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SHORT-RUN SPILLOVER EFFECTS OF CLIMATE SHOCKS TO SMALL OPEN ECONOMIES: AN EMPIRICAL INVESTIGATION

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SHORT-RUN SPILLOVER EFFECTS OF CLIMATE SHOCKS TO SMALL OPEN ECONOMIES: AN EMPIRICAL INVESTIGATION[1]

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This study extends recent work in the climate literature by examining how climate shocks- specifically temperature and precipitation anomalies – spill over across borders, influencing inflation and real economic variables. Using high-resolution gridded climate data, I construct sector-sensitive climate shock measures and embed them in a large two-country VAR framework for Italy and Malta. The analysis shows that climate shocks in Italy can generate inflationary pressures in Malta, particularly through processed food prices, services, and producer prices in food manufacturing. Droughts generate effects similar to those of summer temperature shocks, suggesting a shared transmission pattern across the two countries considered. Importantly, once a shock "crosses borders", it may materialize in different inflation components in Malta reflecting country-specific transmission channels. These findings underscore the importance of cross-border climate vulnerability, especially for small open economies that are closely integrated with larger trading partners.

Introduction

Over the past few decades, global average temperatures have risen sharply, reaching unprecedented levels. Although the increase in average global temperature – around 2°C compared to pre-industrial levels – may appear modest in absolute terms, its environmental consequences have been profound. For instance, the Antarctic alone has lost an average of 107 gigatonnes of ice per year, highlighting the scale of climate-related transformations (Kulp and Strauss, 2019; Morlighem et al., 2020; Otosaka et al., 2022).

These alarming trends have attracted the attention of policymakers, seeking to understand how and to what extent weather phenomena can affect economic activity. A growing body of literature recognise climate change as a major economic threat with the potential to disrupt output and cause inflationary pressures (Dell et al., 2012). The literature documents a negative relationship between rising temperatures and output (Colacito et al., 2019; Kolstad and Moore, 2020) and identifies channels through which weather shocks can affect the economy (Kalkuhl and Wenz, 2020; Dasgupta et al., 2021), including effects on inequality (Mumtaz and Theophilopoulou, 2023).

Recent studies have begun to explore the implications for inflation. Ciccarelli et al. (2023) show that weather shocks influence inflation components across European countries with asymmetric and seasonal effects expanding previous approaches in the literature that underline similar effects (Faccia et al., 2021). Their study estimates country-specific VARs in order to compare the effect of a temperature shock among the big four economies in the euro area. However, little attention has been paid to cross-border transmission beyond aggregate euro area and World control variables (see Burke et al., 2015). This paper addresses the gap by proposing a two-country VAR that explicitly incorporates a small open economy assumption allowing interactions between a large economy and a smaller trading partner.

The paper extends Ciccarelli et al. (2023) by examining spillover effects of temperature shocks and droughts from Italy to Malta. Proxies for climate shocks are derived from high-resolution gridded data, weighted by agricultural gross value added at Nuts 2 level for Italy (see Kotz et al., 2021 and Kotz et al., 2023). This approach allows for seasonal and sector-specific transmission of climate shocks to real activity and inflation in each country.

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Malta's heavy reliance on Italy for food imports, electricity, manufactured goods, and tourism, creates significant one-sided exposure to Italian climate shocks. The results show that Italian shocks are transmitted to Malta with effects of similar magnitude, but they often appear in different components of domestic inflation. For instance, Malta "imports" inflation movements that are mainly visible in processed food, services, and goods. Aggregate activity in Malta mirrors the movements in Italy, except for energy production which tends to compensate the dynamics observed in Italy. This study also highlights that droughts, while similar to summer temperature shocks tend to be more concentrated and pronounced in the agricultural sector, whereas temperature shocks generate broader economy-wide effects. Together, these results emphasize the importance of cross-border climate vulnerability, particularly for small open economies like Malta deeply integrated with larger trading partners.

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From a policy perspective, these findings underline the importance of considering indirect and sector-specific transmission paths when assessing the domestic consequences of foreign climate shocks. For instance, a shock that raises unprocessed food prices in Italy may instead emerge in Malta through higher processed food or services inflation, reflecting country-specific structures and trade flows. Recognising this potential "reshuffling" of sectoral impacts is essential for policymakers in small open economies, as aggregate indicators may mask vulnerabilities among particular household groups or industries.

