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CLIMATE EXTREMES AND INFLATION: EVIDENCE FROM ITALIAN REGIONAL DATA

by Alessandro Mistretta*

Abstract

This paper empirically investigates the impact of climate extremes on inflation, focusing on Italy and providing complementary evidence for the euro area. Using Italian regional data (NUTS2), which better capture the localized nature of climate extremes, it finds that extremely high temperatures generally exert downward pressure on inflation, whereas extremely low temperatures have a pronounced positive effect, mainly driven by energy price dynamics. Extreme precipitation is associated with decreases in energy prices. These findings highlight the need for central banks to incorporate climate-related shocks into their inflation assessments and policy frameworks.

JEL Classification: O1, Q5, R3.

Keywords: inflation, climate change, climate extremes.

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1 Introduction[1]

Climate-related extremes — including floods, droughts, and heatwaves — have become increasingly frequent and severe worldwide, with profound implications for economic systems. Such events can disrupt agricultural production, supply chains, and infrastructure, resulting in substantial economic losses. Their potential impact on inflation has attracted growing attention among central bankers. As Lagarde (2022) emphasized, *"If more and more climate disasters, droughts and famines occur throughout the world, there will be repercussions on prices, on insurance premiums and on the financial sector. We need to take that into account"*.

Climate change impacts inflation through both chronic and acute channels. This analysis focuses on acute effects, mainly associated with extreme weather events — such as heatwaves, floods, and droughts — which cause sudden supply-side disruptions, impairing agricultural output, labor availability, and critical infrastructure. Several studies indicate that these effects are particularly pronounced in low- and middle-income countries, where structural economic vulnerabilities — stemming from a high concentration in climate-sensitive sectors and constrained adaptive capacity — exacerbate exposure to climate-induced disruptions. Demand-side factors are also relevant, though their overall impact remains uncertain. In developed economies, where direct damage is often limited, adverse weather can suppress demand. However, reconstruction activities in the aftermath of climate-related acute events may stimulate demand, in part counterbalancing these effects. Understanding these dynamics is crucial for informing monetary and fiscal policies that account for the adverse economic consequences of climate-related shocks (NGFS, 2024).

In this context, Drudi et al. (2021) investigate the implications of climate change for monetary policy in the euro area. They argue that climate change poses possible challenges to price stability by affecting the structural and cyclical dynamics of the economy and the financial system. These insights have been recently reaffirmed by Nickel et al. (2025) within the ECB's 2025 monetary policy strategy assessment.

Despite the growing literature on the impact of chronically rising temperatures on inflation,

[1] I am extremely grateful to Enrico Bernardini, Pietro Cova, Simone Emiliozzi, Ivan Faiella, Òscar Jordà, Michele Loberto, Patrizio Pagano and Francesco Zollino for their valuable comments. The opinions expressed are those of the author and do not necessarily reflect the views of the Bank of Italy or the Eurosystem. All remaining errors are our mine.

empirical analysis of the effects of climate extremes — i.e., acute climate shocks not solely related to temperature increases — remains limited.

This paper empirically investigates the relationship between climate extremes and inflation, with a particular focus on Italy. To our knowledge, this is the first study to analyze the effects of various types of climate shocks[2] — including extreme *high* and *low temperatures*, *precipitation*, *drought*, *wind*, and *hail* — on different inflation aggregates. Moreover, this work provides estimates for the euro area using monthly data for the 20 countries.

The main findings suggest that *(i)* extremely high temperatures generally can exert a downward effect on overall inflation in Italy, consistent with evidence for the euro area; *(ii)* conversely, extremely low temperatures have a pronounced positive impact; in both cases, energy price dynamics play a pivotal role; *(iii)* extreme precipitation is associated with negative effects on energy prices in Italy, which in turn influence overall inflation; and *(iv)* while overall Italian inflation appears only minimally affected by other climate-related extremes, such events may generate seasonal or item-specific price effects that can nevertheless exert a non-negligible influence.

These findings have important implications. Central banks may need to consider the increasing frequency and intensity of climate-related events in their inflation-targeting frameworks. Moreover, the findings underscore the importance of strengthening adaptation measures to mitigate the economic and financial impacts of climate extremes, particularly for the most vulnerable sectors.

The structure of the paper is as follows. Section 2 reviews the relevant economic literature. Section 3 describes data sources and key variables. Section 4 outlines the econometric strategy, while Section 5 presents the main findings. Finally, Section 6 discusses the implications of the results and offers concluding remarks.

2 Literature review

The growing debate on the economic impact of climate change has spurred a surge in research examining the macroeconomic consequences of climate extremes. Although early studies predominantly focused on the effects of natural disasters on economic activity, usually finding negative impacts, especially in developing countries (see, among others, Noy, 2009; Felbermayr and Gröschl, 2014),

[2]A complete taxonomy of weather-related physical risk events has been provided by IPCC (2023).

a more recent and increasingly prominent strand of the literature explores the relationship between climate and inflation dynamics. Understanding this relationship is crucial for policymakers, particularly central banks, whose primary mandate is to maintain price stability.

Focusing on supply side effects, Beirne et al. (2024) find that extreme storms or floods can destroy crops, damage infrastructure, and disrupt production and supply chains; similarly, temperature anomalies can substantially reduce agricultural yields, with direct consequences for food prices, a key component of consumer price indices (Kim et al., 2025).

Turning to demand-side effects, adverse weather may dampen aggregate expenditure, particularly in developed economies where direct damage is often less severe (Kim et al., 2025; Parker, 2018). On the other hand, reconstruction activities can stimulate demand, partially offsetting these effects. Additionally, fluctuations in energy demand due to temperature variation may influence energy prices and, by extension, overall inflation (Li et al., 2023; Lucidi et al., 2024).

These findings suggest that overall climate extremes can significantly affect price dynamics. Among the various manifestations of climate extremes, temperature shocks have received particular attention in the literature. However, the overall effects of temperature shocks on inflation are highly heterogeneous. Kotz et al. (2023) examine food inflation across 121 countries and find that rising global temperatures are associated with significant increases in food prices, particularly in the Global South, where supply chains are more fragile and food insecurity is widespread. Similarly, Qi et al. (2025) highlight the heterogeneity between advanced and low-income countries, showing that climate change can drive up inflation rates in the short term, though these effects tend to dissipate over the longer term.

Within the euro area, Ciccarelli et al. (2024) document asymmetric impacts of summer temperature shocks across the four largest economies. While countries such as Italy and Spain experience more persistent inflationary pressures, Germany appears less affected. These differences are attributed to underlying structural and climatic factors. Moreover, the study highlights seasonality as an additional and significant source of heterogeneity, emphasizing the importance of accounting for temporal variation when evaluating the inflationary effects of climate-related phenomena. Lucidi et al. (2024), focusing on six European countries, find that warmer-than-average temperature shocks can reduce energy demand, thereby generating mild deflationary pressures.

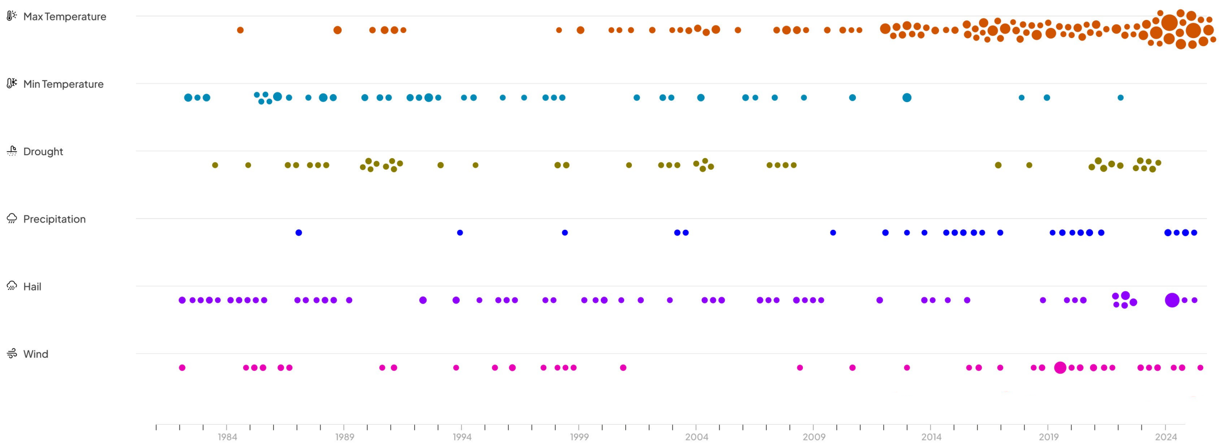
A related body of literature examines the effects of weather-related disasters, defined as discrete extreme events with tangible physical impacts. These studies also point to substantial heterogeneity in outcomes across countries and event types. In advanced economies, inflationary effects tend to be negligible or short-lived, while in developing economies they can persist for several years (Parker, 2018). Using a comprehensive dataset encompassing 151 countries, Ehlers et al. (2025) show that natural disasters are typically followed by a decline in economic output and are often accompanied by an increase in inflation.[3] Focusing on the euro area, Beirne et al. (2024) show that weather-related disasters lead to short-term inflationary spikes driven by supply disruptions and post-disaster reconstruction demand. Although these effects are transitory, they complicate inflation management during periods of elevated climate volatility.

Although weather disasters capture the most immediate and visible impacts of climate variability, recent studies increasingly emphasize the economic relevance of weather extremes beyond catastrophic events. Using the Actuaries Climate Index (ACI), Liao et al. (2024) find that such shocks lead to statistically significant increases in both state- and national-level inflation in the United States, with the effects primarily driven by the tradable sector, which includes agricultural goods. This relationship remains robust even after accounting for nonlinearities across states, with severe impacts in agricultural regions. However, their analysis relies solely on the composite ACI and does not disentangle the contributions of individual event components. Similarly, Kim et al. (2025) also use the same composite index and document a time-varying inflation response that is initially negative in the earlier years of their sample but turns positive in later periods. They show that core CPI, which excludes food and energy, is largely unresponsive to ACI shocks, suggesting that inflationary pressures are primarily driven by volatility in energy and food prices.

Building on this literature, the present study applies a similar index to the Italian (and euro area) context, focusing on the individual components of climate events rather than the composite measure. To our knowledge, this is the first study to analyze the effects of various climate shocks – focusing on extreme *high* and *low temperatures*, *precipitation*, *drought*, *wind*, and *hail* – on different inflation aggregates, employing multiple econometric approaches and varying levels of data granularity.

[3] Cantelmo et al. (2024) propose a theoretical model consistent with these findings.

Figure 1: Extreme Events Climate Index, Italy



Note: This chart reports only the climate extremes (values over 1) recorded in Italy between 1981 and 2025. Each dot represents the impact of extreme events on Italian territory; the larger the dots, the greater the intensity of the anomalies.

3 Data

3.1 Climate extremes indicators

The European Extreme Events Climate Index (E3CI) is an innovative tool designed to monitor, assess, and quantify the impact of climate extremes across European countries (Giugliano et al., 2025).[4] This index provides insights into several key components of climate-induced hazards: extreme maximum and minimum temperatures, heavy precipitation, drought, extreme winds, and hail (Figure 1).[5]

The index tracks extreme *maximum temperatures* to identify anomalies in high-temperature events relative to historical averages. On the other hand, extreme minimum temperatures focus on the frequency and intensity of unusually *low-temperature* events. These temperature-related components are derived from daily maximum (and minimum) temperature observations, with thresholds

[4] Developed by the International Foundation Big Data and Artificial Intelligence for Human Development (IFAB) in collaboration with the Euro-Mediterranean Center on Climate Change (CMCC) and Leithà, the E3CI is based on the corresponding index developed for North America (Actuaries Climate Index, ACI). It integrates data from the ERA5 dataset, a fifth-generation atmospheric reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF).

[5] The E3CI also provides information on wildfires and includes a composite index that captures all extreme meteorological events. However, in this analysis, we focus on the key components of the index. Additionally, we exclude wildfires, as their occurrence is highly correlated with other components. This component measures the frequency and extent of wildfires, which, according to Santos et al. (2024), are primarily the result of other phenomena such as extreme heat, prolonged dry conditions, and strong winds.

established based on the historical top (bottom) 5th percentile.

Heavy *precipitation* events are measured to assess extreme rainfall that exceeds specific thresholds. These events are crucial to understanding the risks of flooding, soil erosion, and challenges in water management. The data for this component are collected and analyzed for both intensity and duration. Complementing this, *drought* conditions are identified by monitoring prolonged periods of below-average precipitation: indicators account for precipitation deficits over time, combined with soil moisture indicators, to provide a comprehensive view of drought risks. The E3CI also evaluates extreme *winds*, focusing on wind speeds that exceed thresholds based on historical trends. High winds disrupt infrastructure, transport systems, and energy networks, resulting in substantial economic and social losses. *Hail* events are another crucial aspect of the index, which tracks occurrences and severity using convective weather models and observational data; hailstorms frequently damage crops, properties, and vehicles, resulting in significant economic losses.

The E3CI components rely on data from ERA5,[6] which are aggregated and standardized to ensure cross-regional comparability. All indicators are normalized, so anomalies are expressed in units of standard deviation, facilitating comparisons across climate variables and geographical regions. Values above 1 indicate anomalies that exceed typical interannual climatic variability and are thus classified as climate extremes. In our analysis, we define the climate shocks as a rescaled version of the raw indices, considering only values greater than one.[7]

The data are reported monthly and are available for all European countries since 1981. Additionally, data are available for Italy at the regional level (NUTS2). The indicators are constructed using a bottom-up approach: they are first estimated locally and then aggregated for various geographical entities.

The analysis of the individual components of the E3CI index reveals a clear trend: from the 2000s to the present, for most exceptional events, the number has been steadily increasing (Figure 1).

Focusing on Italy, compared to previous years, the number of months affected by extreme heat has been increasing (Figure 2a). Between 2020 and 2023 alone, 44% of months experienced extreme

[6]ERA5 provides hourly atmospheric reanalysis data at a resolution of 0.25° x 0.25° globally, covering the period from 1950 to the present, and enabling both historical analysis and real-time monitoring.

[7]In Figure 2, the series is rescaled by setting the value of one in the raw series to zero. Appendix A presents the complete distribution for different shocks. This rescaling, however, results in the loss of the original series standardization.

heat, an increase from 38% recorded between 2010 and 2019. A similar trend is observed for most climate extremes.

Although global warming leads to more frequent and intense heatwaves, it also results in milder winters, with fewer extreme cold events (Figure 2b). Data show a significant decline in the percentage of months impacted by cold waves between 2000-2009 and 2010-2019.

3.2 Price indices

At the euro area level, the Harmonized Index of Consumer Prices (HICP) is a comprehensive measure of inflation. It reflects changes in the prices of goods and services across member states, encompassing various expenditure categories, including food, energy, industrial goods, and services, providing a consistent foundation for cross-country comparisons.[8] To analyze the impact of climate extremes on specific prices, in addition to the HICP, one can focus on selected special aggregates (HICP-SA), such as core inflation, energy, goods, and the index for the first division of the COICOP classification,[9] by using information from all 20 euro area countries.

For the Italian economy, the National Institute of Statistics (ISTAT) complements the HICP with the Consumer Price Index for the Whole Nation (NIC), which measures headline inflation.[10] Like the HICP-SA, the NIC also provides special aggregates for various expenditure categories. Additionally, ISTAT publishes regional NIC data, offering detailed insights into cost-of-living changes across Italy's regions. These regional indices are essential for identifying localized inflationary pressures and understanding the country's economic disparities. Using regional data can enhance the analysis of the impact of climate extremes, which tend to be localized. To include special aggregates consistently across the entire sample, we construct two additional ad hoc measures: the "Super Core" (S-Core) and "Energy-Related Goods and Services" (ER-GS) indices.[11]

[8] The data are available monthly, starting from 1996.

[9] Core inflation is defined as the year-on-year percentage change in the euro area HICP special aggregate "all items excluding energy, food, alcohol, and tobacco"; COICOP01 "food and non-alcoholic beverages".

[10] The NIC measures inflation for the entire economic system, considering the national community as a single, large family of consumers, albeit with diverse spending habits. Monthly NIC data have been available since 1999.

