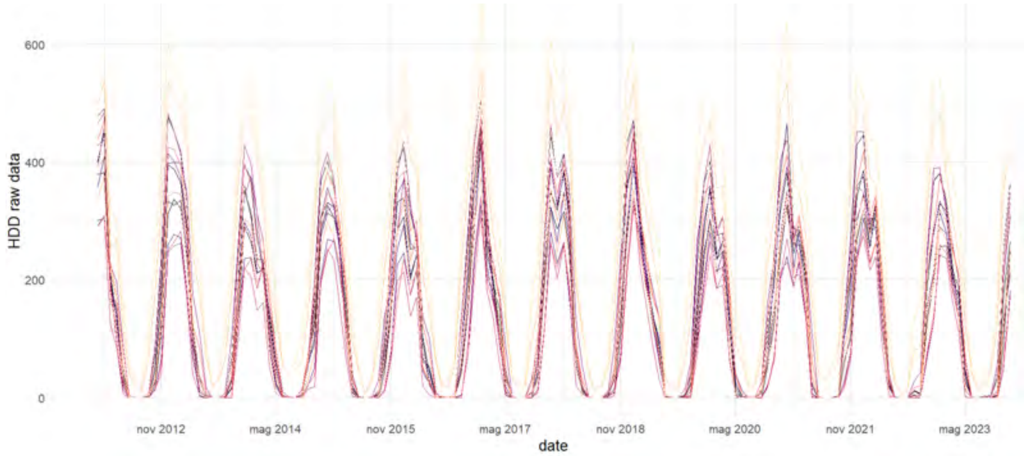
(b) LDC seas. adj. gas consumption series



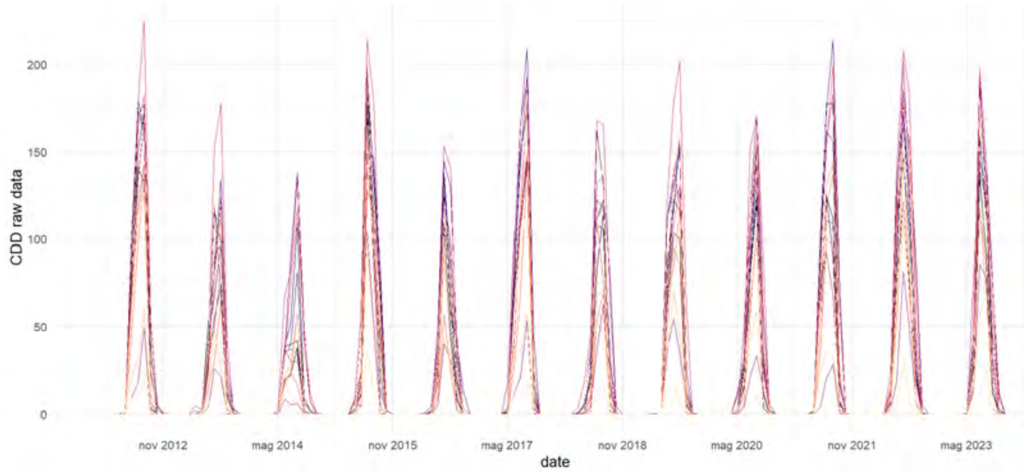
Note: Data span the January 2012 - December 2023 period and are converted in billions cubic meter per month (bcm/month). In the figure only regional capital values are displayed.

Figure A.3: Raw time series on Italian provinces Heating and Cooling degree days (HDD and CDD)