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Methodology

The overall setup follows the Bayesian VAR introduced in Carriero et al. (2016) parameterized in a Kronecker structure following Chan (2020). The general frame of the model is as follows:

$$Y_t = C_t + \sum_{p=1}^{P} B_p Y_{t-p} + A Z_t + U_t$$

Where Y_t is a matrix of endogenous macroeconomic variables, C_t collects the constant terms of the VAR, B_p is a matrix of coefficients of the lagged endogenous data, A is the matrix of coefficients of the exogenous terms Z_t (i.e. the weather proxy) and U_t collects the reduced form residuals.

The model is partitioned into two blocks: the Maltese and the Italian block as follows:

$$\begin{bmatrix} y_t^{MT} \\ y_t^{IT} \end{bmatrix} = \begin{bmatrix} c^{MT} \\ c^{IT} \end{bmatrix} + \sum_{p=1}^{P} \begin{bmatrix} B_p^{MT} & B_p^{IT \to MT} \\ 0 & B_p^{IT} \end{bmatrix} \begin{bmatrix} y_{t-p}^{MT} \\ y_{t-p}^{IT} \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & A^{IT} \end{bmatrix} \begin{bmatrix} Z^{IT} \\ Z^{IT} \end{bmatrix} + \begin{bmatrix} u_t^{MT} \\ u_t^{IT} \end{bmatrix}$$

where all coefficients and variables can be interpreted in a partitioned, i.e., *country-specific* way. For instance, y_t^{IT} captures the Italian block of macroeconomic variables and the coefficient matrix, $B_p^{IT \to MT}$, are the coefficients driving the spillover of Italian variables onto the Maltese ones. A small-country assumption is imposed by setting tight priors around zero for Maltese variables in the Italian equations, allowing only one-sided spillovers from Italy to Malta (see Gatt and Ruisi, 2022 and Ruisi, 2023).

Climate shocks are introduced as exogenous variables, Z^{IT}, which are assumed to hit Italy first. This assumption translates in the model via the structure of matrix A. The first effect of a shock originating in Italy on the Maltese economy, is determined by $B_p^{IT \rightarrow MT}$, which captures the slope coefficients of the Italian block in the Maltese equations and affects Maltese variables with one lag.

In line with Ciccarelli et al. (2023), shocks are interacted with seasonal dummies to capture non-linearities as follows:[2]

$$Z_t = winter * z_t + spring * z_t + summer * z_t + autumn * z_t$$

with *winter, spring, summer, autumn* being seasonal dummies that equal 1 for the specific season.[3] The VAR includes six lags for macroeconomic variables and no lags for the climate proxies. Impulse responses are normalised to the 90th percentile of each season's distribution, facilitating cross-season comparability.

Data

The VAR comprises a large set of macroeconomic variables over the period ranging from January 2001 until December 2024. All endogenous macroeconomic variables are transformed into year-on-year growth rates.

For each country, inflation has been disaggregated into, processed food, unprocessed food, non-energy industrial goods (NEIG), services, and electricity & gas. Additionally, the data include total industrial production (excluding energy), energy production, producer prices, energy producer prices, and producer prices in the food manufacturing sector. To control for broader dynamics, euro area aggregates (HICP, industrial production, farm-gate prices) and global agricultural commodity prices are also included, following the GVAR literature (Burke et al., 2015; Chudik and Pesaran, 2016).

Climate data are drawn from the ERA5 reanalysis dataset introduced in Hersbach et al. (2020) which combines model simulations with meteorological data and provides a consistent data set that covers the entire globe at a high spatial resolution (0.25 degrees X 0.25 degrees grid cell). I use hourly data of every grid cell above Italy and compute monthly deviations from the long-term mean in each grid cell.[4] Temperature is measured in Celsius, 2 meters above the surface, and precipitation represents any form of rainfall or precipitation that occurred within the grid cell. The value represents the height, in millimetres, that the water would reach if it was evenly distributed across the grid cell. Unlike temperature, where the proxy captures one-time shocks, for precipitation I calculate the cumulative seasonal deviation. Specifically, I sum monthly precipitation anomalies within each season and compare the total to the 10th percentile of that season's historical distribution. If cumulative precipitation falls below the 10th percentile of the seasonal distribution, the entire season is classified as a drought.

Results

Impulse response functions (IRFs) to temperature shocks

Figures 1, 2 and 3 present the seasonal responses to a temperature shock in Italy on specific sectors of the two economies.