[11] Regional NIC data have been available since 1999 only for headline inflation and COICOP divisions, while special aggregates have been available only since 2010. Since detailed information is available for the entire sample only at the COICOP division level, we propose two measures that aim to approximate the core and energy components of consumption. The first measure, intended to approximate the core component, excludes Food (01), Beverages and Tobacco (02), Housing and Utilities (04), and Transport (07). The second, referred to as the "energy-related" aggregate, includes only Housing and Utilities (04) and Transport (07). Estimates for the core component and energy are available for a shorter period.

Figures 3 and 4 compare different price measures for the Italian case. Specifically, alongside the HICP, we consider the NIC and an aggregated measure derived from a weighted average of the regional NIC indices. As shown, the national NIC and the aggregated regional NIC closely overlap.[12] The differences between the NIC indices and the HICP are negligible and mainly reflect the methodological differences.[13]

4 Empirical strategy

Local projections (LPs), introduced by Jordà (2005), have become widely used tools for estimating the propagation of shocks in macroeconomics (Jordà, 2023; Jordà and Taylor, 2025). LPs provide a flexible and straightforward framework for estimating impulse response functions (IRFs), which are particularly valuable for analyzing the dynamic impacts of shocks over time.

The use of LPs has extended to climate change research, where they have proven instrumental in examining the dynamic causal effects of temperature anomalies on various economic variables, such as consumer prices, producer prices, and production. This body of work highlights the influence of temperature shocks on energy prices and inflation (Lucidi et al., 2024; Faccia et al., 2021). Beyond average temperature changes, LPs have also been applied to analyze the economic impacts of climate extremes, including floods, heavy rainfall, and droughts (Usman et al., 2025). These studies emphasize the suitability of LPs in capturing the disproportionate impacts of such events on inflation and output, given their capacity to model nonlinearities and asymmetries effectively.

The LPs strategy involves directly estimating the effect of an (exogenous) shock on a variable at multiple time horizons after the shock, denoted as $h = 0, \ldots, T$. Our baseline panel LPs model is specified as follows:

$$y_{i,t+h} - y_{i,t-1} = \alpha_i + \beta^h E3CI_{i,t} + \sum_{l=1}^{L} \gamma^h Z_{i,t-l} + \nu_{i,t} + \varepsilon_{i,t+h} \tag{1}$$

where $y_{i,t+h}$ represents the monthly log transformation of our target inflation variable h periods

[12] Except for some differences in the early years of the sample, before 2010, when regional NIC series are not available.

[13] In particular, seasonal factors embedded in the HICP account for most of the divergence. These differences are unlikely to affect analyses that focus on overall inflation trends.

ahead for region i at time t.[14] As discussed in the previous section, the weather shock $E3CI_{i,t}$ is rescaled for all components to isolate the effects of extreme events, with β^h capturing their impact on inflation.

All regressions include monthly regional-level dummies ($\nu_{i,t}$), which account for unobserved heterogeneity and seasonal patterns across regions (NUTS2). The control variables, $Z_{i,t-l}$, incorporate lagged values of the dependent variable and lagged data on the same inflation aggregate for the euro area. These controls capture common euro area trends, including the effects of climate extremes that may influence the entire eurozone.

The model (1) is estimated using 12 lags of the control variables, with horizons of up to 24 periods (months) following the shock. All estimates employ weights corresponding to the aggregation weights[15] used to compute the aggregate Italian figure (*bottom-up* approach). This ensures that the estimated β^h can be interpreted as the average effect on Italian inflation.

An alternative approach is a *Time-series* method, which estimates the LPs model using only Italian aggregate data,[16] without employing the panel structure. While this model uses the same specification and control variables as the other two, it relies exclusively on Italian national-level aggregates.

Following the empirical strategy proposed in model (1), we estimate the impact on euro area inflation. In this specification, we employ country-level data for both inflation aggregates and climate extremes.[17] All estimations are weighted using the aggregation weights underlying the construction of the euro area HICP, ensuring that the estimated coefficients β^h can be interpreted as the average effect on the euro area HICP. As in the baseline specification, we include lagged values of the dependent variable and lagged euro area inflation for the corresponding aggregate as control variables, thereby accounting for common euro area dynamics. Monthly seasonal effects are modeled at the national level.

Following Ciccarelli et al. (2024), we also examine whether the effects of shocks vary by season. To investigate this, we interact the shock variable with four seasonal dummy variables, obtaining

[14] As argued, we analyze not only the effect on overall Italian inflation but also the impact on different inflation aggregates.

[15] Weights are based on the consumption shares of different Italian regions.

[16] In this exercise and in the following, we are using the HICP component instead of the NIC one. As discussed in Section 3, differences are negligible.

[17] The sample includes each country only from the year it officially joined the euro area.

season-specific β^h estimates.[18] Control variables are also interacted with these seasonal dummies for consistency. This seasonal decomposition enables us to capture potential heterogeneity in the effects of shocks that occur at different times of the year.

Confidence intervals are computed using Driscoll and Kraay (1998) standard errors, which are robust to heteroskedasticity and autocorrelation.

5 Results

Results from the *Bottom-up* and *Time-series* approaches are very similar, supporting the robustness of the findings. However, estimates based on NUTS2 data are slightly more conservative. Since climate extremes are local manifestations of global warming, we discuss the results of the *Bottom-up* approach, which uses more granular regional data.[19]

Extreme high temperatures have a negative impact on overall Italian inflation, with headline inflation declining by approximately 1%. The effect tends to disappear toward the end of the horizon (Figure 5). The energy component shows the strongest response, supporting the energy channel suggested by Lucidi et al. (2024) as the main transmission mechanism.[20] Core inflation exhibits a pattern similar to headline inflation, probably due to pass-through effects from the decline in energy prices during heatwaves to other inflation components (Casoli et al., 2024; Corsello and Tagliabracci, 2023; Conflitti and Luciani, 2019). Seasonal heterogeneity supports this interpretation: the reduction is stronger in winter, when heatwaves have a larger impact on energy demand. Seasonality also emerges in other components: extreme temperatures amplify summer conditions while mitigating winter ones, producing corresponding positive and negative effects on food prices (Figure 11).

In the euro area, the pattern is broadly similar but more persistent and quantitatively stronger, with headline inflation declining by about 1.5% after 24 months (Figure C1). Core inflation reacts

[18] As in Ciccarelli et al. (2024), we conventionally define winter (December-February), spring (March-May), summer (June-August) and autumn (September-November).

[19] Italian estimates are based on data from 2000 (from 2012 for special aggregates) while European estimates use data starting from 1997 (from 2000 for special aggregates). Results hold even when choosing a shorter common time span.

[20] Lucidi et al. (2024) show that, on average, warmer temperature shocks elicit a negative energy demand shift, exerting deflationary pressure.

more modestly (up to 0.8%).[21]

Extreme low temperatures have a visible inflationary impact in Italy, where headline inflation increases by up to 0.7%, especially during spring and winter (Figure 11). The effect is primarily driven by energy prices, which display a sharp increase. This heightened sensitivity underscores the vulnerability of the Italian energy sector to cold weather, particularly during the winter months when demand peaks, thereby confirming its pivotal role in transmitting weather shocks to inflation (Lucidi et al., 2024). In the euro area, by contrast, overall inflation remains broadly unaffected (Figure C1). Only core inflation shows a mild negative response, indicating more limited transmission mechanisms at play.

Extreme precipitation shocks have pronounced effects in Italy, where inflation generally declines, mainly due to marked reductions in energy prices. This response plausibly reflects Italy's higher reliance on hydroelectric power, which accounted for over 20% of electricity production in 2024, compared with an EU average of 15%.[22] Seasonal heterogeneity is evident, with rainfall in spring and summer exerting stronger effects than in autumn (Figure 11). At the euro area level, precipitation events exert only a tiny positive short-term impact on inflation (Figure C2). The effect is most visible in food prices, probably reflecting weather-induced disruptions in agricultural production and supply chains.

Drought events in Italy generate heterogeneous responses across components and seasons. Food prices fall during winter but increase in summer. At the same time, energy-related goods and services tend to rise, particularly in winter (Figure B8), likely due to the sensitivity of hydroelectric generation to water availability. In the euro area, the effects are more contained and short-lived (Figure C2), although over time effects tend to become stronger, especially those occurring during winter months.[23]

Hail events in Italy exert negligible overall effects on inflation, though seasonal variation remains notable (Figure 12). In the euro area, by contrast, hail events are associated with negative effects on both headline and core inflation (Figure C3).

[21] Seasonal analysis confirms that the effect is mainly driven by winter energy prices, plausibly due to lower heating demand, while food inflation increases in summer, consistent with Ciccarelli et al. (2024). Results are available upon request.

[22] Over the past eight years, hydropower has accounted for an average of 13% of electricity production in the EU and 16% in Italy.

[23] Cevik and Jalles (2024) report similar findings.

Wind events in Italy are associated with a weak negative impact on inflation (Figure 10). Core inflation and service prices decline, and energy prices also fall, with a marked seasonal variation. These dynamics may reflect the variability of wind power generation in Italy. In the euro area, wind events instead produce a slightly positive effect on headline inflation. Core inflation and service prices again decline, though the magnitude is roughly double that observed in Italy. Energy prices increase somewhat, underscoring a divergent pattern compared with the Italian case (Figure C3).

6 Conclusion

This paper investigates the relationship between climate extremes and inflation, focusing on Italy and offering complementary evidence for the euro area.

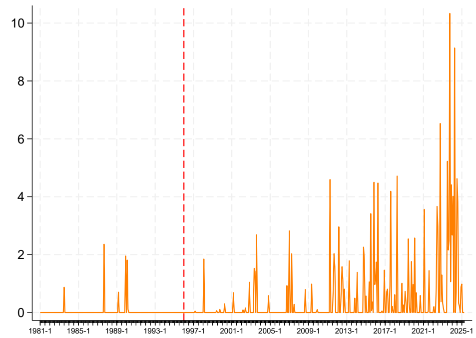
The main findings reveal that extremely high temperatures have a negative impact on overall inflation in Italy, consistent with evidence for the euro area, primarily driven by dynamics in energy prices. This likely reflects reduced energy demand during heatwaves. Seasonally, these temperatures amplify summer conditions and mitigate winter ones, which in turn affects food prices accordingly. Conversely, extremely low temperatures have a pronounced positive impact on Italian inflation, especially during spring and winter, with energy prices playing a pivotal role due to the vulnerability of the Italian energy sector to cold weather. The euro area, however, remains largely unaffected by extremely low temperatures. Extreme precipitation is associated with negative effects on energy prices in Italy, which in turn influence overall inflation. This response plausibly reflects Italy's higher reliance on hydroelectric power. In the euro area, precipitation events have a small, positive short-term effect on inflation, primarily through their impact on food prices resulting from agricultural disruptions. Drought events in Italy exhibit heterogeneous responses, resulting in food prices decreasing in winter but increasing in summer, while energy-related goods and services tend to rise, particularly in winter. Effects are more contained in the euro area. Other climate extremes, such as hail and wind, have minimal or negligible effects on overall Italian inflation, though seasonal variations are notable. In contrast, hail events are associated with negative effects on headline and core inflation in the euro area, and wind events produce a slightly positive impact on euro area headline inflation, differing from the Italian case.

These findings carry potential implications for monetary policy. Although the direct effects of climate extremes on inflation may be transitory, as noted by Angeli et al. (2022) and Nickel et al. (2025), the rising frequency and intensity of extreme weather events could generate more persistent inflationary pressures if such trends continue. This is particularly relevant in the energy sector, where extremely high temperatures may affect prices by reducing demand for heating while increasing demand for cooling. Conversely, heavy precipitation or droughts may affect energy supply through their impact on hydropower generation. In both cases, the central role of energy in the economy implies that such disruptions could generate significant spillover effects on other prices.

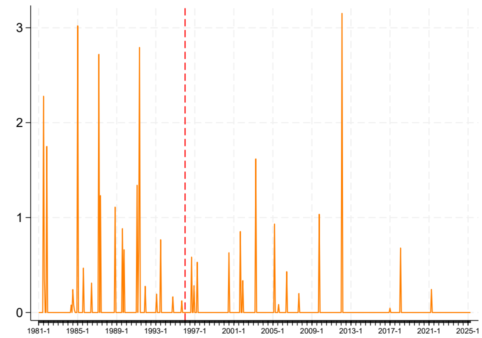
Furthermore, climate change represents a potential source of more frequent and severe shocks, which could amplify inflation volatility and increase heterogeneity across the eurozone. As pointed out by Ciccarelli et al. (2024), this provides an additional motivation to incorporate climate factors into monetary policy assessments. Close monitoring of the localized impacts of extreme climate events may be particularly relevant in the context of a monetary union.

The evidence presented in this work suggests that central banks should account for the growing incidence and intensity of climate-related events within their inflation frameworks. In particular, the results highlight the benefits of integrating climate variables into inflation modeling and macroeconomic forecasting. Moreover, scholars increasingly call for interdisciplinary approaches that address broader environmental risks (Boneva and Ferrucci, 2022; European Commission, 2024).