(a) Raw Heating Degree Days (HDD) in Italian provinces



(b) Raw Cooling Degree Days (CDD) in Italian provinces

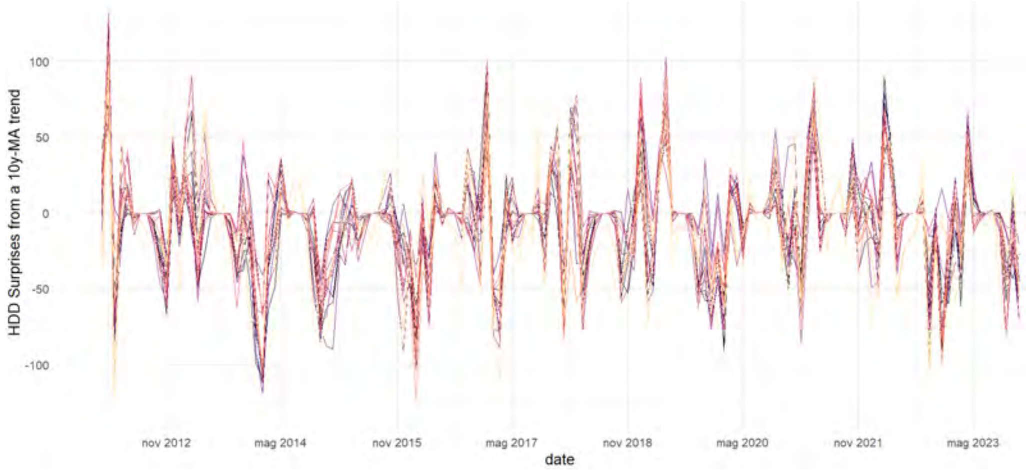


(c) Legend

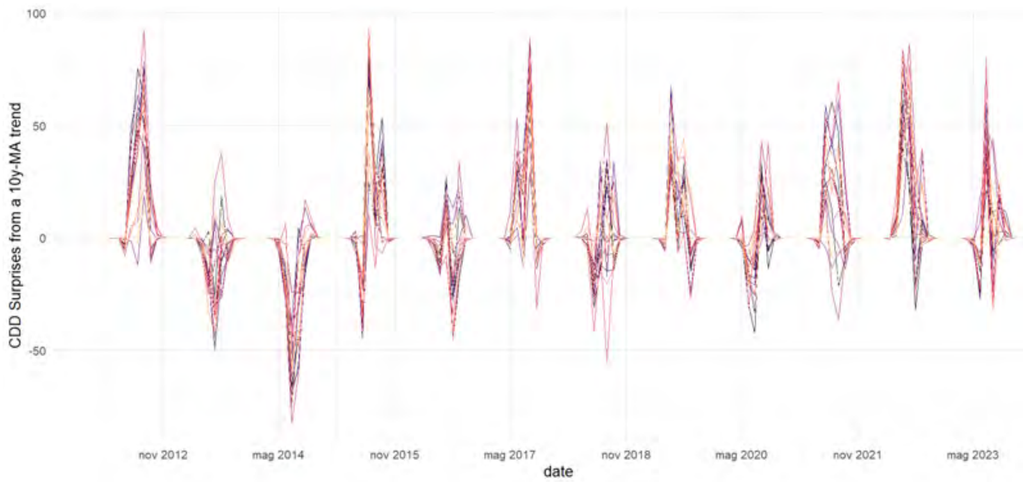
Note: Monthly data spanning the January 2012 - December 2023 period. In the figure only regional capital values are displayed

Figure A.4: Surprise series on Italian provinces Heating and Cooling degree days $HDDSurprise_{jt}$ and $CDDSurprise_{jt}$

(a) Heating Degree Days (HDD) in Italian provinces - Surprises



(b) Cooling Degree Days (CDD) in Italian provinces - Surprises



(c) Legend

Note: Monthly data spanning the January 2012 - December 2023 period. $HDDSurprise_{jt}$ ($CDDSurprise_{jt}$) is computed as the difference between the realized value HDD_{jt} of the heating degree days in province j in month t and a 10-year moving average taken with the past realizations in the same month. In the figure only regional capital values are displayed