In Italy, milder winter temperatures reduce energy production and prices, while hotter summers increase both. These dynamics spill over to Malta, but consumer energy prices are largely insulated by government subsidies. Interestingly, a countercyclical pattern emerges in energy production between the two countries, reflecting the Malta-Italy interconnector installed in 2015: an increase (decrease) in energy production in Italy is accompanied by a decrease (increase) in domestic energy production in Malta.[5]

Food prices in Italy react strongly to positive temperature anomalies: consumer food prices fall in cooler months but rise in summer, with processed food showing stronger and more persistent effects. Moreover, results show there is a heightened responsiveness of processed food prices relative to those of unprocessed food. This result may be due to the former's reliance on other sectors, particularly energy and/or transport. Producer prices mirror this seasonal

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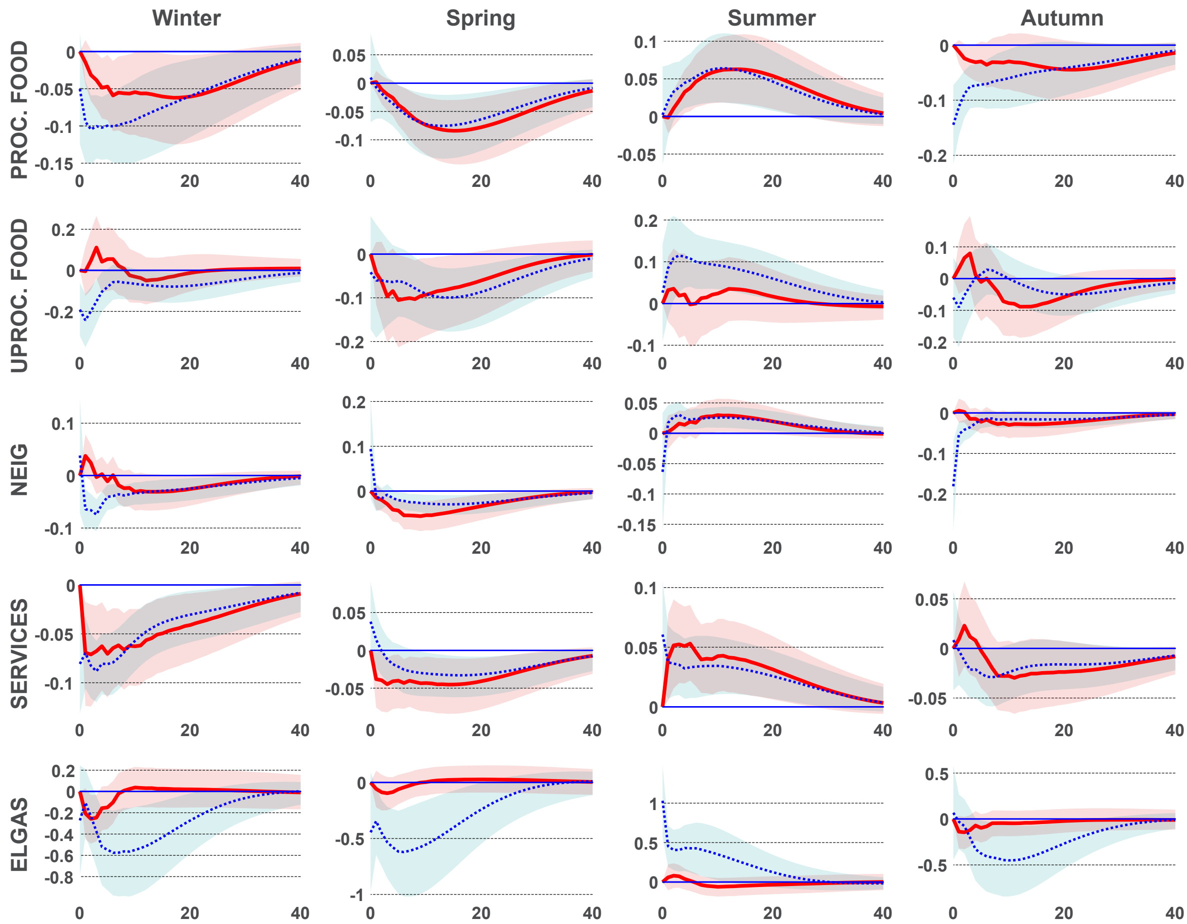
2 Note, in the case of droughts the variable Z_t drops to a binary drought indicator with 1 = *drought*.