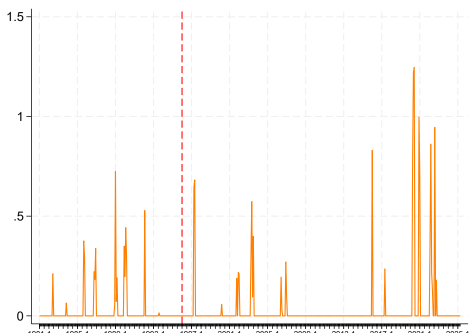
Figure 2: climate extremes, Italy



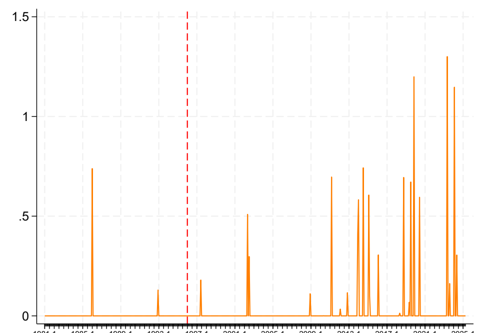
(a) Extreme maximum temperature



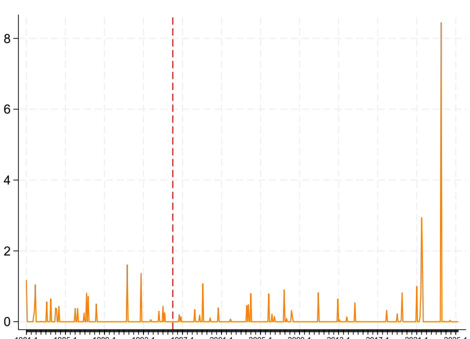
(b) Extreme min temperature



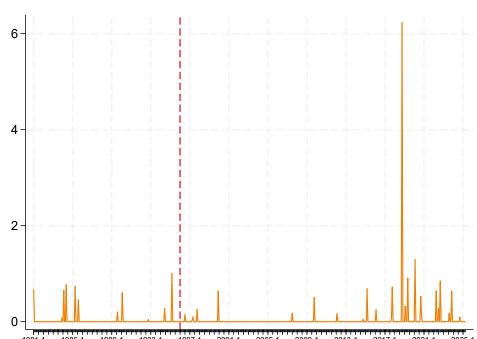
(c) Extreme drought



(d) Extreme precipitation



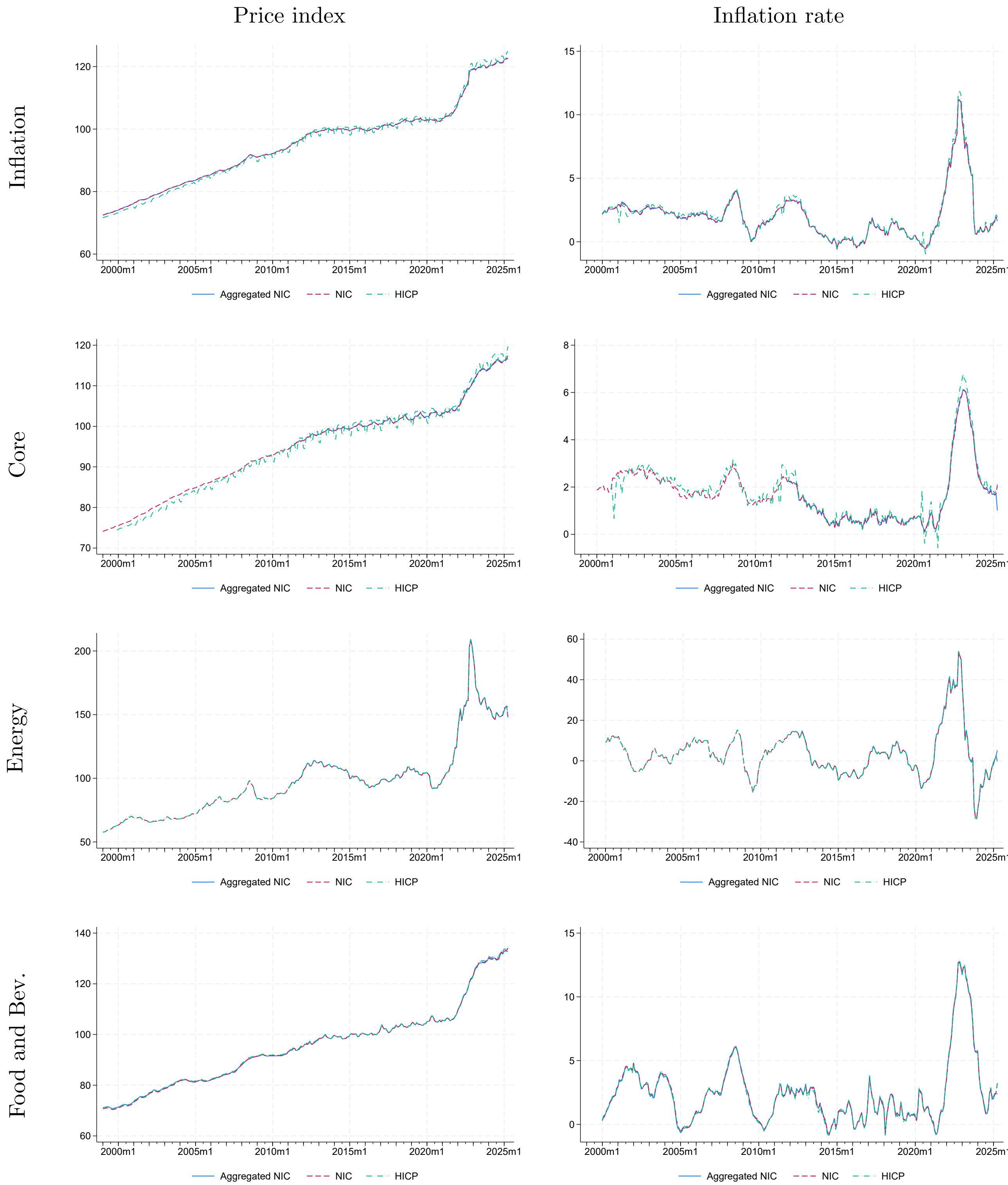
(e) Hailstorms



(f) Extreme wind

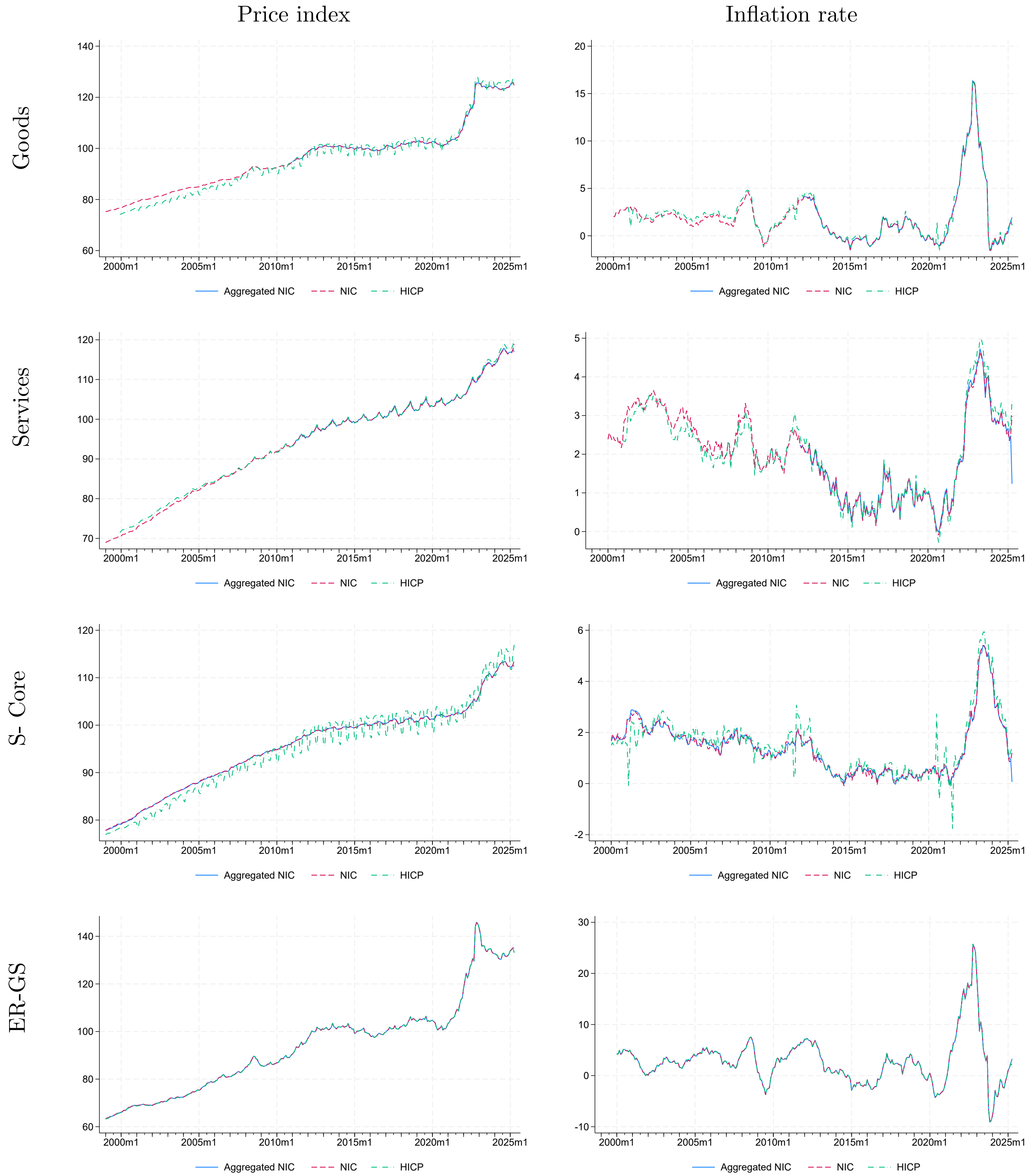
Note: For all indicators, only values exceeding the threshold of 1 — used to define extreme events — are considered, with the threshold itself normalized to zero.

Figure 3: Italian inflation indices



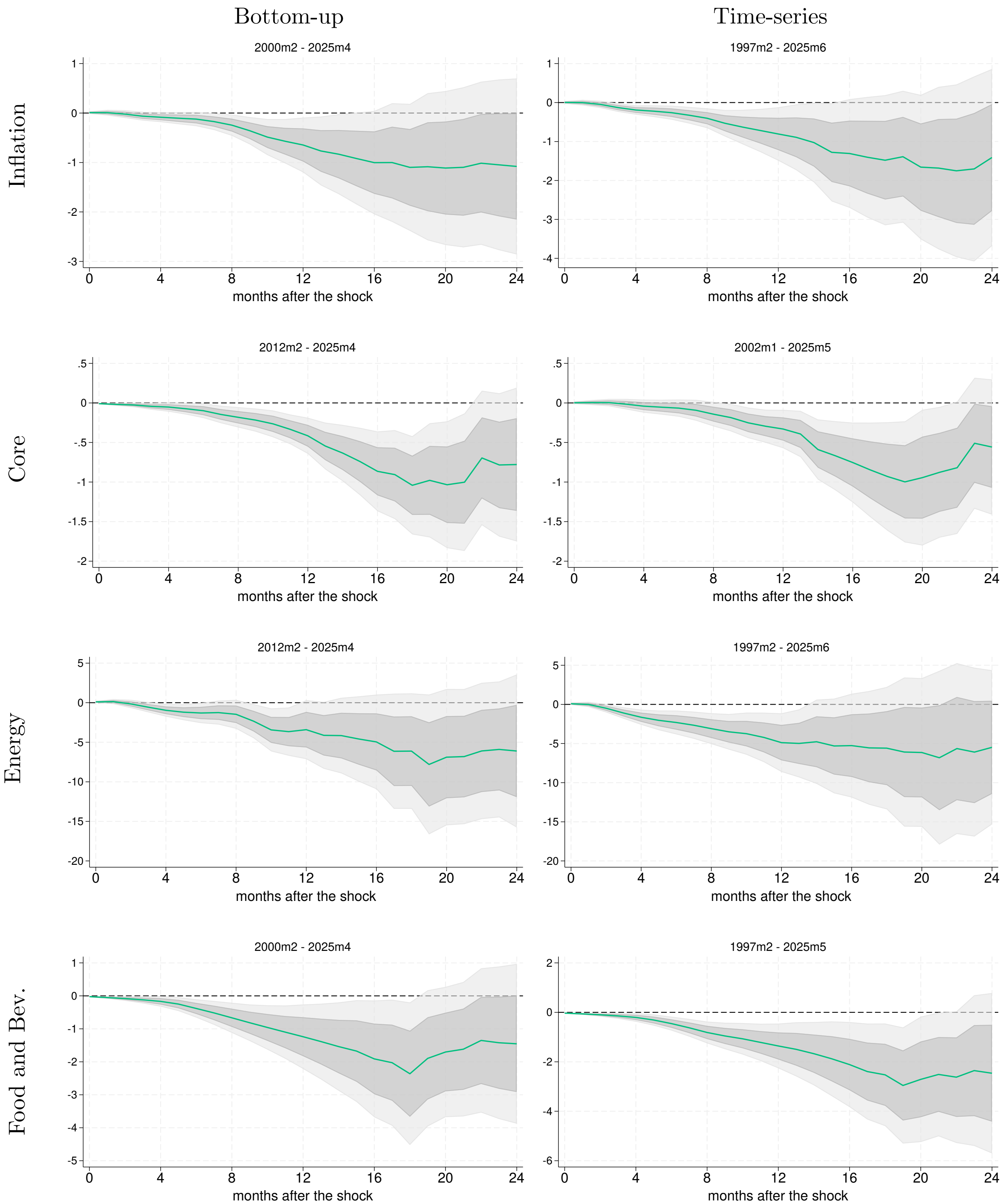
Note: The aggregate NIC is calculated as a weighted average of regional NIC values. The inflation rate is measured as the year-on-year logarithmic difference of the price index.

Figure 4: Italian inflation indices



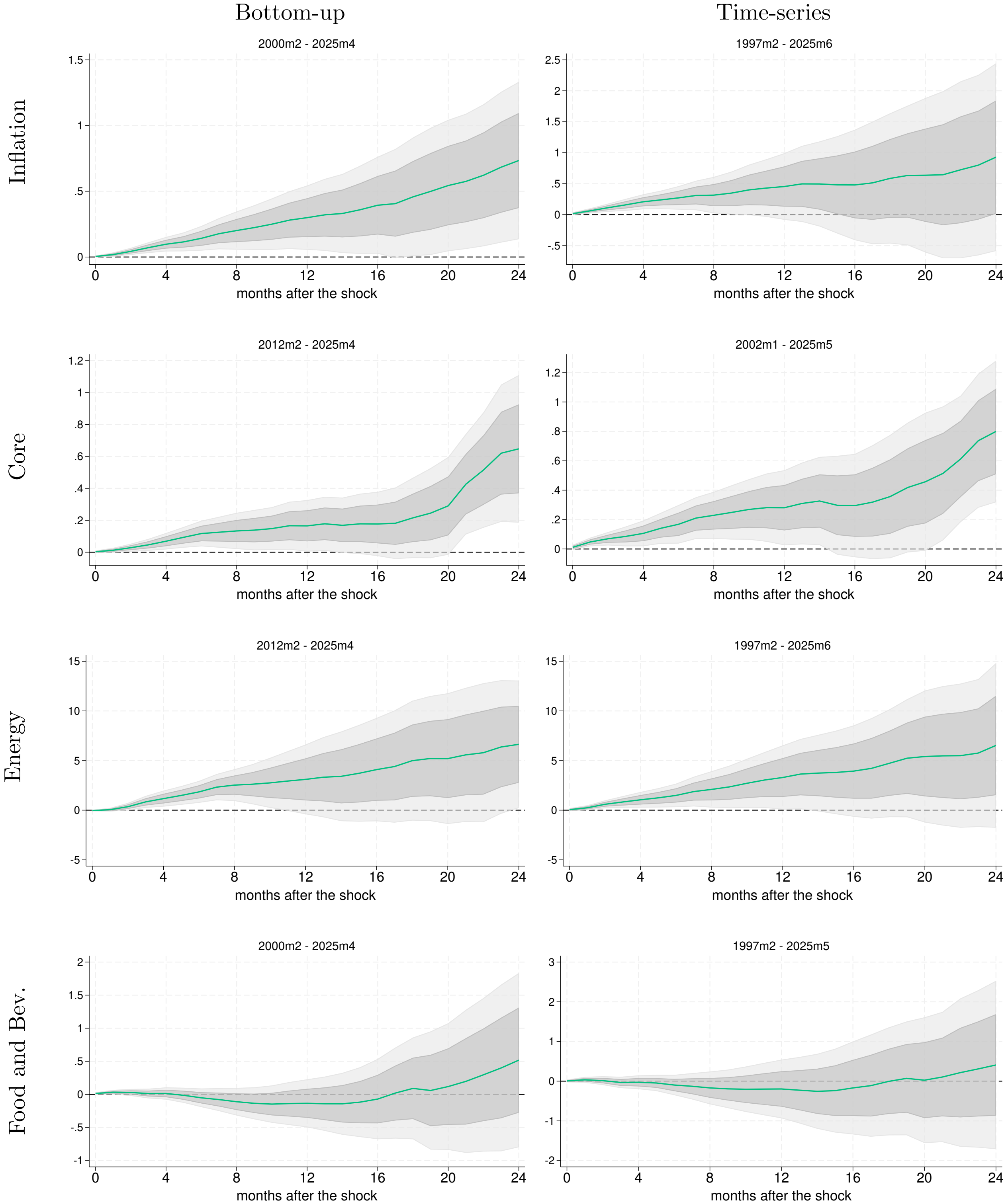
Note: The aggregate NIC is calculated as a weighted average of regional NIC values. The inflation rate is measured as the year-on-year logarithmic difference of the price index.