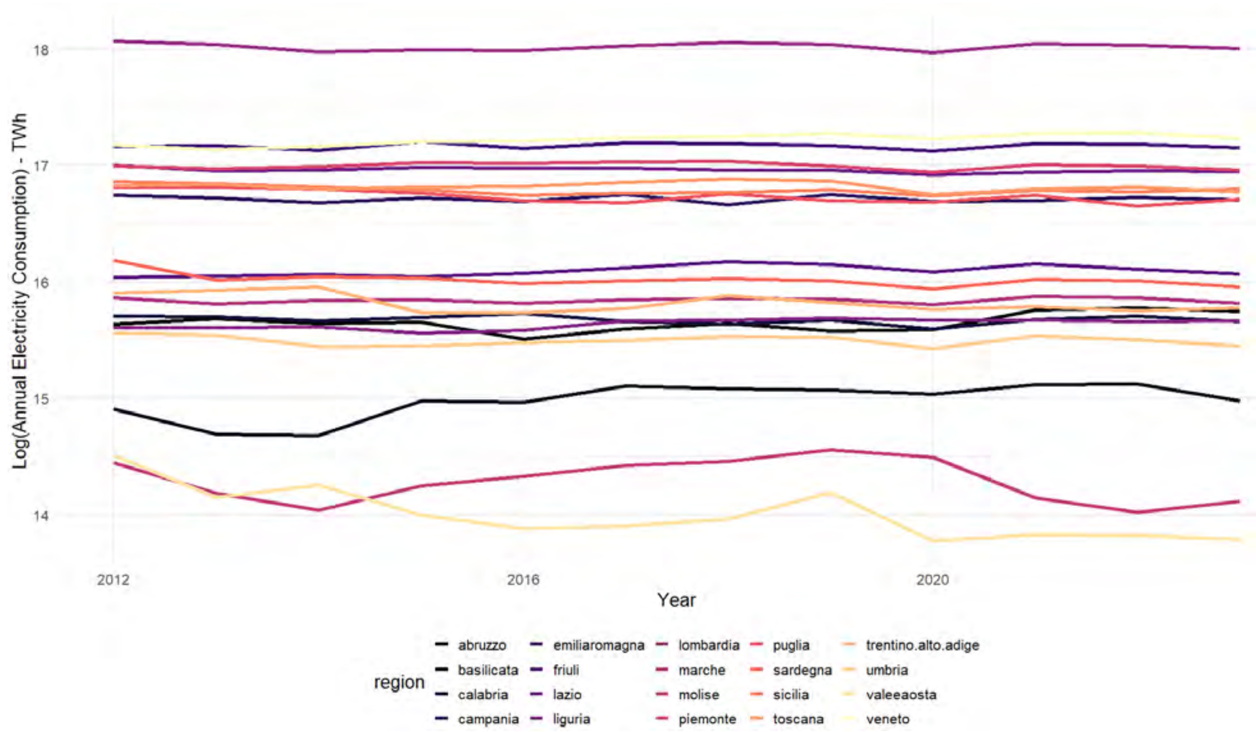


Figure A.5: Italian total annual electricity consumption by region

Note: TWh stands for TeraWatt hours. Data are transformed in logs. The time series span the period 2012 - 2023.

Table 3: Main data sources

Mnemonic	**Description**	**Source**	**Frequency**
$GasCons_{ijt}$	Snam monthly gas consumption for ATECO-2digit i, Province j, and month t	Snam	Monthly
$AGshock_t$	Narrative instrument of natural gas supply disruptions	Alessandri and Gazzani (2023)	Monthly
ETMCS00	TTF - front contract	Refinitiv	Monthly
$ipateco_{it}$	ATECO-2digit industrial production indices for manufacturing	Istat	Monthly
$electricity_{vt}$	Regional electricity consumption in Terawatt hours (TWh)	Terna	Monthly
$HDDSurprise_{jt}$	Heating Degree Days at the provincial level	Eurostat	Monthly
$CDDSurprise_{jt}$	Cooling Degree Days at the provincial level	Eurostat	Monthly
EEXBASE	EU electricity baseload price for the whole day in the EEX market	Refinitiv	Monthly
POWBASE	EU electricity baseload price for the whole day in the Powernext (POW) market	Refinitiv	Monthly
EEXPEAK	EU electricity baseload for peak hours (8:00–20:00) in the EEX market	Refinitiv	Monthly
POWPEAK	EU electricity baseload for peak hours (8:00–20:00) in the POW market	Refinitiv	Monthly

Note: The table contains the major data sources used in the study.

B F-statistic for the cumulative elasticity for Total Natural Gas Demand in Italy

Table 4 presents the Kleibergen-Paap (KP) Wald F-statistic for the first-stage regression (equation (3)) in Subsection 4.2 for the dynamic elasticity of the total natural gas consumption in Italy. For both samples considered in the analysis and each horizon, the Alessandri and Gazzani, 2023 natural gas supply shock is a highly relevant instrument, with the KP Wald F-statistic - that accounts for both heteroskedasticity and clustering of the errors - consistently exceeding the threshold of 10 (J. Stock and Yogo, 2005; Olea and Pflueger, 2013). Similar results are observed across all other analyzed ATECO-2 digit sectors. The complete set of results is available upon request from the authors.

