Weather-related Disasters and Inflation in the Euro Area

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Abstract

This paper investigates the impact of weather-related disasters on inflation in the euro area over the period 1996-2021. Using a panel structural vector autoregression approach, we explore whether weather-related disasters have a significant and persistent effect on inflation, as well as the role that demand-side and supply-side channels play as drivers of inflation. We also analyse the heterogeneous effects of inflation on different product categories. Our results suggest that weather-related disasters have a positive, non-persistent effect on inflation. This reflects the prevalence of negative supply shock channels and positive demand shock channels over negative demand shock channels. We also find that weather-related disasters have more pronounced effects on the inflation of product categories that represent a higher proportion of the spending of low-income households, implying that disasters reinforce inflation inequality. Overall, our results suggest that, as the climate crisis deepens, it might become increasingly challenging for the European Central Bank to control inflation and its inequality effects.

JEL classification: E31, E52, Q54
Keywords: weather-related disasters, climate change, inflation, monetary policy, European Central Bank

Declarations of interest: None

1 Introduction

> *"I want to explore every avenue available in order to combat climate change. This is something that I hold very strongly and I believe that, as we have this price stability mandate [...], climate change actually has an impact on price stability. If we fail to measure externalities, if we fail to anticipate drought, if we fail to anticipate variations of prices of food, of energy, of services, then we are not doing our job."*
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> Christine Lagarde, Interview with the Financial Times, July 7, 2020.

The European Central Bank (ECB) has recently started incorporating climate change into its monetary policy operations and decision-making processes (ECB, 2021, 2022, 2024). Yet, so far little is known on whether and how climate change affects inflation rates in the euro area. Climate change does not only increase the frequency and severity of extreme weather events (Field, 2012; Stott, 2016), which can affect inflation through demand-side and supply-side channels. It also leads to gradual changes in ecosystems that can undermine the capacity of economies to produce, with profound implications for inflation. Understanding these mechanisms of climate-induced inflation in the euro area is essential for the design of monetary policy in the climate crisis era.

In this paper, we fill in the knowledge gap on the effects of climate change on euro area inflation. We do so by exploring the impact of weather-related disasters on euro area inflation over the last three decades. In particular, we ask three questions. First, do weather-related disasters have a significant impact on inflation in the euro area and how persistent is this impact? Second, what are the drivers behind the effects of disasters on inflation? Are supply-side or demand-side effects quantitatively stronger? Third, do the inflationary effects differ across goods and services? By exploring the second and third question, we move beyond existing studies on the effects of climate change on inflation which have confined their attention to the aggregate impact on inflation. From a monetary policy perspective, it is important to understand if weather-related disasters affect mostly the supply-side or the demand-side of the economy: this has implications for whether the ECB can control climate-induced changes in inflation by using its policy rate. It is also important to shed light on the potentially heterogeneous effects of weather-related disasters on the prices of different goods and services: if weather-related disasters have stronger inflationary effects on product categories that have a higher representation in the baskets of low-income households, they can reinforce inflation inequality.[1]

Our analysis relies on a panel structural vector autoregression approach that we apply to euro area countries over the period 1996-2021. To explore the effects of weather-related disasters on inflation, we use the Harmonised Index of Consumer Prices (HICP), which is the target variable of the ECB's primary objective of maintaining price stability. This allows our results to be of direct relevance to the ECB's monetary policy. We employ monthly data to capture the immediate price responses following weather-related events. We use several supply-side and demand-side variables to explore the channels through which inflation can be affected by extreme weather events. To disentangle potentially heterogeneous effects on product categories, and therefore on inflation inequality, we disaggregate the overall HICP inflation into its main 12 sub-indices.

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[1] For a discussion of inflation inequality in the euro area, see Strasser et al. (2023) and the references therein.

According to our results, weather-related disasters have a statistically significant positive average effect on inflation rates in euro area countries, reflecting the prevalence of negative supply shocks and positive demand shocks related to reconstruction activity. Although this effect is not persistent, it illustrates that, as the climate crisis deepens, it might become more challenging for the ECB to control inflation due to its limited ability to affect the supply-side of the economy. It also raises questions on whether the ECB should increase the policy rate after an extreme weather event, since this can undermine reconstruction activity and investment in climate resilience that might be important for long-run macrofinancial stability. Moreover, our empirical analysis shows that disasters have more pronounced effects on the inflation rates of product categories that represent a higher proportion of the spending of low-income households. This implies that climate change can reinforce inflation inequality.

The remainder of this paper is structured as follows. Section 2 briefly discusses the potential impacts of disasters on inflation and reviews the relevant empirical literature. Section 3 describes the data that are used throughout the analysis. The empirical methodology is outlined in Section 4. Section 5 presents the empirical results. Section 6 concludes.

2 Theoretical background and literature review

From a theoretical point of view, we can distinguish between three channels through which weather-related disasters affect inflation. First, inflation can be influenced by a disaster via a *negative supply shock channel*. Weather-related disasters may destroy crops, buildings and infrastructure or disrupt production and supply chains.[2] The gradual increase in global warming can also reduce productivity (Batten et al., 2020; Breckenfelder et al., 2023; Parker, 2023). These supply-side effects cause upward inflationary pressures since they can increase production costs and create supply shortages that might also make it necessary to import goods from abroad (at higher costs) to meet domestic demand.

Second, weather-related disasters can affect inflation through a *positive demand shock channel*. Since such disasters often destroy infrastructure and other physical capital, they can lead to a reconstruction boom during which the demand for investment goods increases, creating inflationary pressures (Batten et al., 2020). This channel is stronger when households, firms and governments have the capacity to finance reconstruction-related investment spending (including through insurance), which is generally more likely in high-income countries.

Third, inflation can also be affected through a *negative demand shock channel*. For example, the destruction of the properties of households and the capital stock of firms can reduce household wealth and firms' profitability, leading to lower consumption and investment spending (Batten et al., 2020; Breckenfelder et al., 2023). Although this negative demand-side effect can be attenuated through insurance, there is a significant proportion of assets that is not insured against weather-related events. This proportion is generally larger in lower-income countries and is expected to grow across the globe (including in high-income countries) as the climate crisis intensifies and insurance com-

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[2] For the effects of natural disasters on trade, see, for example, Gassebner et al. (2010), Oh and Reuveny (2010), El Hadri et al. (2019), and Osberghaus (2019).

panies increase their premiums and reduce their coverage. Spending can also be reduced as a result of lower credit availability in the aftermath of a disaster. Banks can reduce lending due to higher loan defaults (Dafermos et al., 2018) and higher uncertainty about the ability of borrowers to repay their debt. Empirical research has shown, for example, that climate vulnerability influences the availability and cost of corporate credit (Kling et al., 2021).

When the negative supply shock and positive demand shock channels outweigh the negative demand shock channel, weather-related disasters lead to an increase in inflation. In contrast, when the negative demand shock channel dominates, inflation declines. Crucially, the strength of these channels differs across product categories. For example, the negative supply shock channel is stronger in the case of food, energy and housing since these product categories are directly affected by weather-related disasters. The negative demand shock channel is expected to be more pronounced for goods and services of less vital importance, such as those related to transport, communication, culture and entertainment: when disposable income declines, households are more likely to cut spending on these types of goods and services to be able to continue consuming essentials.