Figure 5: Effects on Italian inflation, extreme high temperature



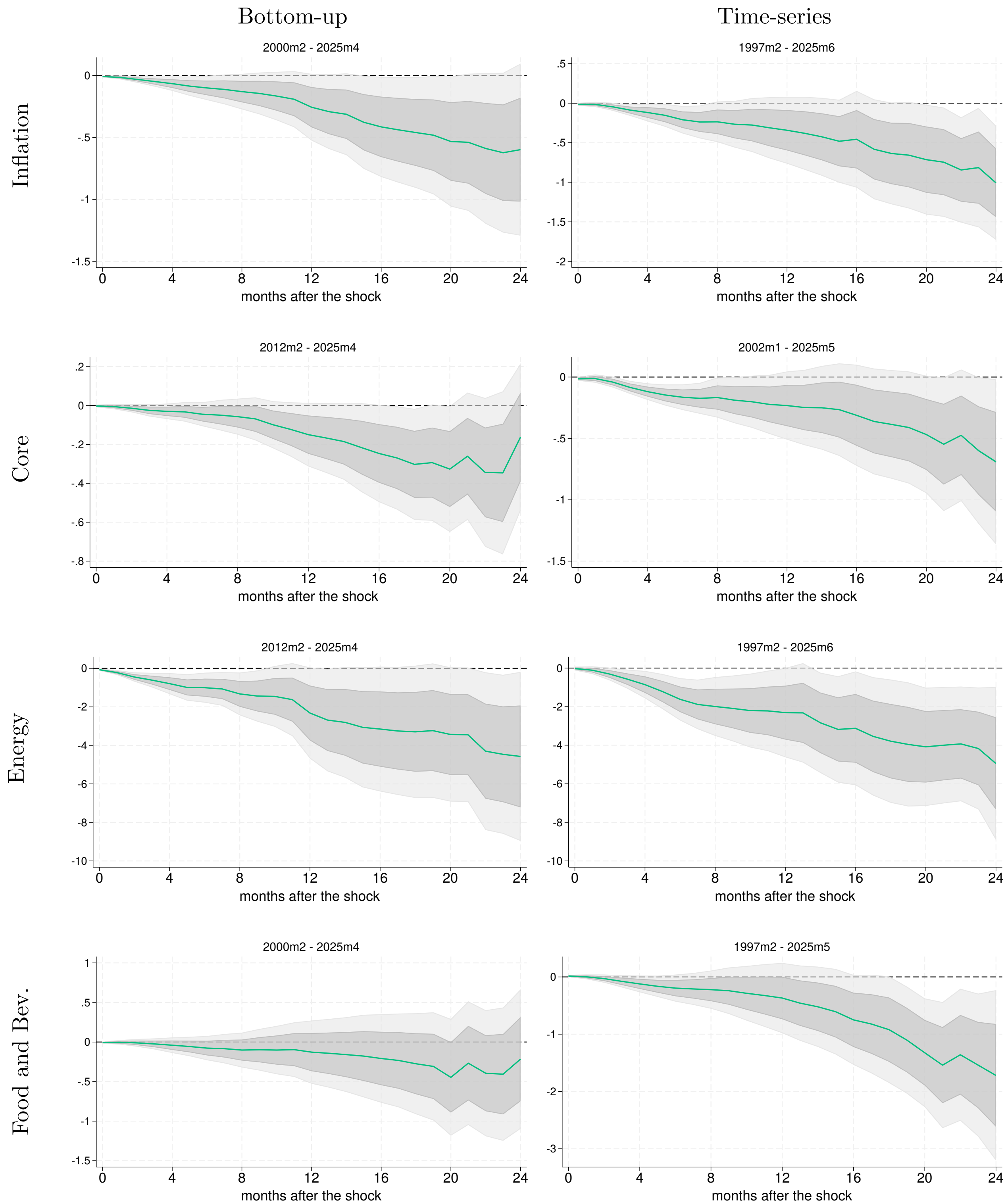
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure 6: Effects on inflation Italian, extreme low temperature



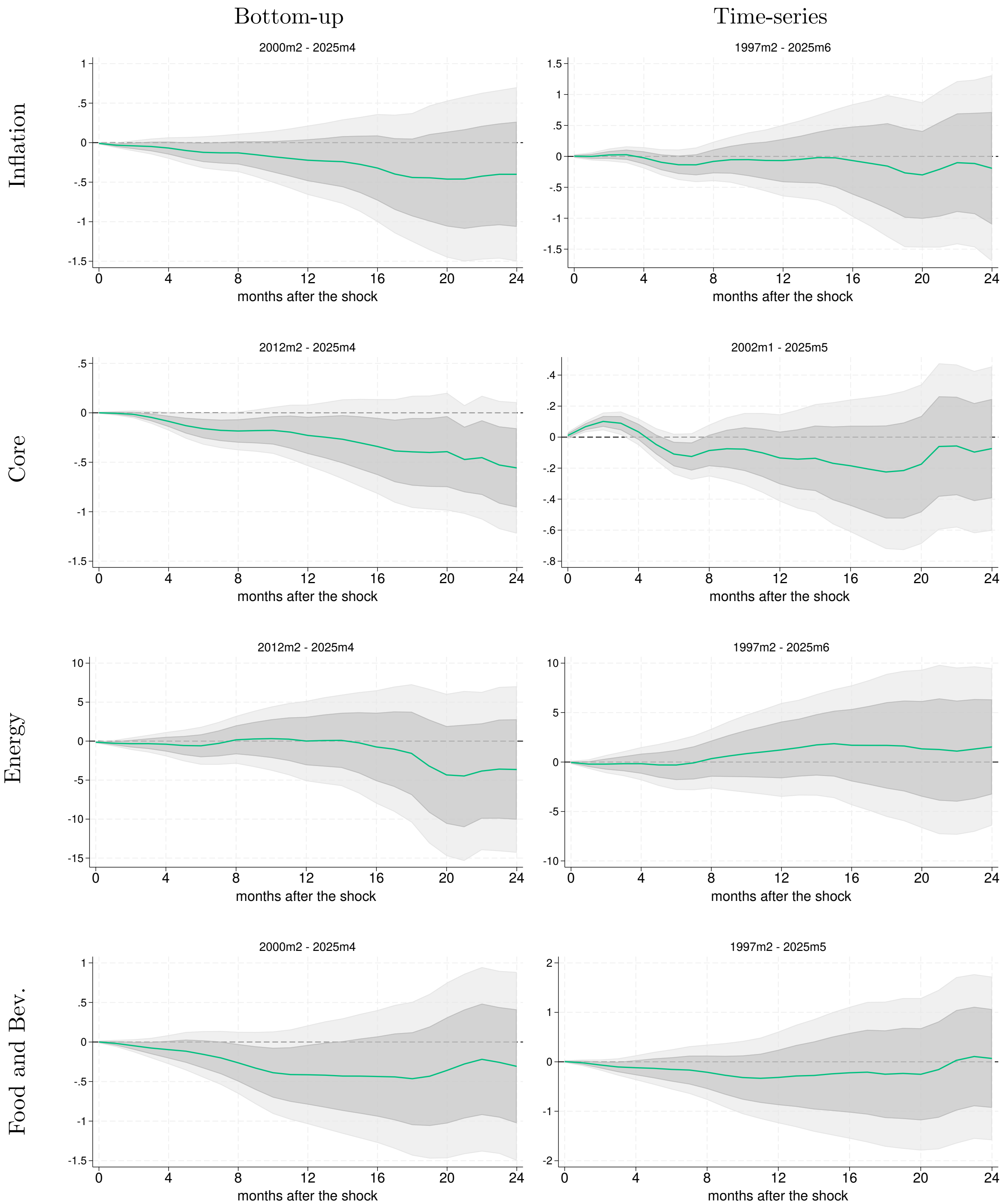
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure 7: Effects on inflation, extreme precipitation



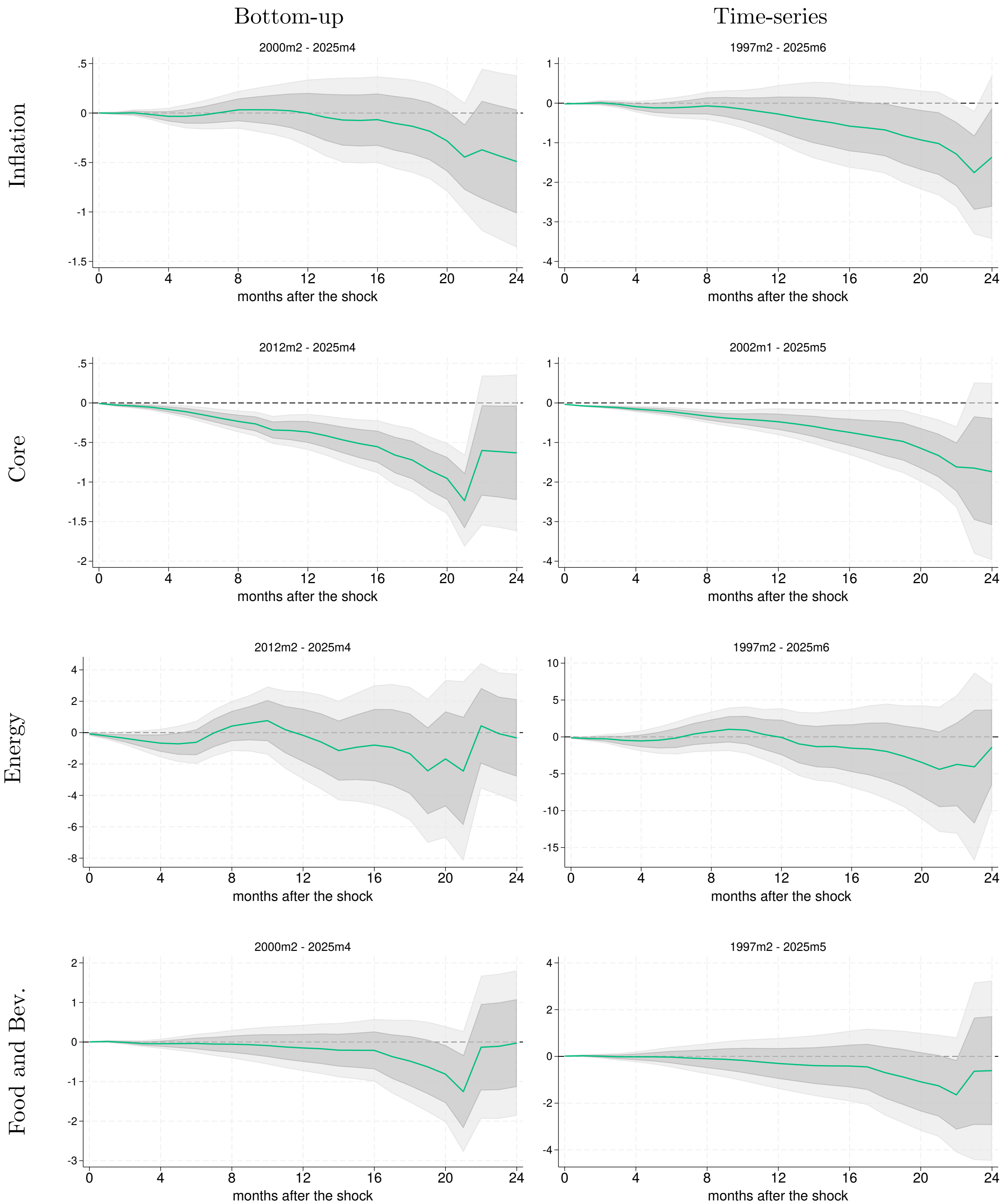
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure 8: Effects on inflation, extreme drought



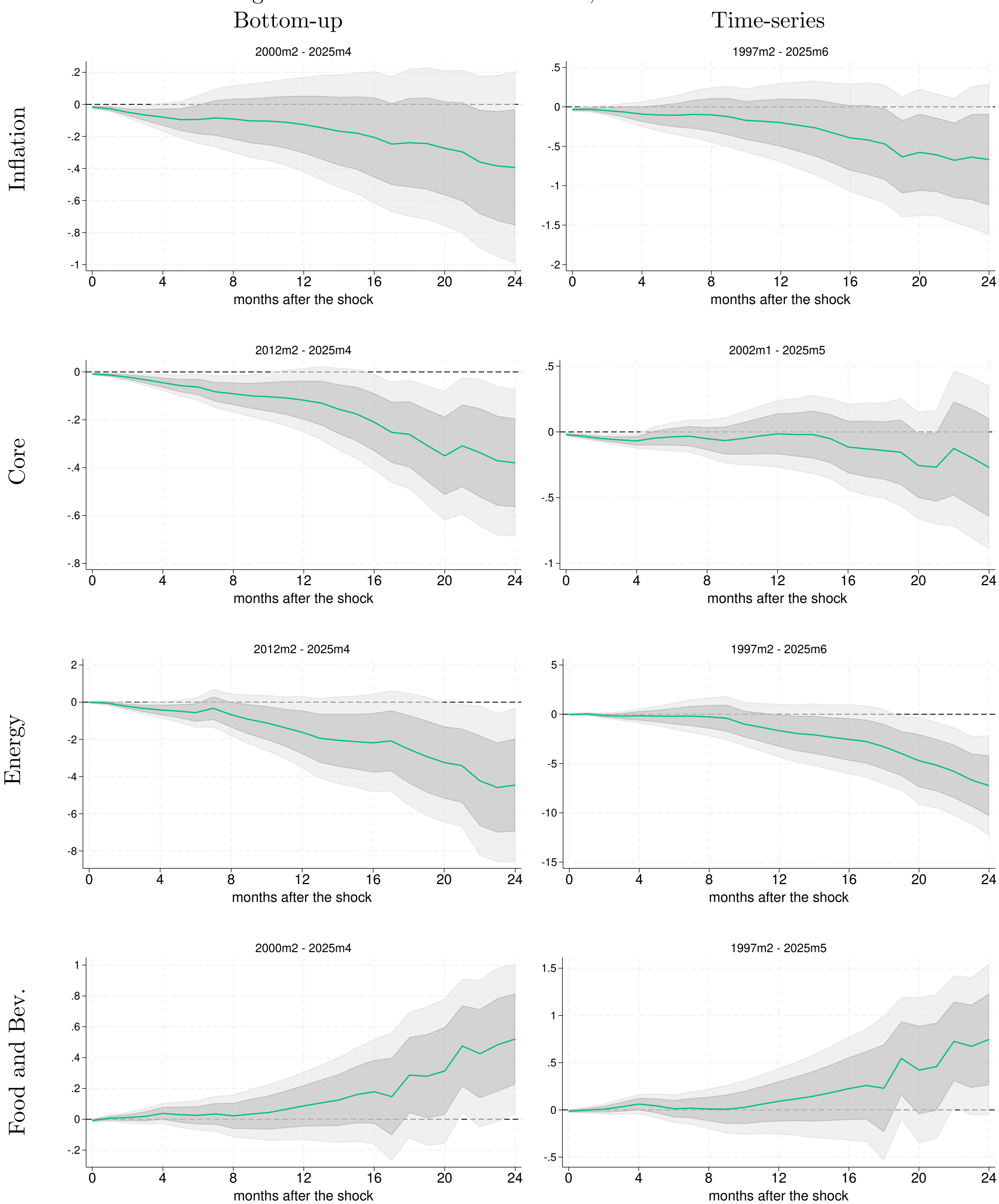
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure 9: Effects on inflation, extreme hail



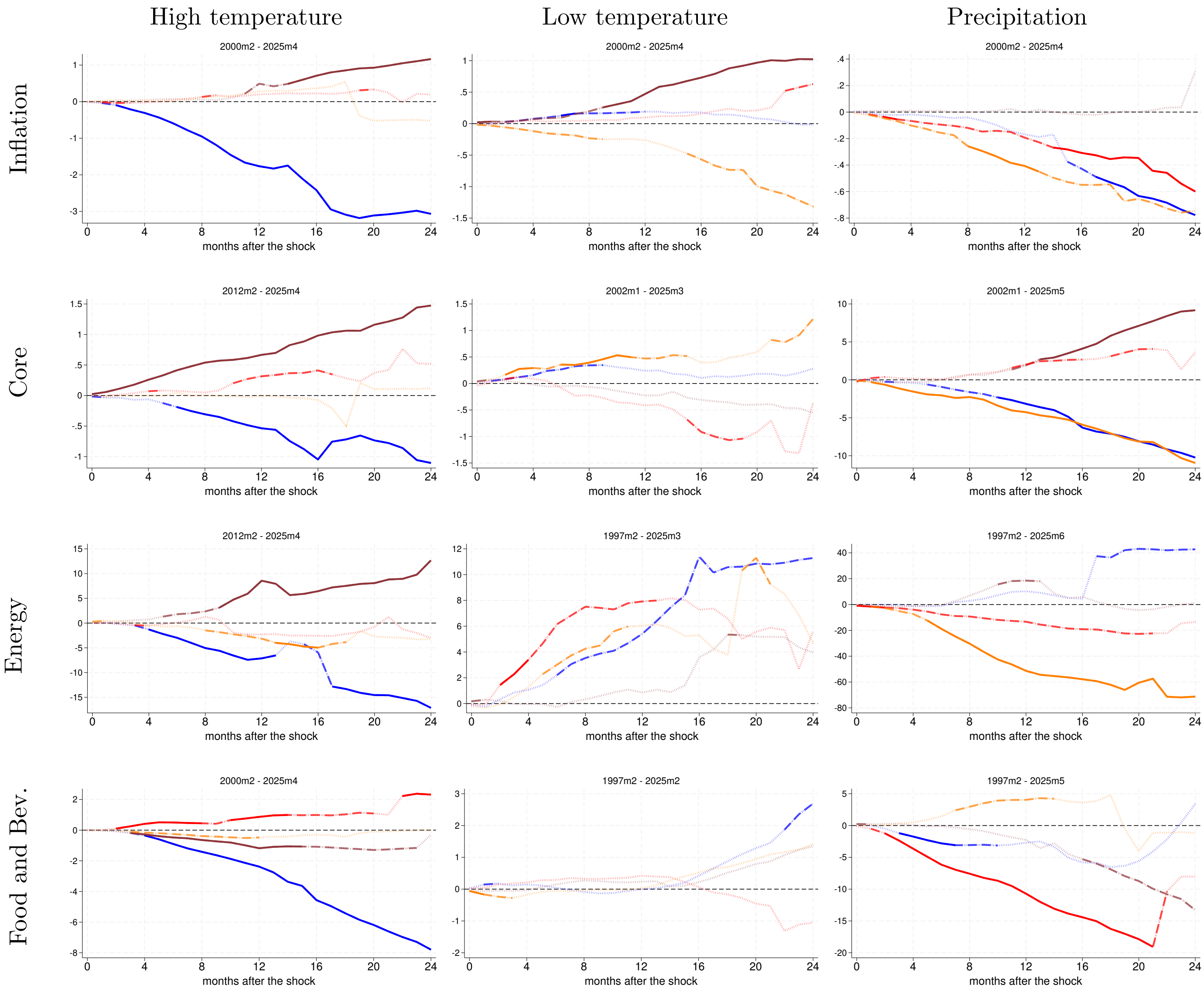
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure 10: Effects on inflation, extreme wind