Table 4: Kleibergen-Paap (KP) Wald F-statistic for the first-stage regression in both sampled for the dynamic elasticity for Total Italian gas consumption

Horizon	KP Wald F-stat full sample	KP Wald F-stat pre-COVID-19
0	19649.4	15835.7
1	16319.8	12573.5
2	13358.3	9629.2
3	11753.6	8137.3
4	10359.7	6856.5
5	8903.2	5682.7
6	7822.9	4740.8
7	7064	3998.1
8	6517.2	3412.5
9	6285.8	3035.8
10	5700.2	2647
11	5213.6	2288.7
12	4754.9	2064
13	4397.8	1844.1
14	4085.5	1654.1
15	3927	1445.1
16	3726.2	1273.3
17	3512.4	1135.3
18	3323.7	1028.6
19	3170.9	939
20	3000	855.7
21	2922	763.9
22	3146.8	723.2
23	3564.2	678.4
24	3543	628.6
25	3523.4	587.5
26	3417.9	556.9
27	3421.7	512.5
28	3345.7	479.4
29	3326.3	448.9
30	3238.4	426.9
31	3227.8	402.1
32	3137.9	382.2
33	3115.7	364.3
34	3063.2	339.9
35	2985.2	323.1
36	2946.9	295.9

Note: The KP Wals F-statistics exceeds 10 for all the horizons considered in both sapmles.

C FEVDs standard error computation for panel local projections

Following Gorodnichenko and Lee, 2020 we compute the FEVD standard errors for the panel local projection equation (1) via the Delta-method since the FEVD is a non-linear function of the estimated parameters β_0^h. The delta method provides an asymptotically valid approximation of the variance of a function of a random variable.

Let:

$$g(\beta) = \frac{\sum_{k=0}^{h} \left(\beta_0^h\right)^2 \sigma^2_{AGshock_t}}{\mathrm{Var}(y_{ijt+h})} \tag{6}$$

denote the FEVD as a function of the impulse response coefficients $\beta = (\beta_0^0, \beta_0^1, \ldots, \beta_0^h)$. The standard error of $g(\beta)$ is obtained by linearizing $g(\beta)$ around the point estimates $\hat{\beta}$. Since $\sigma^2_{AGshock_t}$ is equal to one by construction equation 7 simplifies to:

$$g(\beta) = \frac{\sum_{k=0}^{h} \left(\beta_0^h\right)^2}{\mathrm{Var}(y_{ijt+h})} \tag{7}$$

The variance of the FEVD can be approximated as:

$$\mathrm{Var}\left(\mathrm{FEVD}_h\right) \approx \nabla g(\hat{\beta})' \Sigma \nabla g(\hat{\beta}), \tag{8}$$

where $\nabla g(\hat{\beta})$ is the gradient of $g(\beta)$ evaluated at $\hat{\beta}$, and Σ is the variance-covariance matrix of the estimated impulse response coefficients $\hat{\beta}$.

The gradient vector $\nabla g(\beta)$ can be computed as:

$$\frac{\partial \mathrm{FEVD}_h}{\partial \beta_k} = \frac{2\beta_0^h}{\mathrm{Var}(y_{i,j,t+h})}, \quad \text{for } k = 0, 1, \ldots, h. \tag{9}$$

The full expression for the estimated standard error of the FEVD is then:

$$\hat{\sigma}_{\mathrm{FEVD}_h} = \sqrt{\nabla g(\hat{\beta})' \hat{\Sigma} \nabla g(\hat{\beta})}, \tag{10}$$

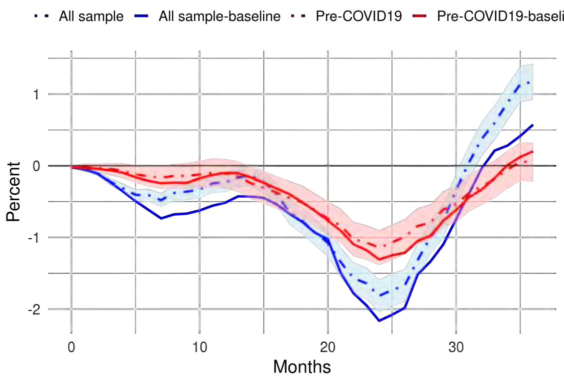
where $\hat{\Sigma}$ is the estimated variance-covariance matrix of the impulse response coefficients $\hat{\beta}$.