The three channels discussed above are also relevant for the analysis of spillover effects across countries. Suppose that Country A, which is a trading partner of Country B, suffers from a weather-related disaster. In the context of the negative supply shock channel, Country A might face supply shortages and the trade between Country A and Country B can be disrupted. As a result, import prices for Country B might increase. The weather-related disasters in Country A can also affect the demand in this country and, therefore, its imports. Part of these imports correspond to the exports (and thus the aggregate demand) of Country B.

The empirical studies on the physical effects of climate change on inflation are limited. They can be classified into two groups. The first group includes scenario analyses that explore how inflation can evolve in the coming decades under different scenarios. These analyses rely on theoretical models (e.g. NGFS, 2023) or econometric estimates (e.g. Kabundi et al., 2022). The second group includes econometric studies that analyse climate-induced inflation using historical data. This paper contributes to the second group of studies. Arguably, in the case of climate change, the past cannot be a good guide for the future: the non-linearities associated with global warming imply that the climate-economy relationships might fundamentally change in the future, especially if atmospheric temperature passes specific thresholds. However, given that atmospheric temperature has substantially increased over the last decades and several weather-related disasters have occurred around the globe, exploring how these events affected inflation can provide useful insights into how the channels discussed above work in reality.

Some econometric studies have investigated the impact of temperature on inflation. Faccia et al. (2021) analyse the impact of country-specific temperature anomalies on medium-term inflation for 48 advanced and emerging market economies over the period 1990-2018. They find that higher temperatures have significant effects on consumer prices, producer prices and the GDP deflator. Hot summers increase food price inflation in the short run, especially in emerging market economies, with the effect being stronger in the cases of large shocks and high temperatures. However, over the medium term, the impact on inflation tends to become insignificant or negative. Using a sample of both developed and developing countries, Mukherjee and Ouattara (2021) document positive effects of temperature shocks on inflation, with these effects being persistent for developing countries. Kotz et al. (2023) find positive non-linear inflationary pressures of increased temperatures in both developed and developing countries. These effects persist over 12 months and are more pronounced in the case of food price inflation. Ciccarelli et al. (2023) focus on the effects of temperature shocks on inflation in the four largest euro area countries (France, Germany, Italy and Spain). They find that a rise in monthly mean temperatures has inflationary effects in summer and autumn, with the effects being stronger in warmer euro area countries.

Some other econometric studies have explored the inflationary effects of natural disasters, including weather-related events. Heinen et al. (2019) document a positive impact of hurricanes and floods on inflation using a sample of 15 Caribbean countries. Kunawotor et al. (2022) find that weather-related disasters increase inflation in African countries, with droughts and floods having a particularly large effect on food prices. Parker (2018) explores the effects of natural disasters on inflation in a large global panel of 212 countries. Using a panel regression over the period 1980-2012, he finds that, while the impact of natural disasters on inflation in developed countries is negligible, natural disasters have persistent effects on inflation in developing countries. His results also suggest that there are differences in the inflation impact by type of disaster and inflation sub-index. The heterogeneous effects of different types of disaster shocks on inflation are supported by the findings of Kabundi et al. (2022). Using a sample of 183 countries over the period 1970-2018, they find that droughts have the largest positive impact on inflation, while floods tend to reduce inflation.

This paper moves beyond these econometric studies in three ways. First, using a panel dataset, we analyse the average effects of weather-related disasters on inflation rates in the euro area. We thus provide the first comprehensive analysis of how climate change might affect the ECB's primary objective of price stability and its ability to achieve this objective. Second, we disentangle the demand and supply shock channels behind the effects of weather-related disasters on inflation. Third, by exploring the effects of weather-related disasters on inflation sub-indices, we shed light on how these disasters affect inflation inequality.

3 Data

Our sample includes monthly observations from 1996:01 to 2021:03 for 19 euro area countries.[3] To measure monthly inflation rates, we use data on headline inflation and its sub-indices.[4] Data are taken from Eurostat and capture the monthly price changes of consumer goods and services acquired by euro area households. Unlike other consumer price data, they are based on harmonised statistical methods and thus allow for cross-country comparisons. Data are available for overall headline inflation, as well as for its 12 main sub-indices and further sub-categories. This allows to disentangle differences in the direction and strength of price effects across consumption categories.

To capture the impact of weather-related disasters, we draw on the EM-DAT database from the Center for Research on the Epidemiology of Disasters (CRED) at the Université Catholique de Louvain. This extensive database with widespread coverage across countries and years is widely used in the literature (for an overview, see Felbermayr and

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[3] We exclude Croatia that adopted the euro in 2023.

[4] For details on the classification of the individual sub-indices, see: `https://ec.europa.eu/eurostat/cache/metadata/en/prc_hicp_esms.htm`.

Gröschl, 2014).[5] It comprises detailed data on weather-related disasters, such as storms, floods, droughts, temperature extremes and landslides, which have occurred worldwide since 1900. It also contains information on the strength of disasters, as well as on the number of people killed and affected and the estimated monetary damage. The EM-DAT data are compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies.

Following the literature on the macroeconomic effects of natural disasters (Noy, 2009; Noy and Nualsri, 2011; Parker, 2018; Fratzscher et al., 2020), we use the reported estimated damage as our disaster variable. This measure captures the direct damage to crops, property and livestock, measured in US dollars and valued at the moment of the event. As the effects of the disasters on inflation depend on the size of the disaster and to standardise across countries, we follow Fratzscher et al. (2020) and divide the estimated damage by the level of monthly current-price GDP in the affected country, 12 months prior to the event. Hence, our disaster variable captures the estimated monetary damage of the event in percent of GDP.

This *ex-post* measure of weather-related disasters is better suited for our analysis than alternative disaster variables, such as temperature, precipitation or wind speed. This is so for two reasons. First, the same weather-related disaster can cause very different economic damages depending on the location of the event and the adaptation measures that have been taken. For instance, the strength of a storm does not *per se* determine the economic damage that it causes. A storm in a densely populated area with low adaptive

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[5] The high data coverage is the key reason why we prefer this database over other natural disaster datasets, such as the ifo Geological and Meteorological Events (GAME) database by Felbermayr and Gröschl, for which data end in 2010.

capacity causes more damage and thereby has a stronger potential to affect inflation than a storm of the same size in an unpopulated area or in an area where measures have been taken to protect people and properties. Second, the use of monetary damages allows us to capture through a single variable the damages caused by disasters of different nature.

For our sample of euro area countries and the period 1996-2021, the EM-DAT disaster database contains 224 weather-related disasters, for which the estimated monetary damage has been reported. Table 1 displays the distribution of disaster events across countries and event types. Among our sample countries, France, Germany, Italy and Spain – the euro area's largest economies – have experienced the highest number of disasters. Storms and floods constitute the majority of events, while wildfires, extreme temperature events and droughts are more rare. Following Noy (2009) and Fratzscher et al. (2020), we weight the disasters by the occurrence within a month. Specifically, the weighted estimated damage ($wDAM$) is calculated as $wDAM = DAM(3 - OD)/3$, where DAM stands for the estimated damage, OD denotes the onset day, i.e. the reported starting day of the disaster. OD is equal to 0 if the disaster started between day 1 and 10 of a given month, it is equal to 1 for starting days between 11 and 20 of a given month, and it is equal to 2 for starting days between 21 and 31 of a given month. This accounts for the fact that events taking place earlier within a given month have a larger effect on monthly inflation than ones that occur towards the end of a month. In addition, we remove outliers through a 97.5% winsorization (see Fratzscher et al., 2020).