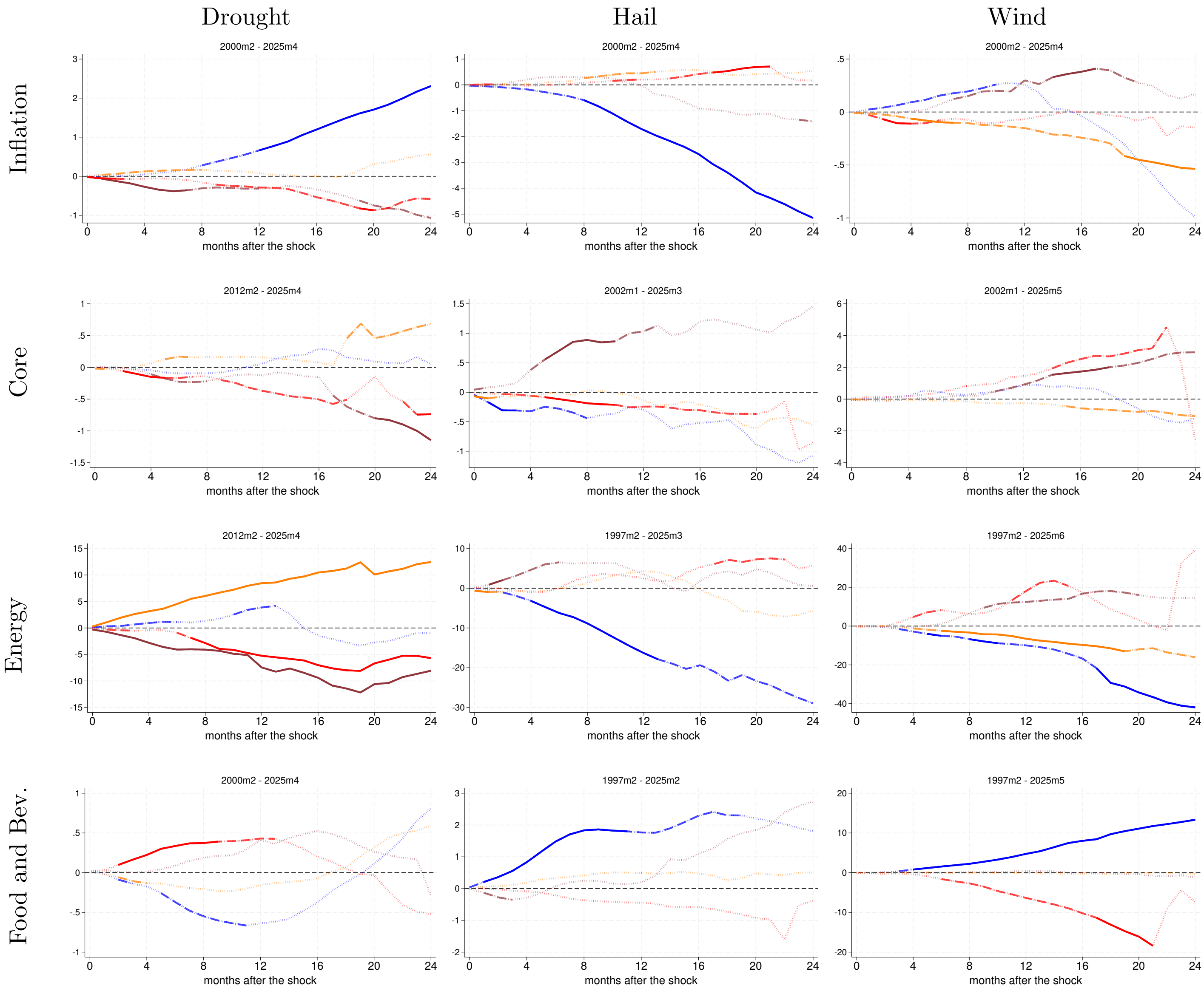
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure 11: Seasonal effects on Italian inflation, climate extremes



Note: Estimates are based on the *Bottom-up* approach; results from alternative approaches are available upon request. Solid lines denote estimates significant at the 90% level, dashed lines those significant at the 68% level, and dotted lines non-statistically significant results. Seasonal effects are represented as follows: winter (blue), spring (maroon), summer (red), and autumn (orange).

Figure 12: Seasonal effects on Italian inflation, climate extremes



Note: Estimates are based on the *Bottom-up* approach; results from alternative approaches are available upon request. Solid lines denote estimates significant at the 90% level, dashed lines those significant at the 68% level, and dotted lines non-statistically significant results. Seasonal effects are represented as follows: winter (blue), spring (maroon), summer (red), and autumn (orange).

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Appendix

A Data on climate extremes

A.1 Extreme maximum temperature

BASELINE CALCULATION

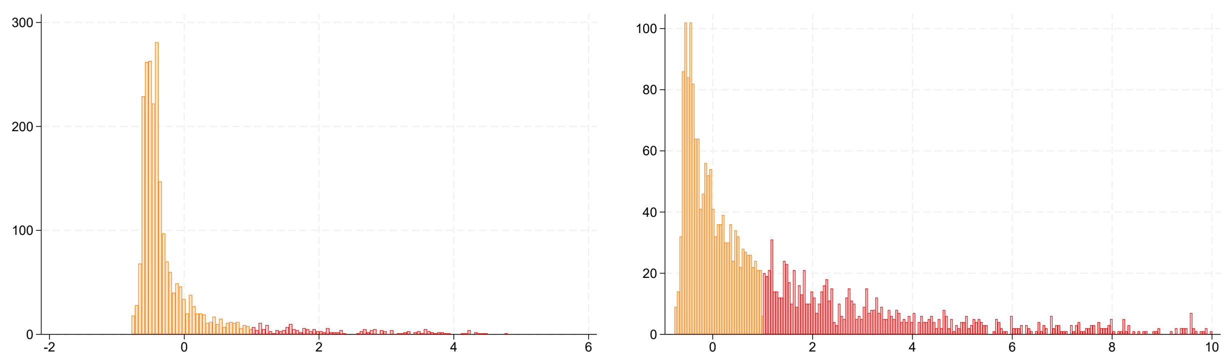
In the reference period 1981-2010, the maximum daily temperature of the surrounding five days is considered for each calendar day. The 95th percentile among the 150 values (5 days x 30 years) is computed and assumed as the threshold. Then, the exceedance value every month is computed as:

$$HS_{j,k} = \sum_{i=1}^{n_j} \max\left[0; Tmax_{i,j,k} - Tmax_{95i,j}\right]$$

where $T_{max_{i,j,k}}$ represents the maximum daily temperature (day i, month j, year k)

Over the reference period, for each month j, the mean value $\mu(HS_j)$ and the standard deviation $\sigma(HS_j)$ of the cumulative exceedance values are calculated.

Figure A1: Extreme maximum temperature



(a) 1989-1999

(b) 2015-2024

Note: This chart reports the distribution of the weather shock. Values above 1 (red part) are considered extreme.

STANDARDIZED ANOMALY COMPUTATION

Each month j and year k, the cumulative value of daily exceedance beyond the corresponding threshold ($HS_{j,k}$) is transformed according to the formula:

$$HSZ_{-s,j,k} = \frac{HS_{j,k} - \mu(HS_j)}{\sigma(HS_j)}$$

A.2 Extreme minimum temperatures

BASELINE CALCULATION

In the reference period 1981-2010, the minimum daily temperature of the surrounding five days is considered for each calendar day. The 5th percentile among the 150 values (5 days x 30 years) is computed and assumed as the threshold. Then, the exceedance value every month is computed as:

$$CS_{j,k} = \sum_{i=1}^{n_j} \max\left[0, \left|T_{\min,i,j,k} - T_{\min,95i,j}\right|\right]$$

Where $T_{min_{i,j,k}}$ represents the maximum temperature (day i, month j, year k) Over the reference period, for each month j, the mean value $\mu(CS_j)$ and the standard deviation $\sigma(CS_j)$ of the cumulative exceedance value are calculated.

STANDARDIZED ANOMALY COMPUTATION

Each month j and year k, the cumulative value of daily exceedance beyond the corresponding threshold ($CS_{j,k}$) is transformed according to the formula:

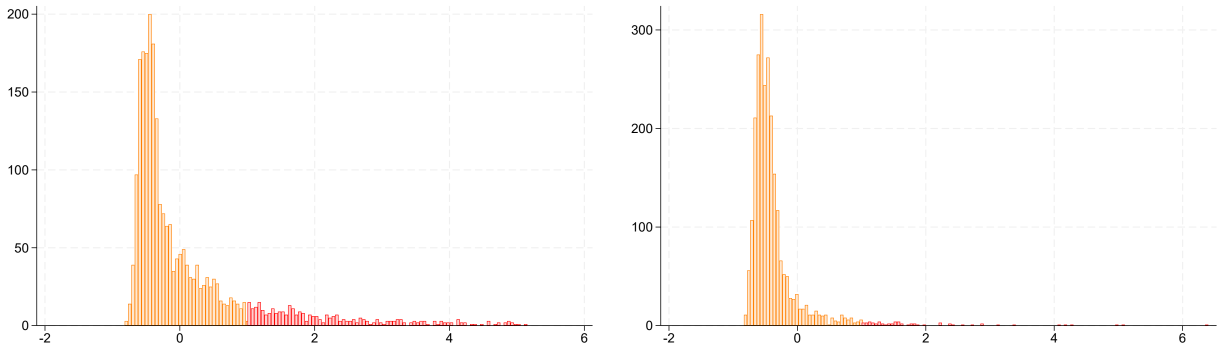
$$CSZ_{-s,j,k} = \frac{CS_{j,k} - \mu(j,T_{min})}{\sigma(j,T_{min})}$$

A.3 Drought

BASELINE CALCULATION

Standard Precipitation Index (SPI) is used as a reference indicator, considering a three-month precipitation accumulation period (SPI-3). Between 1981 and 2010, for each month j, the 30

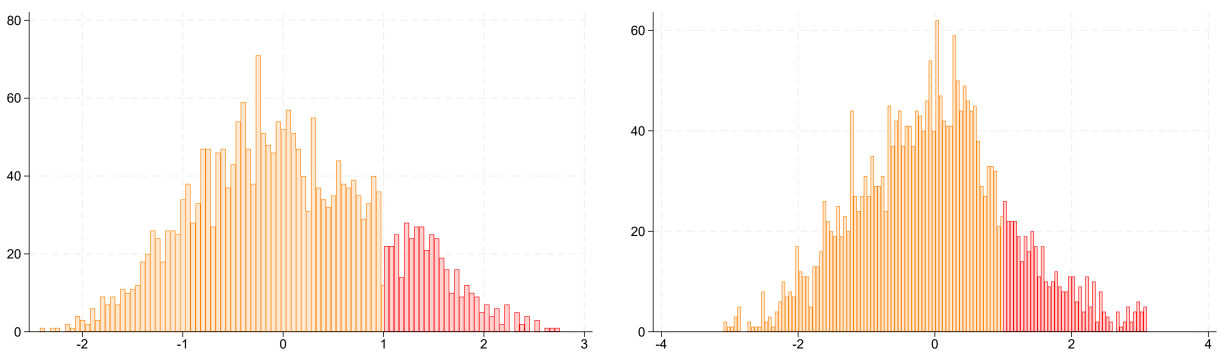
Figure A2: Extreme minimum temperatures



(a) 1989-1999 (b) 2015-2024

Note: This chart reports the distribution of the weather shock. Values above 1 (red part) are considered extreme.

Figure A3: Drought



(a) 1989-1999 (b) 2015-2024

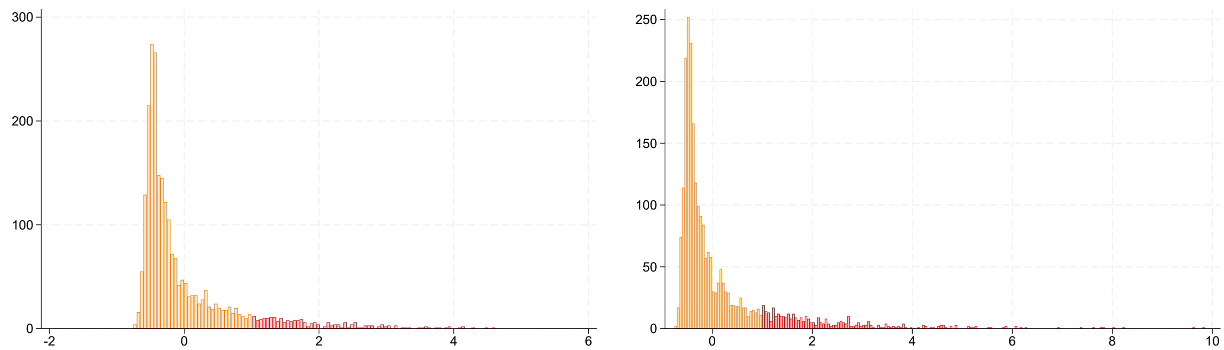
Note: This chart reports the distribution of the weather shock. Values above 1 (red part) are considered extreme.

cumulative values are fitted to a gamma probability distribution, which is then transformed into a normal distribution.

STANDARDIZED ANOMALY COMPUTATION

For each month j and year k,$SPI-3_{j,k}$ value represents units of standard deviation from the long-term reference mean. According to the canonical approach, positive SPI indicates greater than median precipitation, and negative values indicate less than median precipitation. In E3CI, the opposite of $SPI-3_{j,k}$ is taken to maintain consistency with the other components.

Figure A4: Extreme precipitation



(a) 1989-1999

(b) 2015-2024

Note: This chart reports the distribution of the weather shock. Values above 1 (red part) are considered extreme.

A.4 Extreme precipitation

BASELINE CALCULATION

For the reference period 1981-2010, the 95th percentile of daily precipitation is computed for each month j. Then, the exceedance value every month is computed as:

$$EP_{j,k} = \sum_{i=1}^{n_j} \max\left[0; P_{i,j,k} - P_{95i,j}\right]$$

Where $P_{i,j,k}$ represents the daily precipitation (day i, month j, year k) Over the reference period, for each month j, the mean value $\mu(EP_j)$ and the standard deviation $\sigma(EP_j)$ of the exceedance values are calculated.