D Robustness

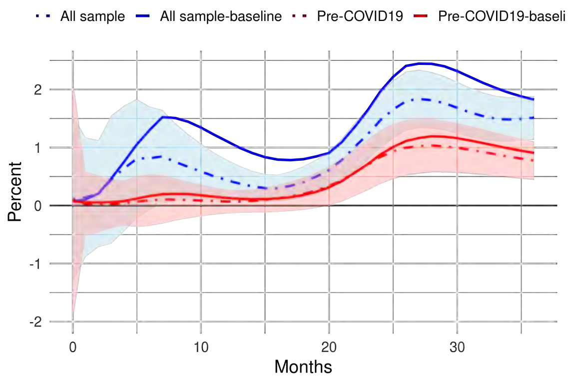
This section of the Appendix reports the robustness results presented in Section 5.

Figure D.1: Total Italian gas consumption. Comparison between the baseline results and the model with 18 lags of the variables

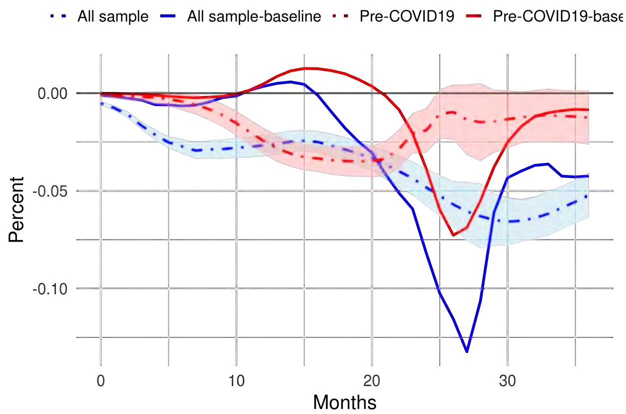
(a) IRFs



(b) FEVDs



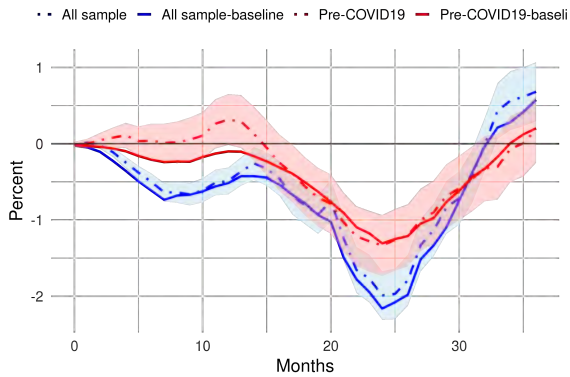
(c) Cumulative elasticity



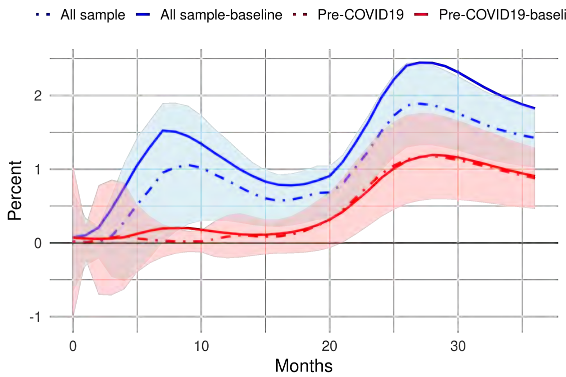
Note: Impulse responses are normalized so that the real TTF increases by 10% on impact. Solid lines represent the baseline results while the dashed-dotted ones refer to the robustness exercise. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the ATECO-2-digit / province level.