Table 1: Distribution of weather-related disasters across countries and event types

	Storms	Floods	Wildfires	Extr. temp.	Droughts	Landslides	Total
Austria	6	7	0	1	0	1	15
Belgium	7	2	0	0	0	0	9
Cyprus	1	0	0	0	0	0	1
Estonia	1	0	0	0	0	0	1
Finland	0	0	0	0	0	0	0
France	25	14	1	1	1	1	42
Germany	21	7	0	2	0	1	31
Greece	1	5	2	1	0	0	9
Ireland	4	1	0	0	0	0	5
Italy	8	23	1	2	3	2	39
Latvia	2	0	0	0	0	0	2
Lithuania	2	0	0	0	1	0	3
Luxembourg	1	0	0	0	0	0	1
Malta	0	0	0	0	0	0	0
The Netherlands	7	1	0	1	0	0	9
Portugal	4	2	5	0	2	1	14
Slovak Republic	1	6	0	1	0	0	8
Slovenia	2	2	0	1	0	0	5
Spain	10	12	4	1	1	1	29
Total	103	82	13	11	8	7	224

Note: *Extr. temp.* is an abbreviation for Extreme temperatures and comprises heat and cold waves.

In the cases in which several distinct disasters took place within one month, we sum over all estimated damages during that month, as in Fratzscher et al. (2020). For our disaster variable, we thus retain 213 non-zero observations. The disaster variable is measured as the estimated monetary damage of the event in percent of monthly GDP. During our sample period, the average estimated damage per disaster amounted to 1.44% of monthly national GDP, with values ranging from 0 to 28.28% (see Table 2). Table A1 in the Appendix contains a list of the 20 largest disasters in our sample.

Table 2: Disaster variable (monetary damages in percent (%) of monthly GDP)

	Obs.	Mean	Std. Dev.	Min.	Max.
Disaster variable	213	1.44	3.20	0.00	28.28
Disaster variable (weighted and winsorized)	213	0.91	2.02	0.00	12.84

We add numerous control variables to our model to account for other driving forces of inflation rates. We extract monthly data on industrial production (excluding construction) and the unemployment rate for all euro area countries, as well as on the nominal exchange rate to US dollars from the OECD's *Main Economic Indicators* and *Key Short-Term Economic Indicators* databases.[6] Data on industrial import prices are taken from Eurostat, while brent crude oil prices are extracted from the *World Bank Commodity Price Data*. With respect to variable specification, the inflation rate is estimated as the log-difference of HICP, the unemployment rate is in percent, while industrial production, the exchange rate, import prices, and oil prices are entered in econometric regressions in logs.

4 Empirical methodology

A panel structural vector autoregression (PSVAR) is used to examine the response of headline inflation and its sub-indices for a panel of 19 euro area countries to shocks imposed on our disaster variable. The analysis also controls for the drivers of inflation outlined in Section 3.[7] This approach enables us to identify the dynamics and duration of the effect of weather-related disasters on inflation. The PSVAR can be denoted as follows in its general specification, with structural shocks identified by a recursive restriction:

$$Y_{i,t} = A(L)Y_{i,t-1} + \alpha_i + \mu_{i,t} \tag{1}$$

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[6] An increase in our exchange rate variable reflects a depreciation of the euro (or the national currency in the pre-euro periods).

[7] Our control variables do not include interest rates. The inclusion of interest rates would create multicollinearity problems due to their correlation with the exchange rate and the unemployment rate.

where $Y_{i,t}$ refers to a vector of our selected endogenous variables of country i in month t; $A(L)$ is a matrix of polynomials in the lag operator L; α_i denotes country-specific fixed effects to account for unobserved time-invariant heterogeneity across countries; and $\mu_{i,t}$ is a vector of disturbances. Note that the exogenous nature of the disaster variable allows us to employ a recursive identification scheme.

Due to the autoregressive nature of the PSVAR, fixed effects are intrinsically correlated with the regressors. Hence, we use the forward orthogonal deviation procedure proposed by Arellano and Bover (1995) to eliminate fixed effects, such that the transformed variables are orthogonal to the lagged regressors. The lag structure in the PSVAR (three lags) has been selected using the Akaike Information Criterion (AIC). Following Christiano et al. (1999), the identification strategy is based on a block recursive restriction, which results in the following matrix A to fit a just-identified model:

$$A_{m,n} = \begin{pmatrix} a_{1,1} & 0 & \cdots & 0 \\ a_{2,1} & a_{2,2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ a_{m,1} & a_{m,2} & \cdots & a_{m,n} \end{pmatrix} \tag{2}$$

Even though the Arellano-Bond estimator can be sensitive to the specification, we have opted to use this estimator instead of the Least Squares Dummy Variable (LSDV) estimator for two reasons. First, our panel is unbalanced and our regressors are not strictly exogenous. Therefore, the use of the LSDV estimator would be problematic (Bruno, 2005). Second, as Judson and Owen (1999) have shown, the Arellano–Bond estimator performs well even as the time dimension increases.

The ordering of the variables imposed in the recursive form implies that the variables at the top will not be affected by the contemporaneous shocks to the lower variables while the lower variables will be affected by the contemporaneous shocks to the upper variables. We place our disaster variable at the top in the ordering, which implies that it will only be affected by a contemporaneous shock to itself. This is a reasonable identifying assumption as disasters do not respond within one period to macroeconomic variables. Following the disaster variable, we place next in the ordering oil prices (on the basis that a change in oil prices is more likely an external shock relative to the domestic business cycle), industrial production, the unemployment rate, the US dollar nominal exchange rate, and import prices. In our robustness analysis, we check whether our results change if an alternative ordering is used. Note that we have not added a linear trend in our specifications since inflation is stationary during our sample period.

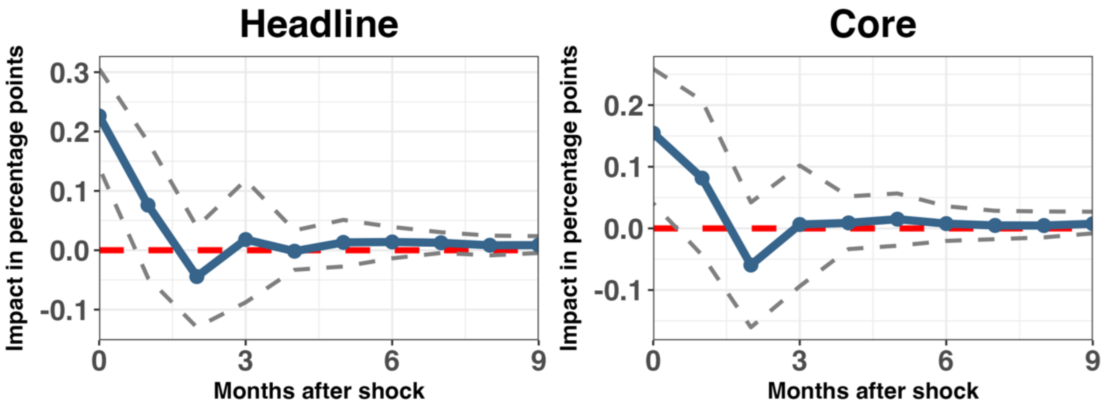
5 Results

5.1 Average country effects

Figure 1 shows the impulse responses of average headline and core inflation to a weather-related disaster shock in the euro area, together with 95% confidence intervals generated by 500 Monte Carlo repetitions. The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. We find that headline inflation in euro area countries significantly increases by 0.2 percentage points right after the disaster takes place. The magnitude of the effects declines over the subsequent 3 months and becomes insignificant. For euro area core inflation, a similar pattern as for headline inflation emerges, albeit at somewhat lower magnitudes, which is potentially explained by the fact that weather-related disasters have a more significant effect on food and energy prices. Overall, while euro area inflation responds significantly and positively to disaster shocks during the first month, these effects are not very substantial in size. Moreover, the effects are not long-lasting, as expected, and in line with the literature.