STANDARDIZED ANOMALY COMPUTATION

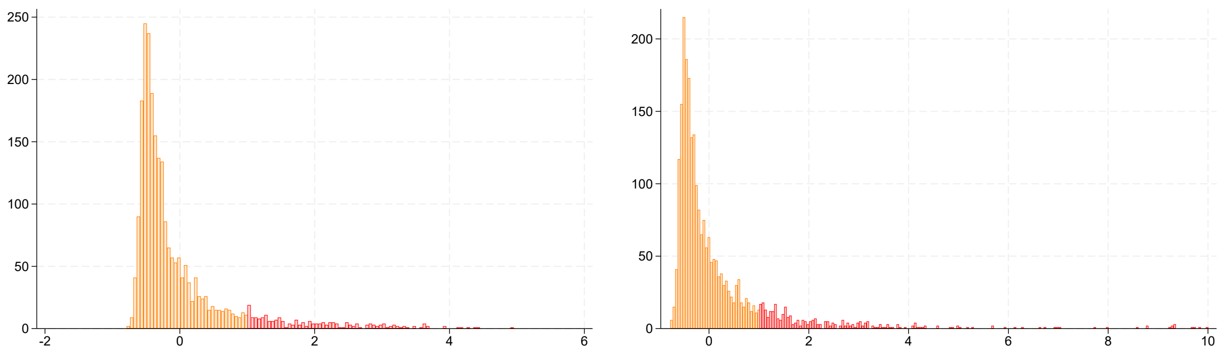
For each month, j, and year, k, the exceedance value is transformed according to the formula:

$$EPZ_{-s,j,k} = \frac{EP_{j,k} - \mu(j, EP_{min})}{\sigma(EP_{min})}$$

A.5 Extreme winds

BASELINE CALCULATION

Figure A5: Extreme winds



(a) 1989-1999

(b) 2015-2024

Note: This chart reports the distribution of the weather shock. Values above 1 (red part) are considered extreme.

On the reference period 1981-2010, for each month j, the 95th percentile of daily maximum wind speed is computed, $w_{95,j}$. Then, every month, the Local Loss Index (LLI, Donat et al., 2011; doi:10.5194/nhess-11-1351-2011) is calculated as:

$$EP_{j,k} = \sum_{i=1}^{n_j} \max\left[0; P_{i,j,k} - P_{95i,j}\right]$$

Where $w_{max,ij,k}$ is the maximum wind speed computed considering mean hourly values for day i, month j, and year k. Over the reference period, for each month j, the mean value $\mu(LLI_j)$ and the standard deviation $\sigma(LLI_j)$ are calculated.

STANDARDIZED ANOMALY COMPUTATION

For each month, j, and year, k, the exceedance value is transformed according to the formula:

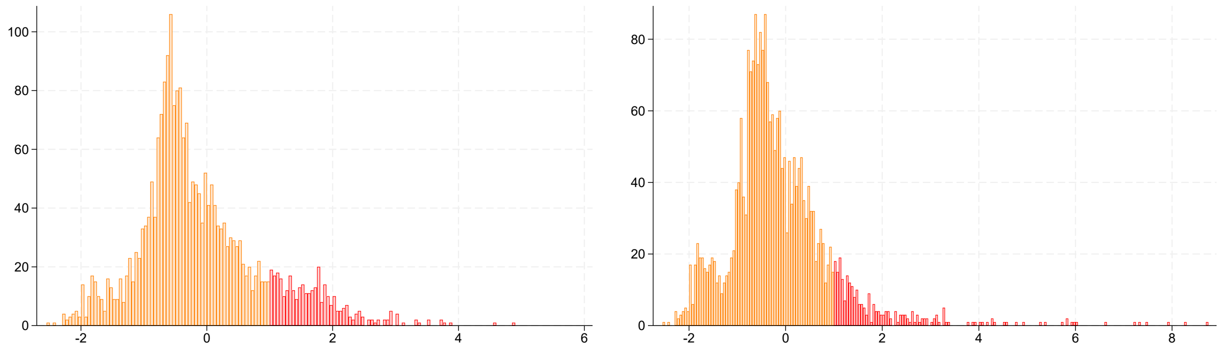
$$LLI_{-s,j,k} = \frac{LLI_{j,k} - \mu(j, LLI_{min})}{\sigma(LLI_{min})}$$

A.6 Hailstorms leading conditions

BASELINE CALCULATION

On the reference period 1981-2010, for each month j, the cumulative value of the exceedance of the daily SHiP (Significant Hail Parameter) indicator value from the threshold (1) is computed.

Figure A6: Hailstorms



(a) 1989-1999

(b) 2015-2024

Note: This chart reports the distribution of the weather shock. Values above 1 (red part) are considered extreme.

The threshold is fixed based on indications provided by authoritative agencies that utilize the index for operational purposes. Subsequently, for each month j, the mean value $\mu(ES_j)$ and the standard deviation $\sigma(ES_j)$ of the exceedance value are calculated. Then, every month, the exceedance of SHIP indicator values from the threshold value is computed.

$$ES_{j,k} = \sum_{i=1}^{n_j} \max\left[0; S_{i,j,k} - 1\right]$$

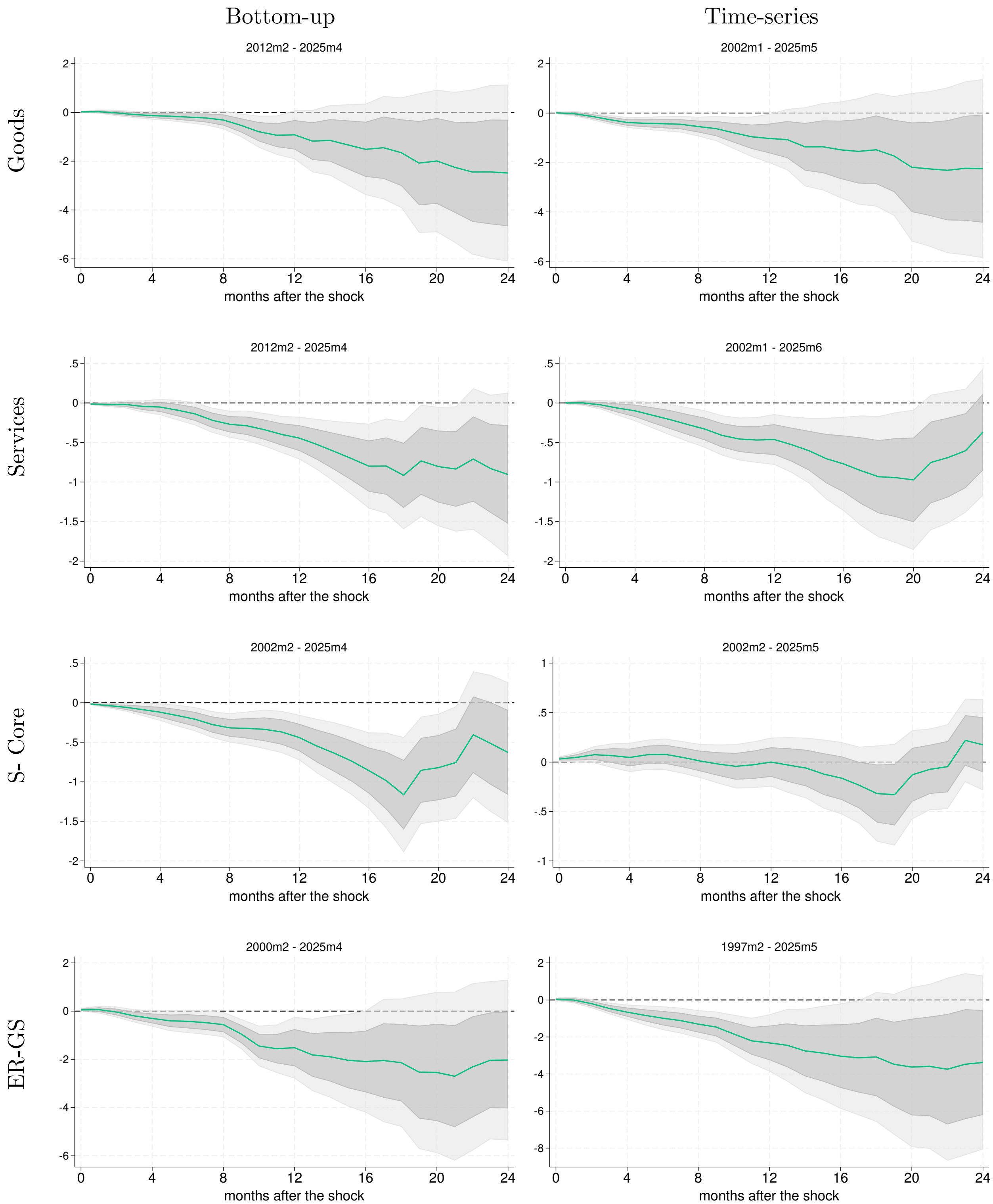
STANDARDIZED ANOMALY COMPUTATION

For each month j and year k, the exceedance value is transformed according to the formula:

$$ES_{Z-s,j,k} = \frac{ES_{j,k} - \mu(ES_j)}{\sigma(ES_j)}$$

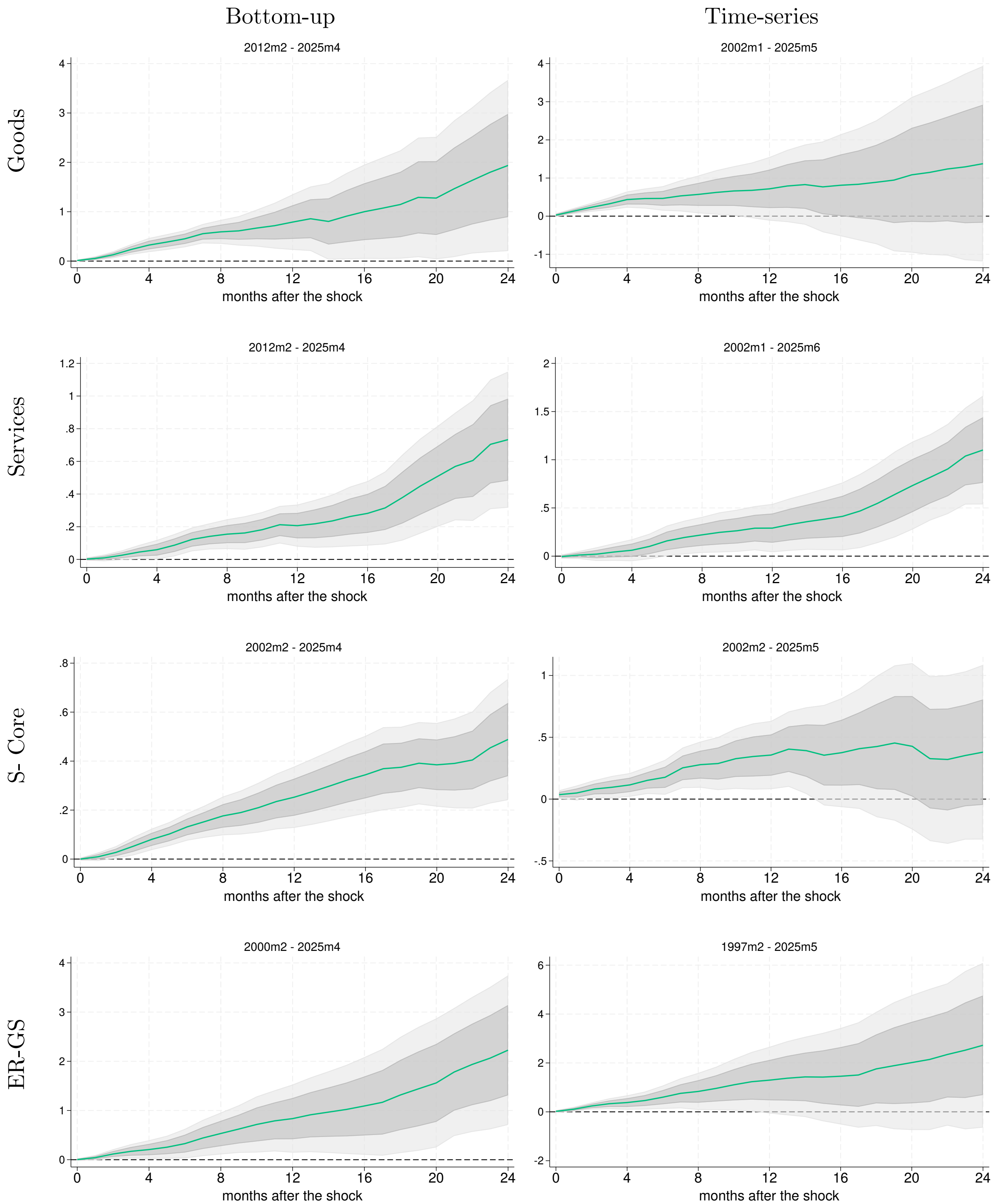
B Additional results

Figure B1: Effects on inflation, extreme high temperature



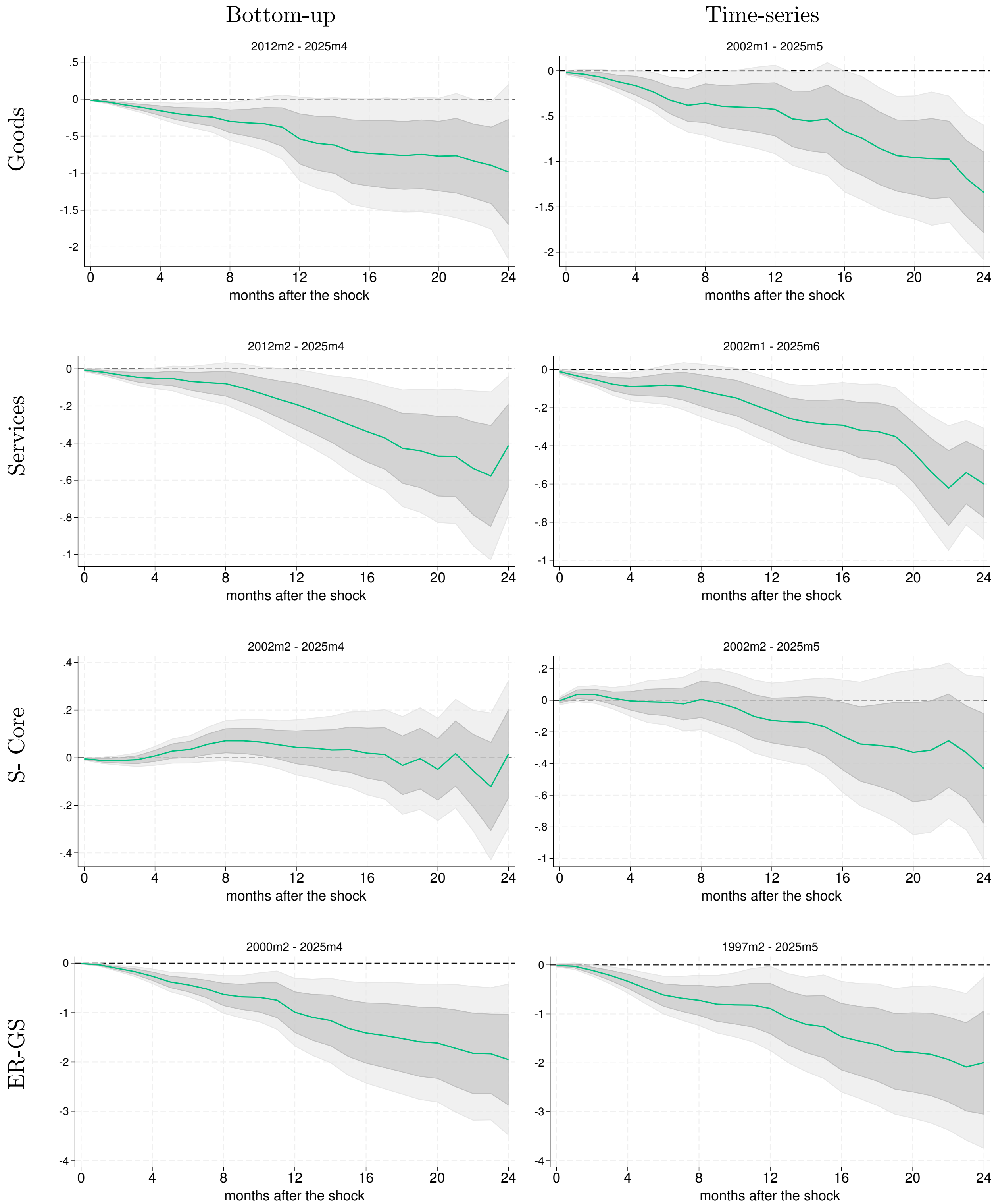
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure B2: Effects on inflation, extreme low temperature