Figure D.2: Total Italian gas consumption. Comparison between the baseline results and the model with 12 lags of the European benchmark electricity baseload price (EEXBASE)

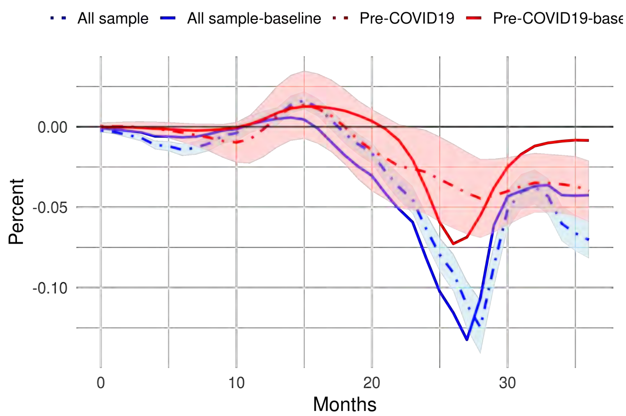
(a) IRFs



(b) FEVDs



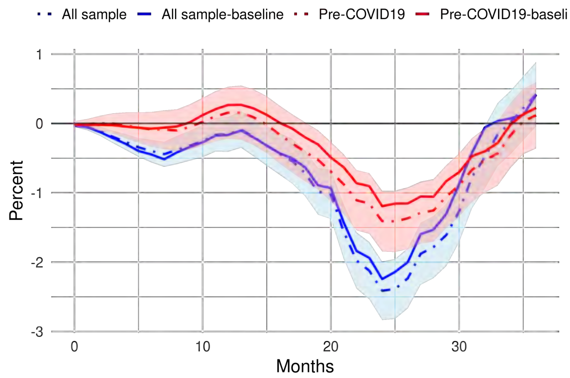
(c) Cumulative elasticity



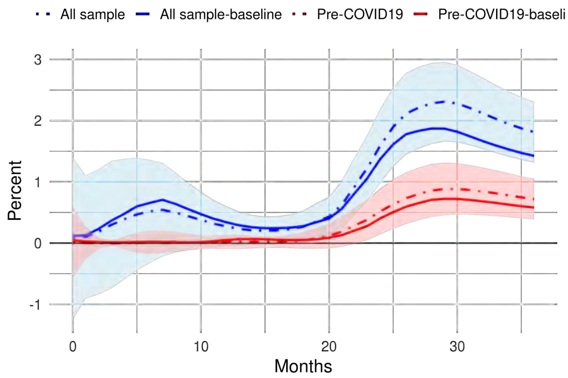
Note: Impulse responses are normalized so that the real TTF increases by 10% on impact. Solid lines represent the baseline results while the dashed-dotted ones refer to the robustness exercise. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the ATECO-2-digit / province level.

Figure D.3: Gas-intensive gas manufacturing sectors. Comparison between baseline results and the model that includes 12 lags of the European benchmark energy prices, the ATECO-2-digit industrial production indices, the regional electricity consumption, and the sectoral level trends