From the perspective of the transmission channels discussed in Section 2, the results shown in Figure 1 suggest that, initially, the negative supply shock channel and the positive demand shock channel outweigh the negative demand shock channel. As time passes, the channels either become very weak or offset each other.

Figure 1: Impulse responses of headline and core inflation to a weather-related disaster shock, euro area, 1996:01-2021:03



Note: The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. The grey dashed lines represent 95% confidence intervals generated by 500 Monte Carlo repetitions.

5.2 Demand-side vs. supply-side channels and average effects on inflation sub-indices

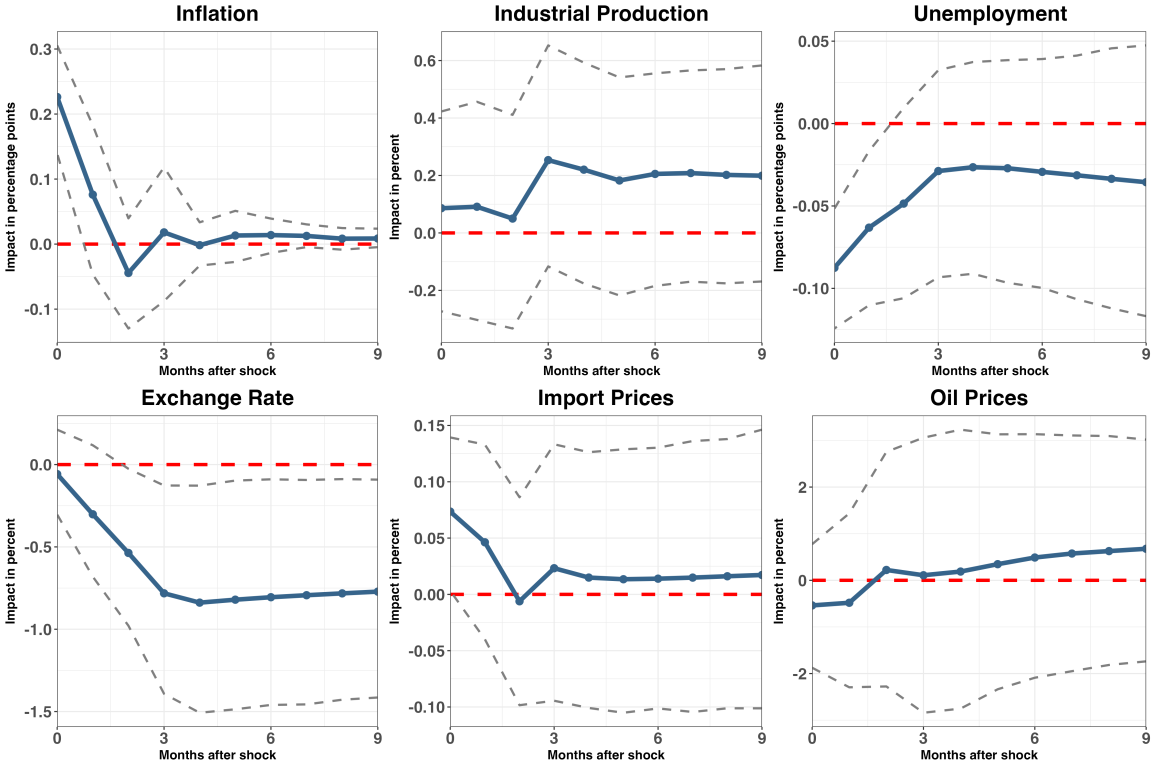
To further explore the role of demand- and supply-side effects, we show how other key macroeconomic variables respond to weather-related disaster shocks in Figure 2. Moreover, in Figure 3, we present the effects of the shocks on the prices of different product categories. As explained in Section 2, the strength of the demand- and supply-side effects is expected to differ across product categories. This allows us to get an additional understanding of how demand and supply shocks materialise.

Figure 2 shows that weather-related disasters have no statistically significant impact on industrial production, suggesting that, on average, the negative supply shock channel may not be strong enough. In addition, unemployment declines after the shock, implying that the negative demand shock channel is outweighed by the positive demand effects of reconstruction activity.

The results shown in Figure 3 imply that the demand- and supply-side channels materialise differently across product categories. In the case of ‘food and beverages’, ‘clothing, shoes’ and ‘housing, electricity, gas etc.’, inflation increases. Given the nature of these products, this seems to suggest that the negative supply shock channel dominates as a driver of inflation in these sub-indices. The increase in the inflation of ‘household equipment’ might reflect reconstruction-related demand associated with the destruction of residential properties. Finally, the decline in inflation rates related to transport and communication might reflect the decline in the demand for goods and services that are considered to be of less vital importance.

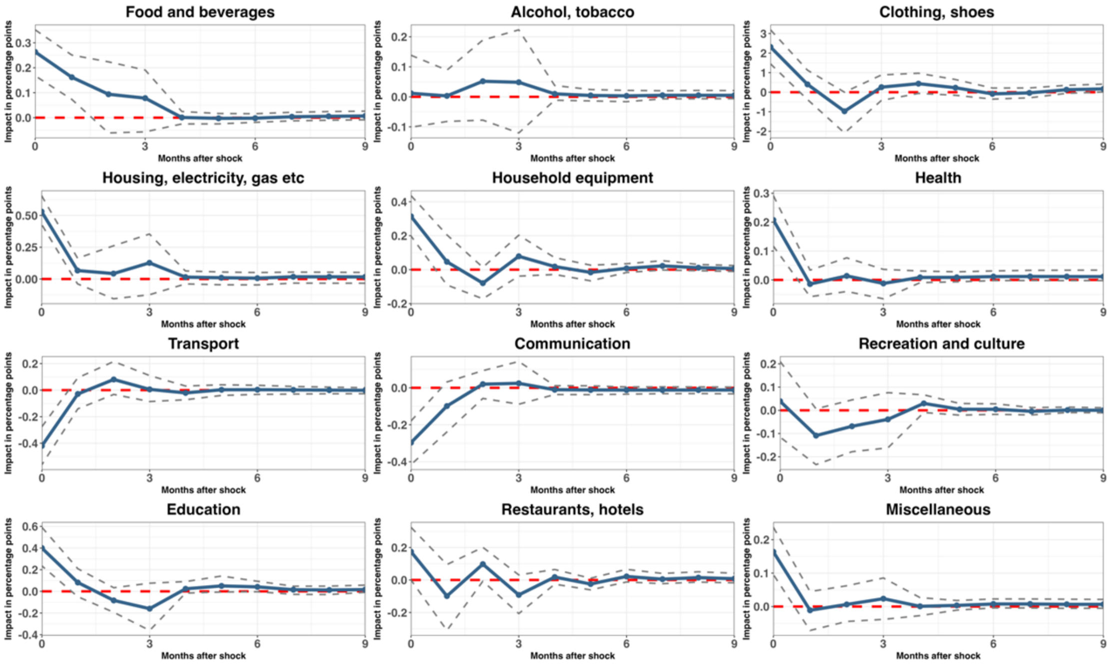
The impulse response functions in Figure 3 also suggest that weather-related disasters affect inflation inequality. As shown in Bobasu et al. (2023), the proportion of household spending on (i) electricity, gas and other fuels, (ii) actual rentals for housing and (iii) food and beverages is higher for poorer households compared to richer households in the euro area. At the same time, the share of household spending on transport is higher for richer households. These facts, in combination with the results presented in Figure 3, suggest that weather-related disasters tend to have a more pronounced effect on the inflation faced by poorer households compared to the inflation faced by richer households, reinforcing inflation inequality.