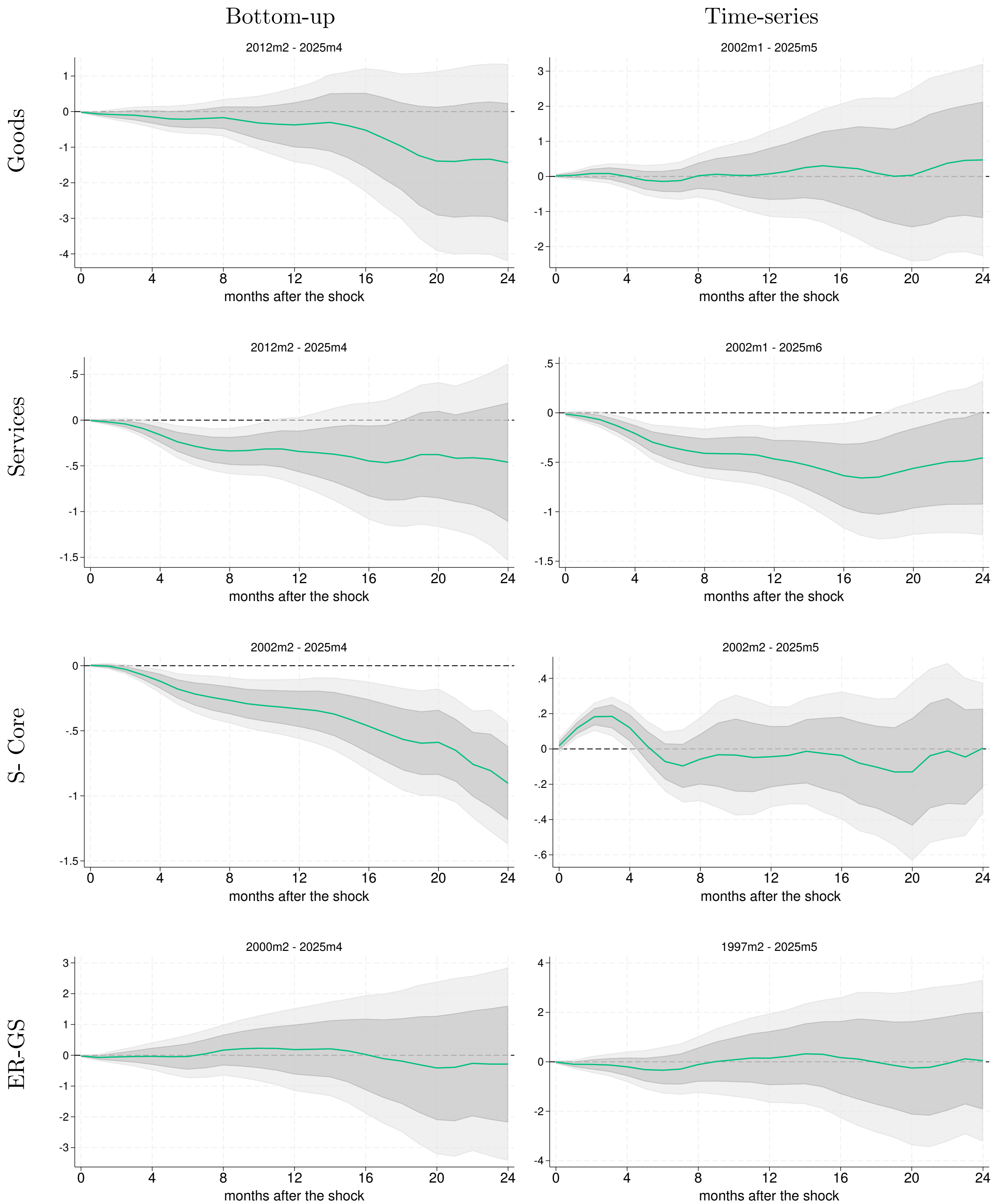
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure B3: Effects on inflation, extreme precipitation



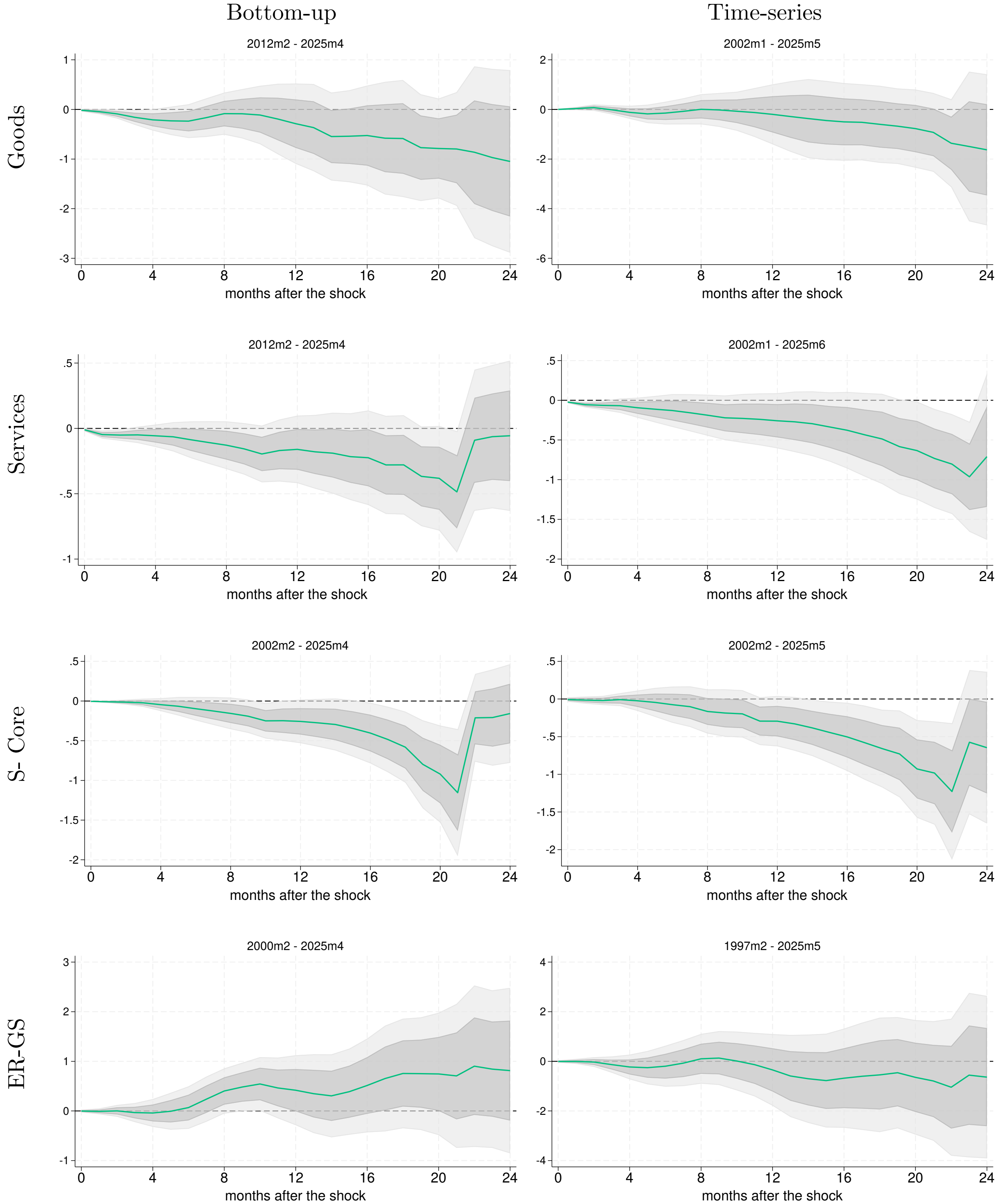
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure B4: Effects on inflation, extreme drought



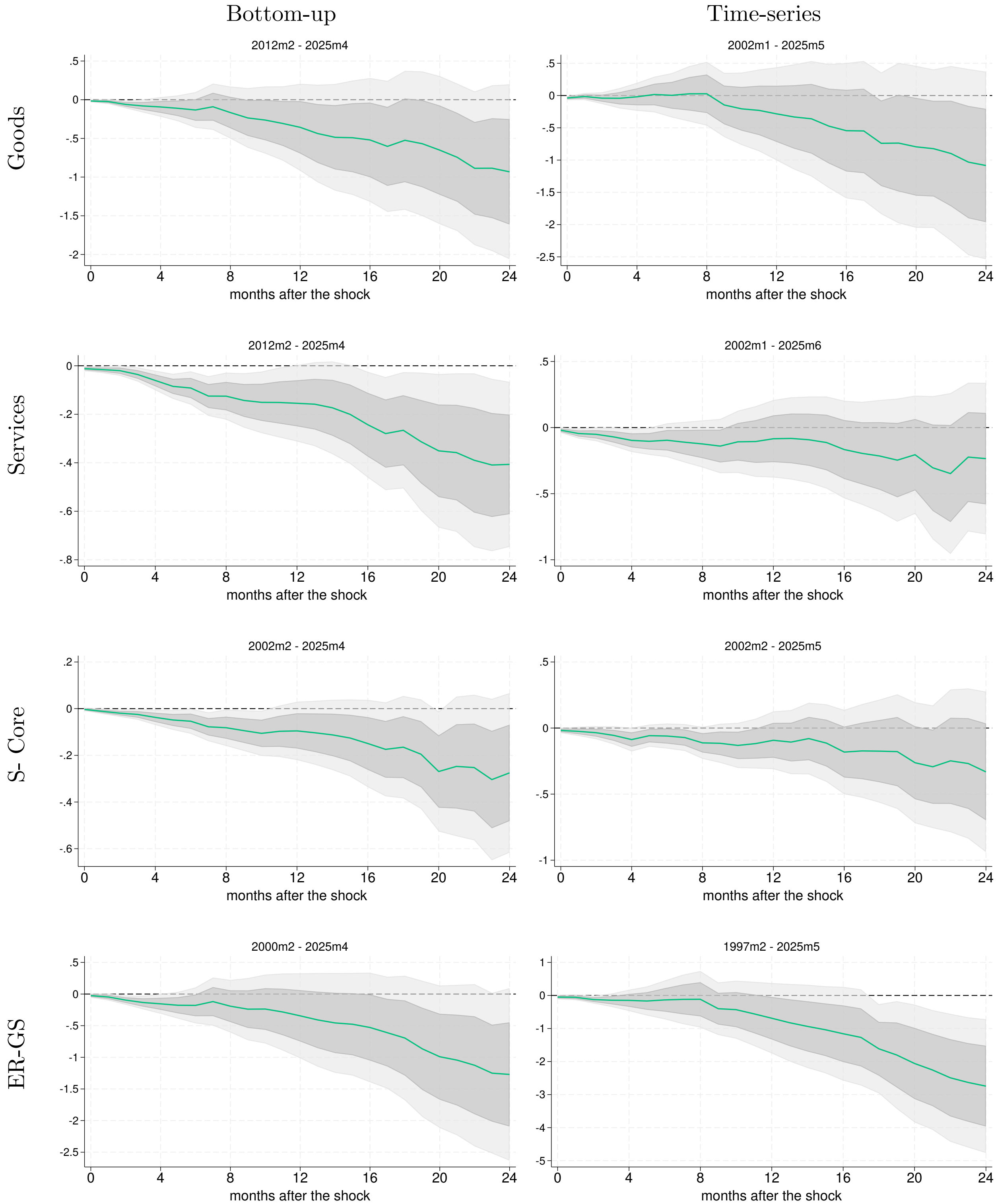
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure B5: EFFECTS ON INFLATION, EXTREME HAIL



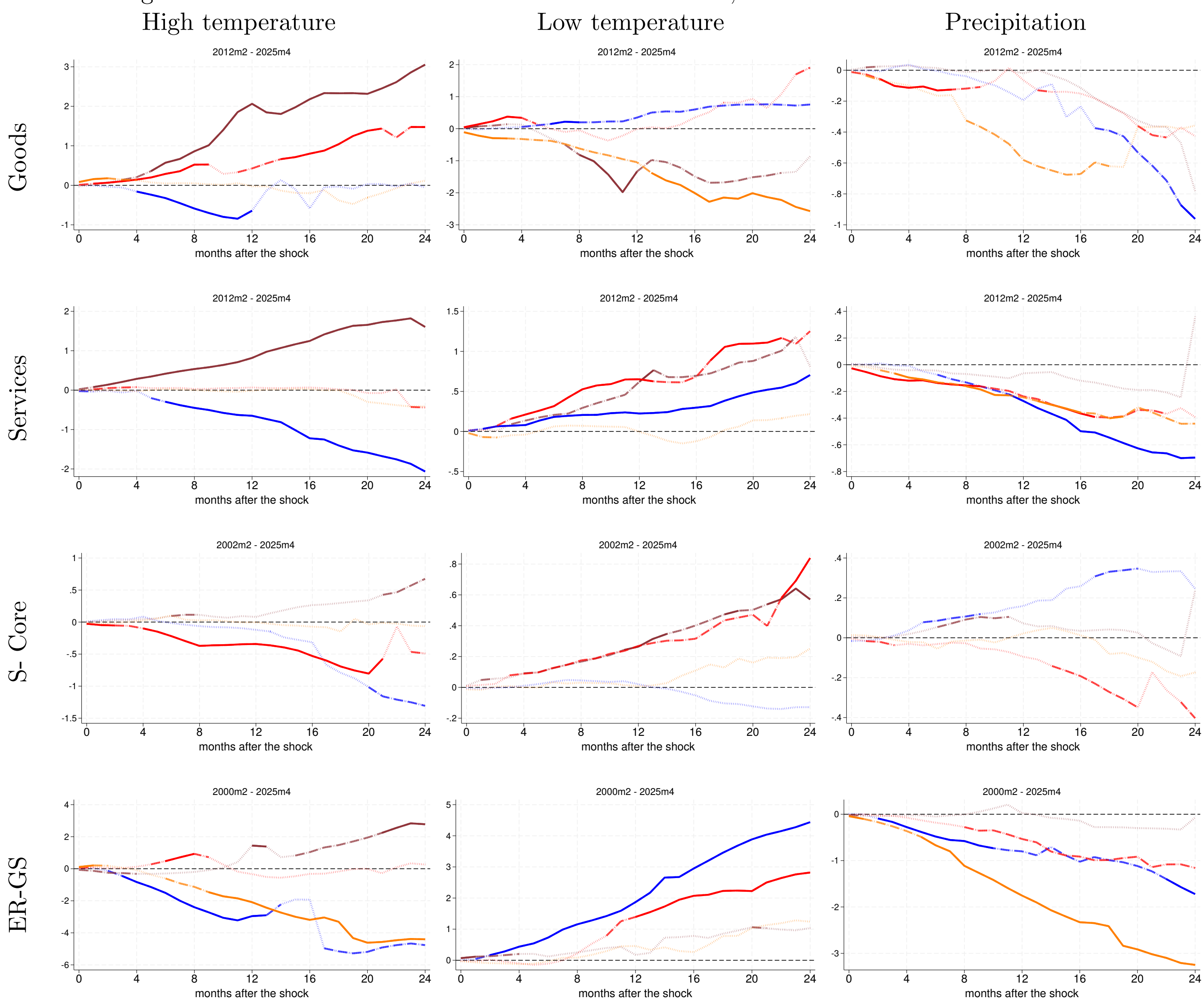
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure B6: Effects on inflation, extreme wind