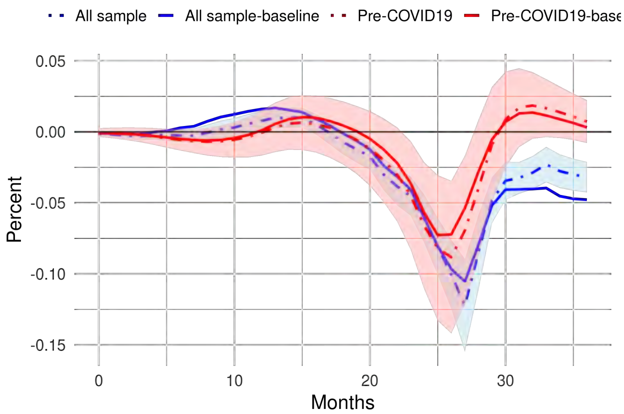
(a) IRFs



(b) FEVDs



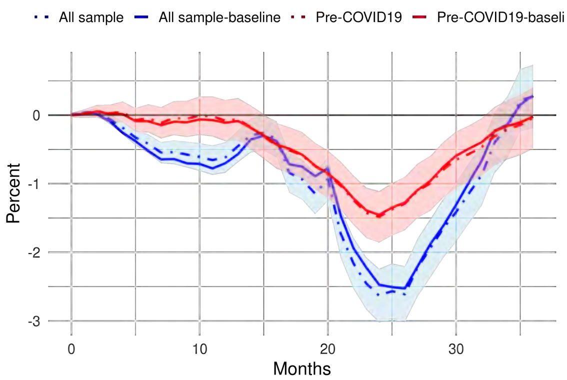
(c) Cumulative elasticity



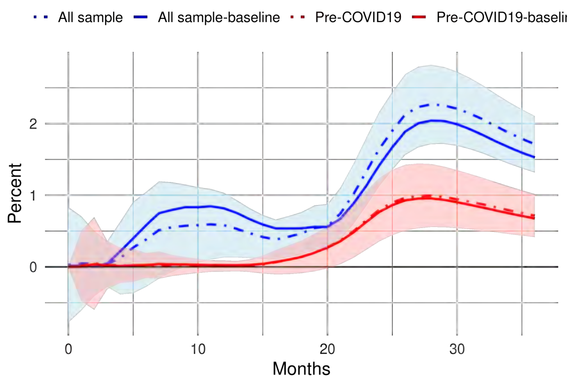
Note: Impulse responses are normalized so that the real TTF increases by 10% on impact. Solid lines represent the baseline results while the dashed-dotted ones refer to the robustness exercise. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the ATECO-2-digit / province level.

Figure D.4: Non-gas-intensive gas manufacturing sectors. Comparison between baseline results and the model that includes 12 lags of the European benchmark energy prices, the ATECO-2-digit industrial production indices, the regional electricity consumption, and the sectoral level trends

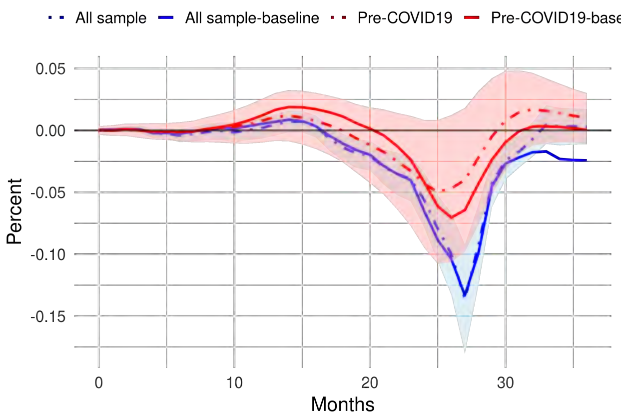
(a) IRFs



(b) FEVDs



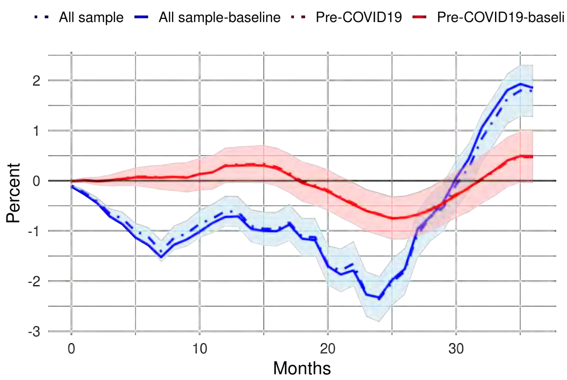
(c) Cumulative elasticity



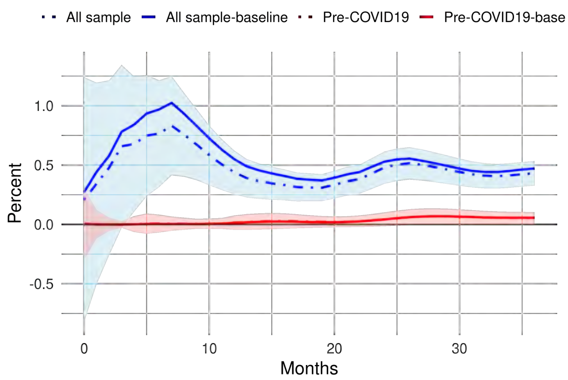
Note: Impulse responses are normalized so that the real TTF increases by 10% on impact. Solid lines represent the baseline results while the dashed-dotted ones refer to the robustness exercise. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the ATECO-2-digit / province level.