Figure 2: Impulse responses of macroeconomic variables to a weather-related disaster shock, euro area, 1996:01-2021:03



Note: The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. The grey dashed lines represent 95% confidence intervals generated by 500 Monte Carlo repetitions.

Figure 3: Impulse responses of inflation sub-indices to a weather-related disaster shock, euro area, 1996:01-2021:03



Note: The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. The grey dashed lines represent 95% confidence intervals generated by 500 Monte Carlo repetitions.

5.3 Robustness checks

We now move on to examine the sensitivity of our main findings to several robustness tests. Our sensitivity analysis focuses on: (i) the inclusion of spillover effects of disasters across countries, (ii) the successive removal of single countries from the panel to examine whether a single country drives the results, (iii) the use of different lags, and (iv) the implementation of a different panel SVAR structure using an alternative ordering of the endogenous variables. The results for the performed robustness tests are reported in the Appendix.

First, to account for the possible role of cross-country spillovers of weather-related disasters on average euro area inflation, we extend our baseline model with a foreign disaster variable in equation Eq. (1), computed as the average of weather-related disasters in all countries except country i. Controlling for foreign spillovers, our baseline results remain largely unchanged: (i) we continue to find a statistically significant positive impact of weather-related disasters on average headline and core euro area inflation in the short run (Figure A1); and (ii) with the exception of 'clothing, shoes', the sign and the statistical significance of impact of the disaster shock on inflation sub-indices remains the same as in the baseline results (Figure A2). This suggests a limited effect of foreign spillovers, as expected.

Second, to explore whether our results are driven by a specific country, we re-estimate our baseline model by dropping one country at a time. Our results are largely consistent: in the vast majority of cases, the short-run effect of the disaster shock on headline inflation remains positive and statistically significant (see Figure A3). When we drop Lithuania or Slovenia, the effect loses statistical significance. However, the results on the effects of the disaster shock on inflation sub-indices, when Lithuania or Slovenia are dropped, allay concerns (see Figures A4 and A5). The vast majority of the inflation sub-indices are affected in the same way as in the baseline results. In addition, our finding about the impact of the disaster shock on inflation inequality does not change: the effect of the disaster shock on the 'food and beverages' and 'housing, electricity, gas etc.' inflation sub-indices remains positive and statistically significant, while the effect on the 'transport' sub-index remains negative and statistically significant. As we explained above, changes in these inflation sub-indices are the key drivers of inflation inequality.

Third, although in our baseline setup, the lag length has been selected based on the AIC criterion, it is worth exploring whether changing the lag length has an impact on our results. We therefore re-estimate the model using alternative lags ranging from 1 to 12 months. As shown in Figure A6, the immediate response of headline inflation to the disaster shock is positive and statistically significant irrespective of the lag length.

Fourth, we check whether the results are sensitive to the ordering of the endogenous variables used in our identification scheme. To do so, we impose an alternative Cholesky ordering in the estimation of Eq. (1). Different from the baseline setup, we place industrial production, the unemployment rate, the US dollar nominal exchange rate, import prices and oil prices next in the ordering, after the disaster variable which remains at the top. We find no major changes in the direction, scale and statistical significance of the impulse response of headline and core inflation to a disaster shock, compared to our baseline results (see Figure A7).

Overall, the sensitivity analysis suggests that our baseline results are largely robust across the tests performed. In the two cases where statistical significance is lost for headline inflation (i.e. when Lithuania or Slovenia are dropped from the sample), the effect of the disaster shock is not reversed and the impacts on inflation sub-indices are largely the same as in the full panel results. Therefore, we can confidently argue that the negative supply shock and positive demand shock channels tend to prevail over the negative demand shock channel in the euro area, immediately after a weather-related disaster shock. Moreover, in these two cases, the finding about the adverse effect of the disaster shock on inflation inequality remains unchanged.

6 Conclusion

This paper contributes to the growing literature about the effects of climate change on inflation. Using a PSVAR approach, we estimate the effects of weather-related disasters on inflation and its main sub-indices in the euro area over the period 1996-2021. Our results suggest that headline inflation increases in the aftermath of a disaster, without this effect being long-lasting. This positive effect of weather-related disasters on inflation implies that, at the aggregate level, the adverse effects of disasters on the supply-side of the economy and the positive demand-side effects related to reconstruction activity outweigh any weather-related decline in demand.

Our analysis about inflation sub-indices shows that the effects of weather-related disasters on different product categories are highly heterogeneous. The negative supply shock channel seems to dominate in product categories such as ‘food and beverages’, ‘clothing, shoes’ and ‘housing, electricity, gas etc.’, creating inflationary pressures. For ‘household equipment’, inflation also increases after a weather-related disaster, but this is more likely to stem from the increase in reconstruction-related demand as a result of the destruction of residential properties. In contrast, disasters lead to a reduction in the inflation in transport and communication, potentially reflecting the decline in the demand for non-essential goods and services.

Our results are particularly important from an inflation inequality perspective. Those goods and services that represent a higher proportion of poor households’ spending in the euro area experience an increase in inflation after weather-related disasters. In contrast, inflation goes down for goods and services that are proportionally more important for the spending of high-income households. Therefore, weather-related disasters reinforce inflation inequality.

Our empirical results have several implications for the ECB's monetary policy in the climate crisis era. First, as global warming accelerates, climate-induced disaster impacts on inflation in the euro area might increase. Thus, the management of inflation by the ECB is likely to become more challenging in the future, especially if short-run climate-induced inflationary pressures lead to second-round effects in the medium run and affect inflation expectations. Second, the challenges facing the ECB in managing inflation are likely to be exacerbated by the fact that changes in the policy rate cannot directly address the inflationary pressures that stem from the negative supply shock channel of weather-related disasters. On top of that, an increase in the ECB policy rate as a response to climate-induced inflation might harm reconstruction activity as well as investment in climate resilience. Although this activity might be inflationary in the short run, reconstruction is necessary for rebuilding the supply side of the economy – without this rebuilding, inflationary pressures might be higher in the medium run. Therefore, the effectiveness of the ECB policy rate as a tool for managing climate-induced inflation might be low. Third, the divergent inflation responses to weather-related disasters at the product level suggest that the climate crisis is likely to increase inflation inequality. This might call into question the rationale of targeting an aggregate index of inflation. Finally, given these potentially fundamental effects of climate change on the ability of the ECB to achieve its inflation target, the ECB needs to consider how it can use more actively its monetary policy and prudential tools to contribute to the reduction of emissions in the context of its ongoing climate action plan.[8] Contributing to an alignment

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[8] For several proposals in this direction, see e.g. Dafermos et al. (2021, 2023), Dikau et al. (2021) and

of the financial system with a net-zero pathway in order to prevent catastrophic climate change is the best way for the ECB to mitigate climate-induced disruptions to its ability to achieve price stability.