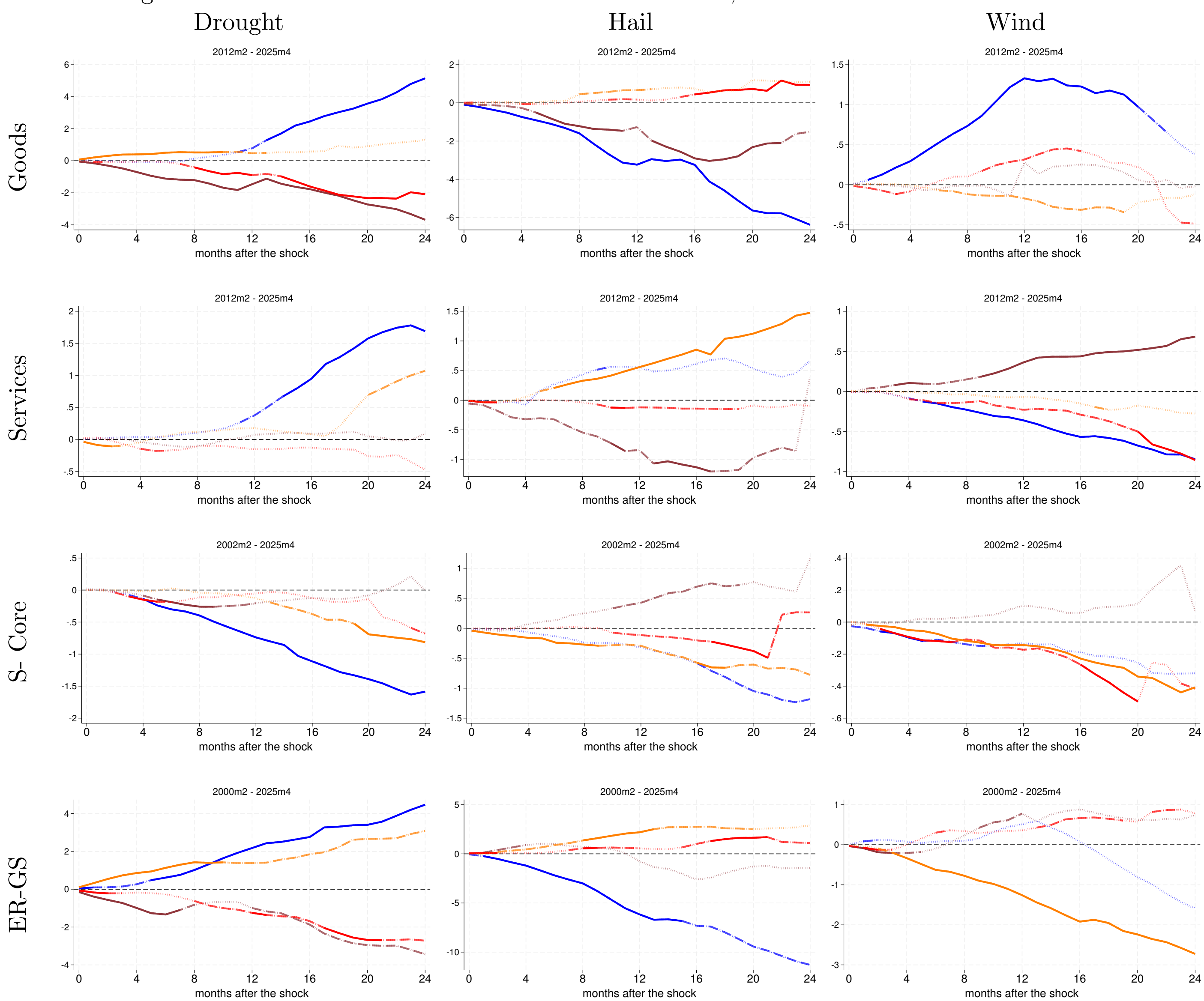
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure B7: Seasonal effects on Italian inflation, climate extremes



Note: Estimates are based on the *Bottom-up* approach; results from alternative approaches are available upon request. Solid lines denote estimates significant at the 90% level, dashed lines those significant at the 68% level, and dotted lines non-statistically significant results. Seasonal effects are represented as follows: winter (blue), spring (maroon), summer (red), and autumn (orange).

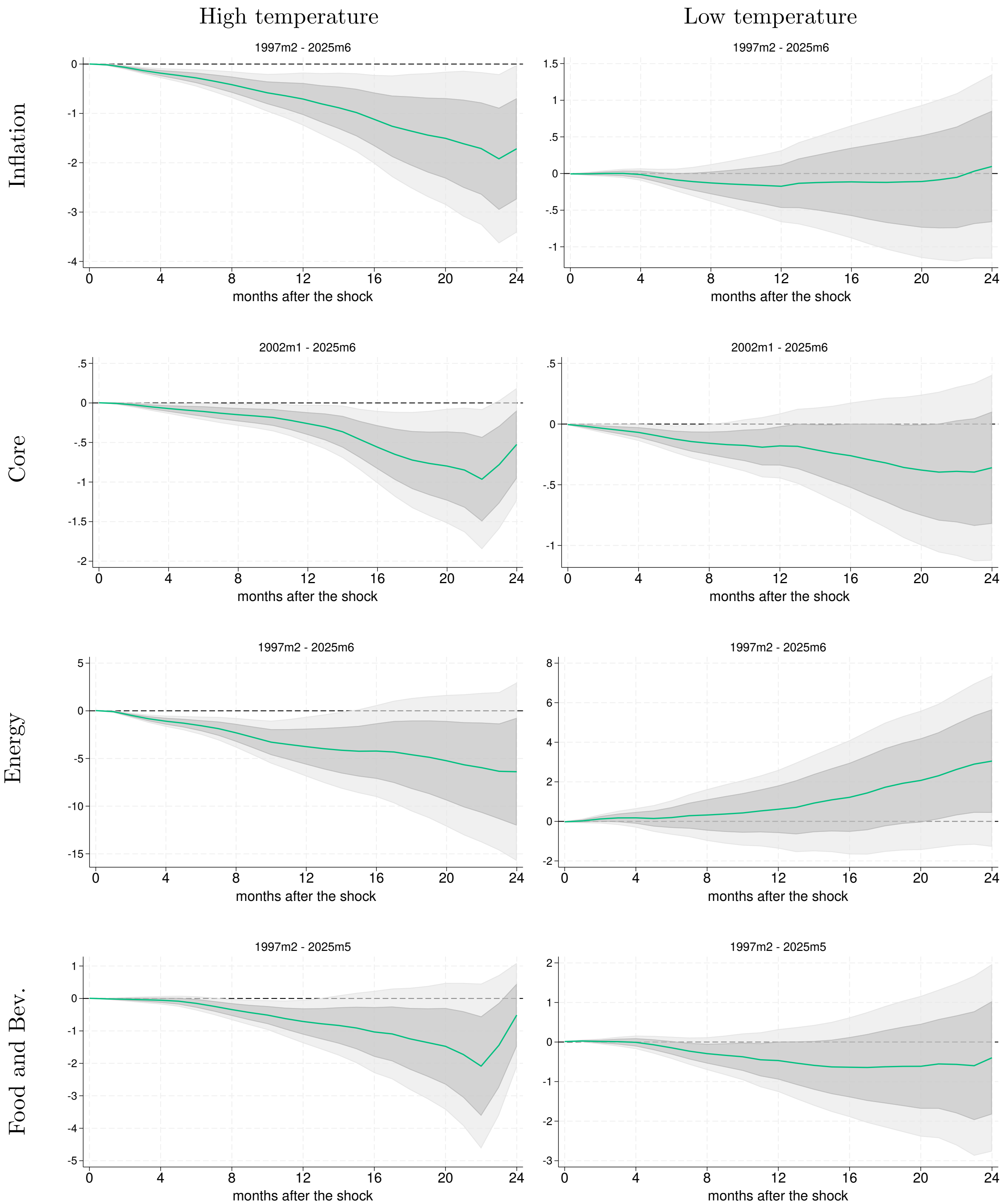
Figure B8: Seasonal effects on Italian inflation, climate extremes



Note: Estimates are based on the *Bottom-up* approach; results from alternative approaches are available upon request. Solid lines denote estimates significant at the 90% level, dashed lines those significant at the 68% level, and dotted lines non-statistically significant results. Seasonal effects are represented as follows: winter (blue), spring (maroon), summer (red), and autumn (orange).

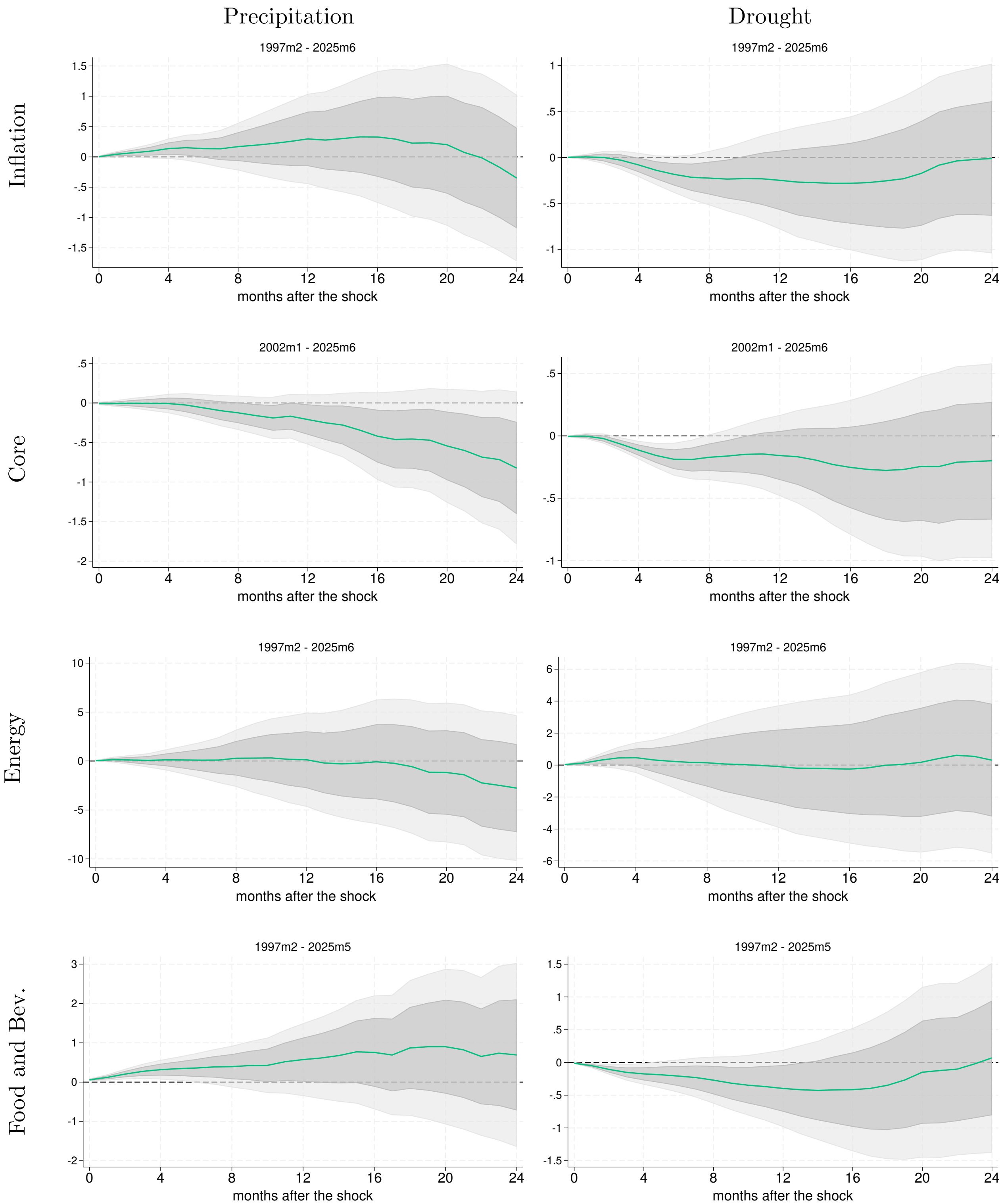
C Effects on euro area Inflation

Figure C1: Effects on euro area inflation, Climate extremes



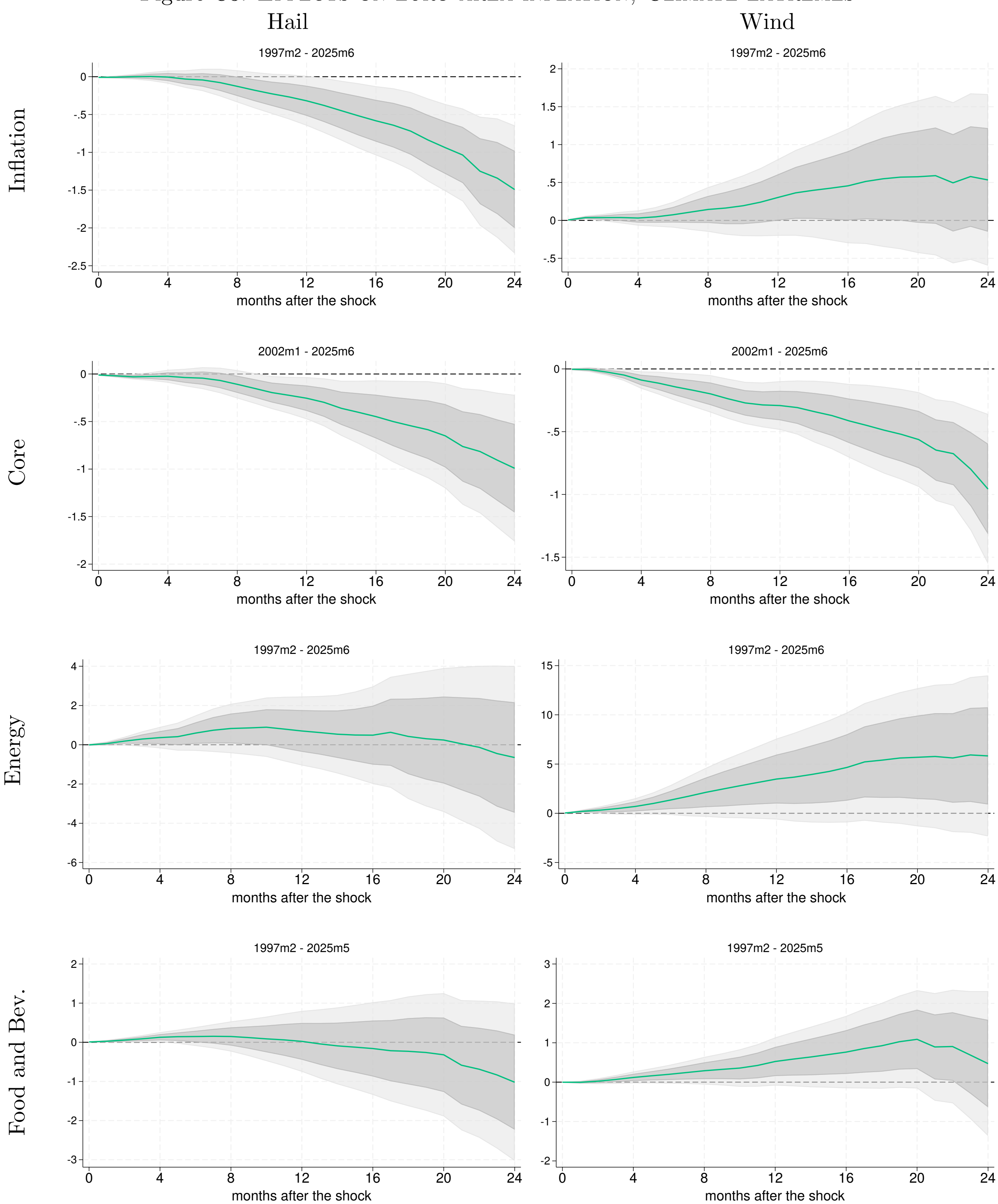
Note: Confidence intervals are considered at the 68% and 90% levels.

Figure C2: Effects on euro area inflation, Climate extremes



Note: Confidence intervals are considered at the 68% and 90% levels.

Figure C3: Effects on euro area inflation, Climate extremes



Note: Confidence intervals are considered at the 68% and 90% levels.