Figure D.5: Services. Comparison between baseline results and the model that includes 12 lags of the European benchmark energy prices, the ATECO-2-digit industrial production indices, the regional electricity consumption, and the sectoral level trends

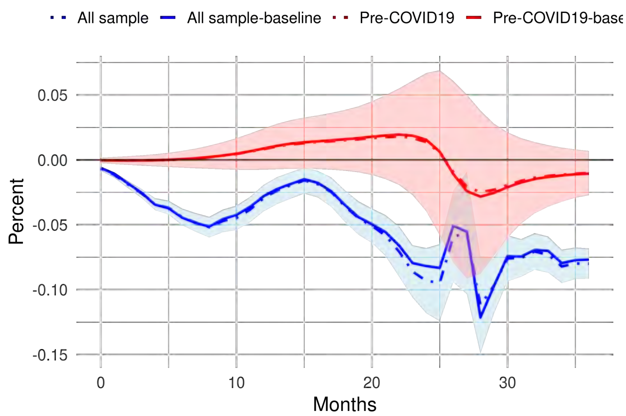
(a) IRFs



(b) FEVDs



(c) Cumulative elasticity



Note: Impulse responses are normalized so that the real TTF increases by 10% on impact. Solid lines represent the baseline results while the dashed-dotted ones refer to the robustness exercise. Estimates for the whole sample ranging from January 2012 to December 2023 are in blue; those for the sub-sample January 2012 - December 2019 are in red. Shaded areas represent 95% confidence bands computed via clustered standard errors at the ATECO-2-digit / province level.

Table 5: List of Italian Provinces in the Snam gas dataset

Region	Province code	Province	Region	Province code	Province
Abruzzo	PE	Pescara	Marche	AP	Ascoli Piceno
	CH	Chieti		MC	Macerata
	AQ	L'Aquila		AN	Ancona
	TE	Teramo		PU	Pesaro-Urbino
Basilicata	PZ	Potenza		FM	Fermo
	MT	Matera	Molise	CB	Campobasso
Calabria	RC	Reggio Calabria		IS	Isernia
	CS	Cosenza	Piemonte	CN	Cuneo
	KR	Crotone		AL	Alessandria
	CZ	Catanzaro		NO	Novara
	VV	Vibo Valentia		TO	Torino
Campania	BN	Benevento		VB	Verbano-Cusio-Ossola
	CE	Caserta		VC	Vercelli
	NAP	Napoli		BI	Biella
	SA	Salerno		AT	Asti
	AV	Avellino	Puglia	TA	Taranto
Emilia Romagna	BO	Bologna		FG	Foggia
	RA	Ravenna		LE	Lecce
	PC	Piacenza		BA	Bari
	MO	Modena		BT	Barletta-Andria-Trani
	PR	Parma		BR	Brindisi
	RE	Reggio Emilia	Sicilia	ME	Messina
	FE	Ferrara		CT	Catania
	FC	Forlì-Cesena		TP	Trapani
	RN	Rimini		RG	Ragusa
Friuli Venezia Giulia	GO	Gorizia		CL	Caltanissetta
	PN	Pordenone		SR	Siracusa
	TS	Trieste		AG	Agrigento
	UD	Udine		PA	Palermo
Lazio	RM	Roma		EN	Enna
	LT	Latina	Toscana	LI	Livorno
	RI	Rieti		FI	Firenze
	VT	Viterbo		PI	Pisa
	FR	Frosinone		LU	Lucca
Liguria	SV	Savona		AR	Arezzo
	GE	Genova		PO	Prato
	IM	Imperia		MS	Massa-Carrara
	SP	La Spezia		PT	Pistoia
Lombardia	PV	Pavia		GR	Grosseto
	CR	Cremona		SI	Siena
	MI	Milano	Trentino-AltoAdige-Sudtirol	BZ	Bolzano/Bozen
	CO	Como		TN	Trento
	LC	Lecco	Umbria	PG	Perugia
	MB	Monza-Brianza		TR	Terni
	VA	Varese	Valle d'Aosta	AO	Valle d'Aosta/Vallée d'Aoste
	BG	Bergamo	Veneto	VR	Verona
	MN	Mantova		VI	Vicenza
	BS	Brescia		RO	Rovigo
	LO	Lodi		TV	Treviso
	SO	Sondrio		VE	Venezia
				PD	Padova
				BL	Belluno

Note: The table contains for each region the provinces that are present in the Snam dataset. Sardegna is not included since there is no gas infrastructure.