Importantly, our analysis has only considered the physical impacts of climate change on inflation. We have not analysed transition impacts. As part of its European Green Deal, the EU has committed to achieving climate neutrality by 2050 – a goal that has been made legally binding by the European Climate Law. Climate policies that intend to achieve the decarbonisation of the EU economy, such as carbon pricing, are likely to affect inflation and complicate the monetary policy decision-making process (McKibbin et al., 2020; Moessner, 2022). Moreover, the transition to net-zero can be expected to cause large-scale structural changes in EU member countries (Semieniuk et al., 2021), which may affect both short- and long-run inflation dynamics. Overall, it is imperative for the ECB to carefully consider the impacts of climate change on price stability and do whatever it takes to support a smooth transition of the EU to a climate-neutral economy.

Kriwoluzky and Volz (2023).

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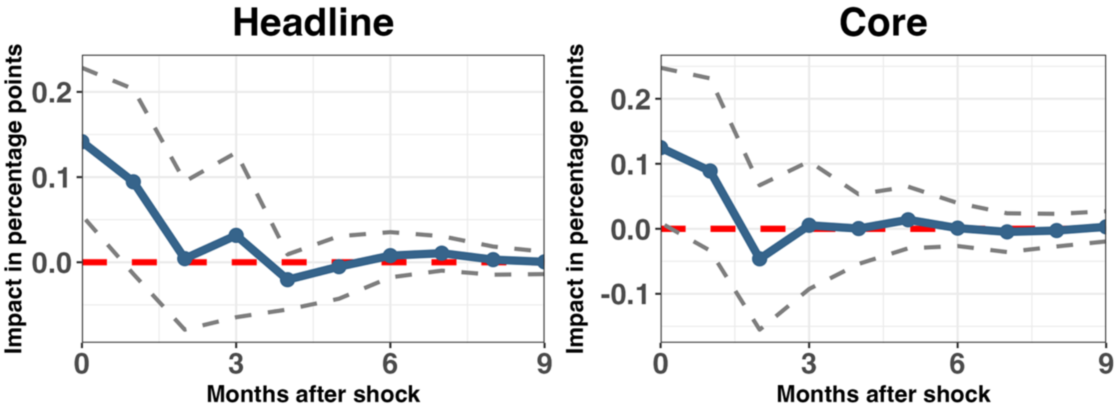
Appendix

Table A1: Large weather-related disasters and their estimated damages

Country	Event type	Date	Damage	Damage over GDP
Latvia	Storm	01/2005	0.49	28.28
Portugal	Wildfire	08-09/2003	2.75	15.45
Austria	Flood	08/2002	3.90	14.60
Estonia	Storm	01/2005	0.19	12.84
Portugal	Wildfire	05-07/2005	2.47	10.47
Lithuania	Drought	08/2006	0.33	10.38
Slovak Republic	Storm	11/2004	0.59	9.81
Portugal	Drought	09/2004	2.07	9.73
Slovenia	Storm	09/2007	0.41	8.87
Greece	Wildfire	08/2007	2.47	7.68
Italy	Flood	10/2000	13.60	7.68
Germany	Flood	08/2002	18.87	7.16
Portugal	Flood	02/2010	1.81	6.64
France	Storm	12/1999	14.06	6.33
Greece	Wildfire	06-08/1998	1.21	6.25
Slovenia	Flood	11/2012	0.34	6.17
Spain	Drought	04/1999	5.62	6.16
Slovak Republic	Extreme Temperature	07-08/2003	0.24	5.11
Greece	Flood	02/2003	0.95	4.67
Slovak Republic	Flood	06-07/1999	0.20	4.54

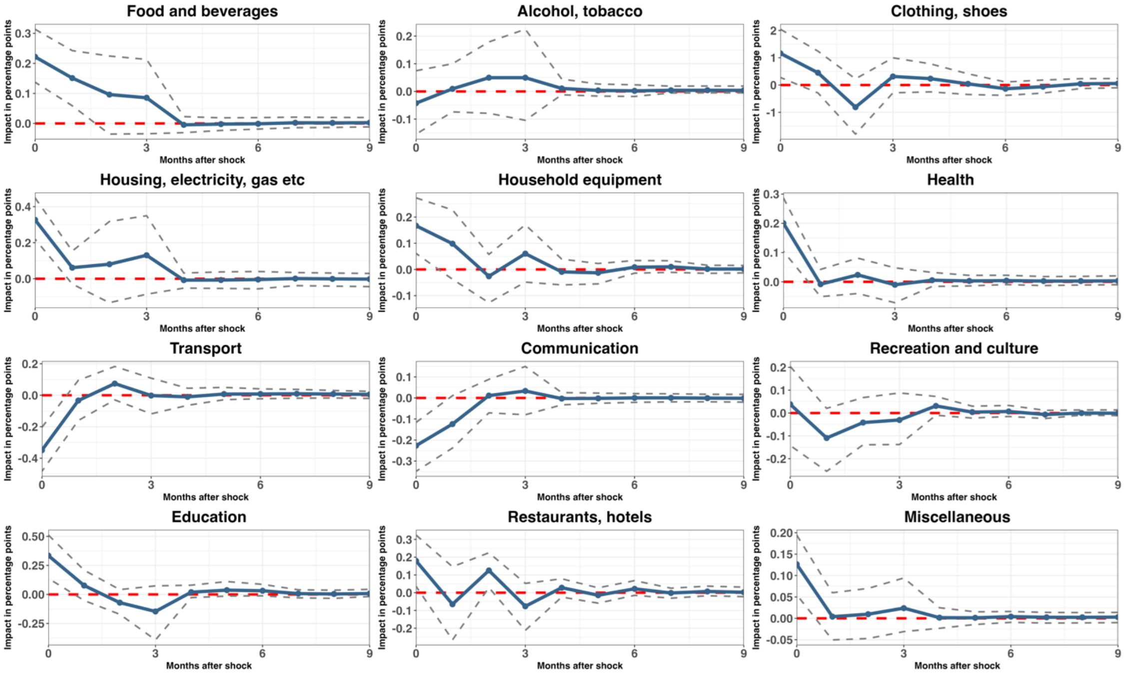
Note: *Damage* is reported in inflation-adjusted billion US dollars. *Damage over GDP* is reported as the current-price damage in percent of monthly current-price GDP in the respective country, 12 months prior to the event.

Figure A1: Impulse responses of headline and core inflation to a weather-related disaster shock with foreign spillovers, euro area, 1996:01-2021:03



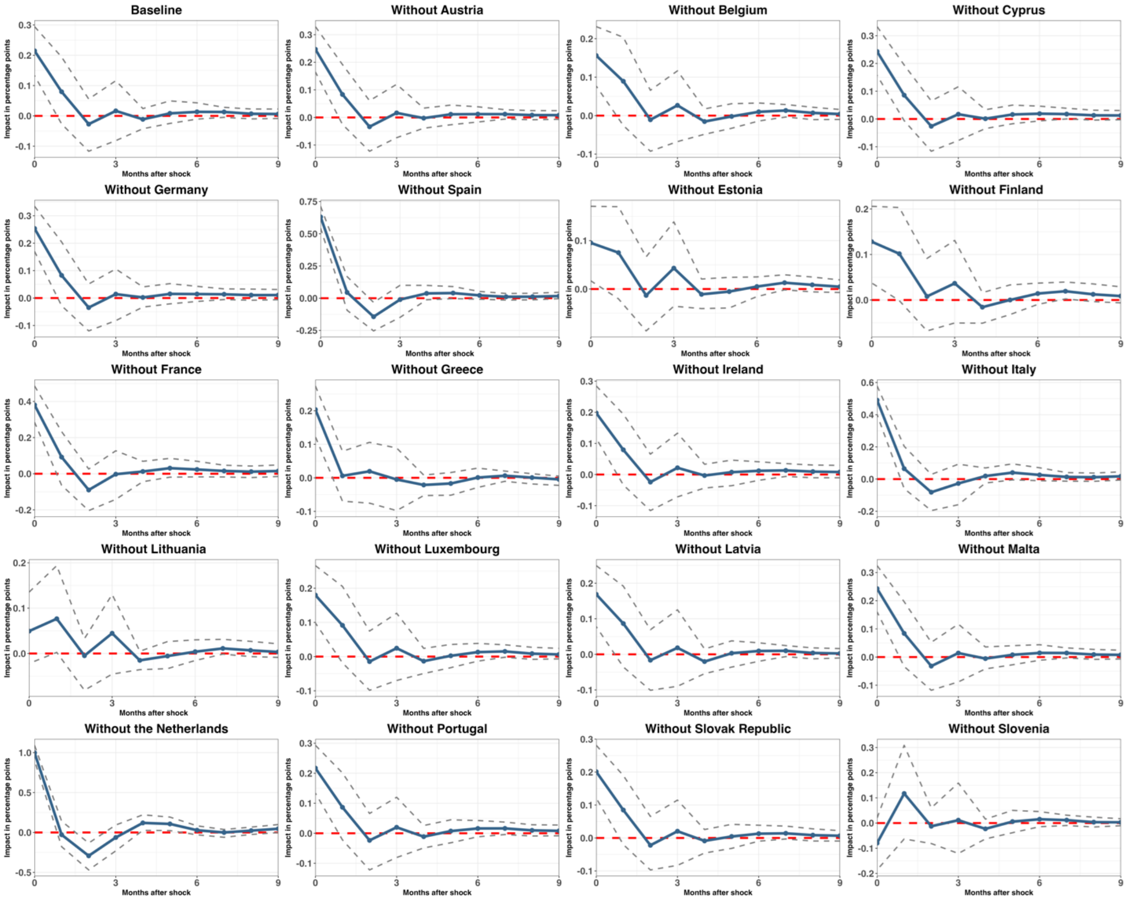
Note: The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. The grey dashed lines represent 95% confidence intervals generated by 500 Monte Carlo repetitions. To account for foreign spillovers, we extend our baseline model in Eq. (1) by adding a foreign disaster variable, computed as the average of weather-related disasters in all countries except country i.

Figure A2: Impulse responses of inflation sub-indices to a weather-related disaster shock with foreign spillovers, euro area, 1996:01-2021:03



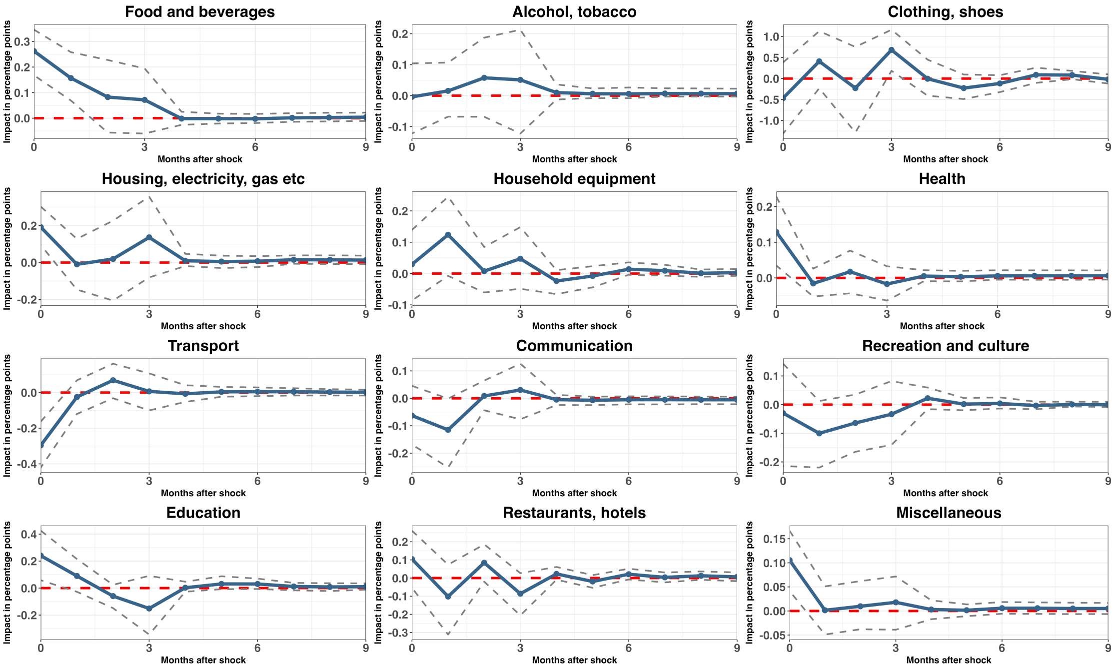
Note: The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. The grey dashed lines represent 95% confidence intervals generated by 500 Monte Carlo repetitions. To account for foreign spillovers, we extend our baseline model in Eq. (1) by adding a foreign disaster variable, computed as the average of weather-related disasters in all countries except country i.

Figure A3: Impulse responses of headline inflation to a weather-related disaster shock after dropping one country from the panel at a time, euro area, 1996:01-2021:03



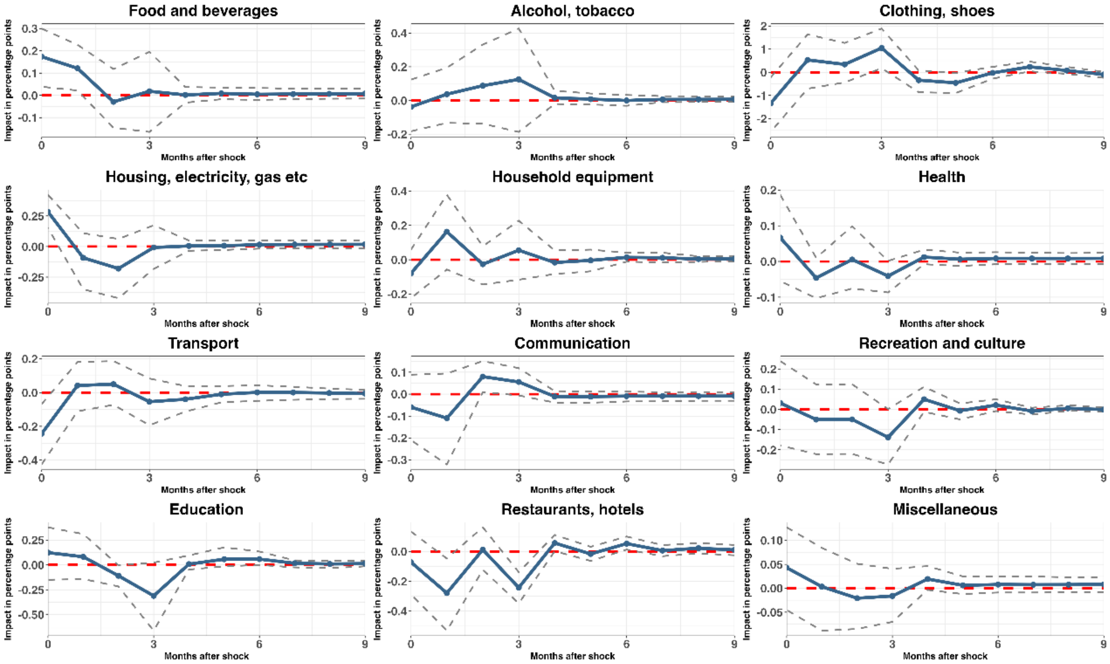
Note: The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. The grey dashed lines represent 95% confidence intervals generated by 500 Monte Carlo repetitions.

Figure A4: Impulse responses of inflation sub-indices to a weather-related disaster shock, euro area panel without Lithuania, 1996:01-2021:03



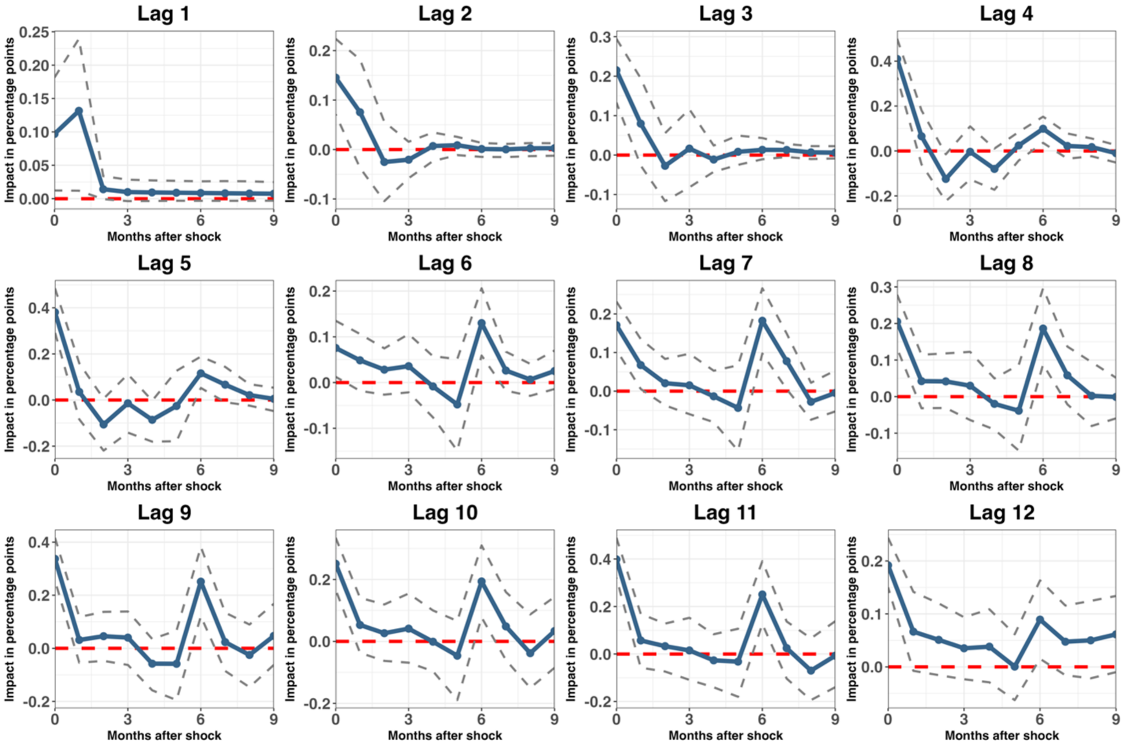
Note: The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. The grey dashed lines represent 95% confidence intervals generated by 500 Monte Carlo repetitions.

Figure A5: Impulse responses of inflation sub-indices to a weather-related disaster shock, euro area panel without Slovenia, 1996:01-2021:03



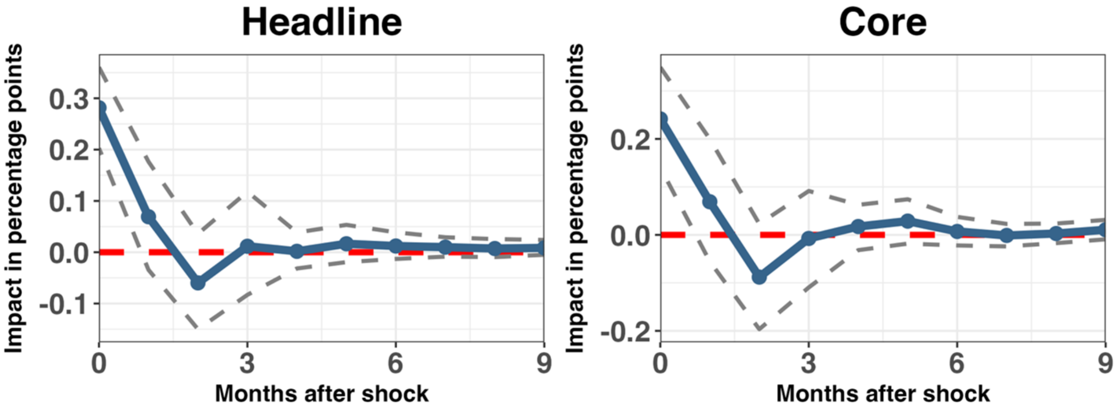
Note: The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. The grey dashed lines represent 95% confidence intervals generated by 500 Monte Carlo repetitions.

Figure A6: Impulse responses of headline inflation to a weather-related disaster shock under different lag structures, euro area, 1996:01-2021:03



Note: The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. The grey dashed lines represent 95% confidence intervals generated by 500 Monte Carlo repetitions.

Figure A7: Impulse responses of headline and core inflation to a weather-related disaster shock for an alternative ordering of the endogenous variables, euro area, 1996:01-2021:03



Note: The disaster shock captures an increase in weather-related monetary damages by one percentage point of monthly GDP. The grey dashed lines represent 95% confidence intervals generated by 500 Monte Carlo repetitions. According to the alternative ordering, industrial production, the unemployment rate, the US dollar nominal exchange rate, import prices and oil prices are placed next after the disaster variable.