3 The seasons are defined meteorologically: $winter = Dec.;\ Jan.;\ Feb,\ spring = Mar.;\ Apr.;\ May, summer = Jun; Jul.;\ Aug., autumn = Sep.;\ Oct.;\ Nov.$

4 Meteorologically, the long-term mean is computed over 30 years (1990-2020).

5 Ending the sample before the installation of the interconnector leads to comoving IRFs.

Figure 1
SPILLOVER EFFECTS OF A TEMPERATURE SHOCK ON HICP COMPONENTS IN MALTA

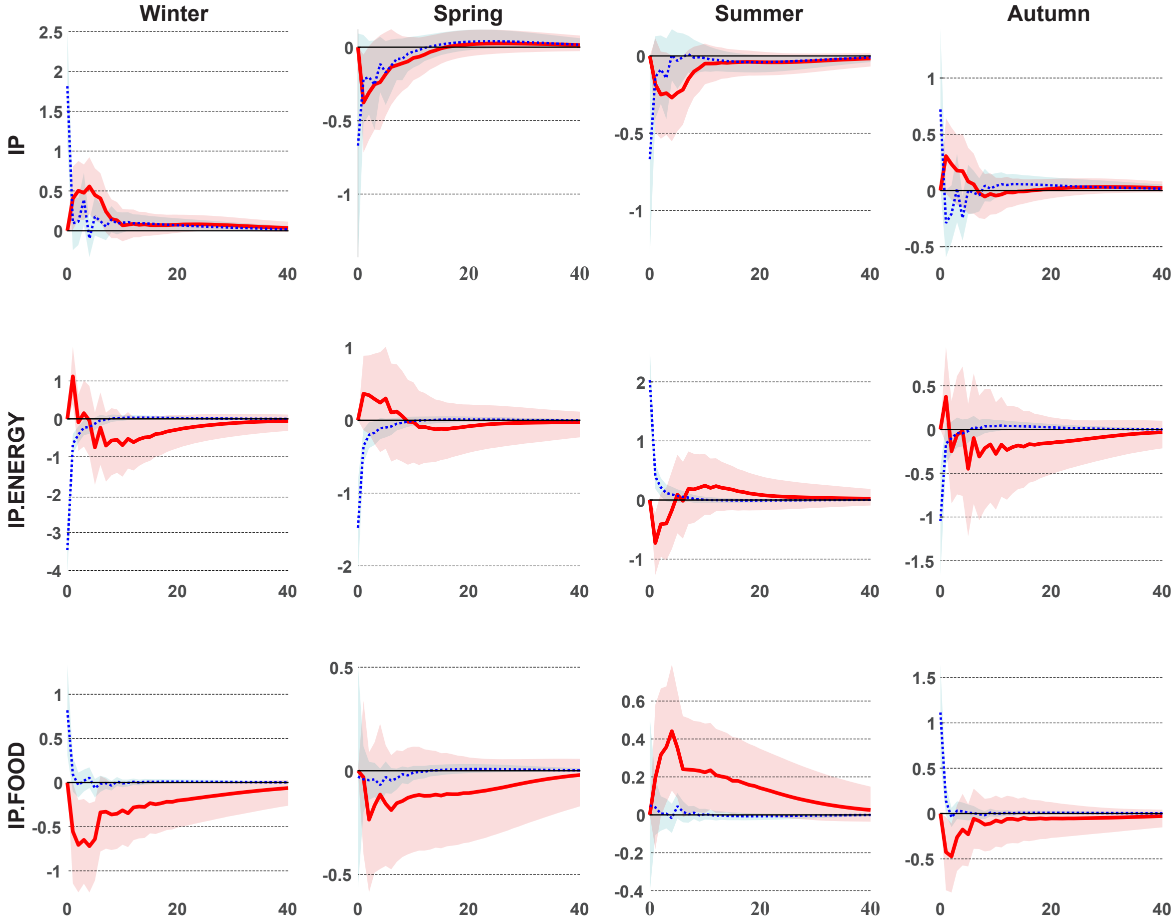


Note: The figure displays IRFs for selected Italian (blue) and Maltese (red) macroeconomic variables, with 68% credibility bands shown around the median responses. The temperature shock is normalised to represent an increase equal to the 90th percentile of the seasonal temperature distribution, capturing the effect of an extreme temperature event within each season.

pattern. The results suggest that milder winter temperatures enhance agricultural productivity in Italy, leading to lower prices, while extreme heat in summer may stress agricultural production and increase energy demands, thereby raising production costs. Notably, both the peak effect and the duration of responses to temperature shocks differ between consumer and producer prices. While producer price responses tend to be strong yet short-lived, the impact on consumer prices, particularly in summer, is more gradual and can persist for over 20 months. This prolonged effect highlights the broader transmission mechanisms and potential lag between production disruptions and their full appearance in consumer markets.

Turning to results for Malta, one can note that there are significant spillover effects that are evident for processed food and food manufacturing prices. These tend however to be weaker for unprocessed food, with the latter's price responses being largely statistically insignificant, especially when shocks materialise in summer or winter. These results might reflect Malta's limited yet important reliance on domestic unprocessed food production as well as diversified sources for unprocessed food imports, which somehow limit the spillover effects of temperature shocks in Italy.

Figure 2
SPILLOVER EFFECTS OF A TEMPERATURE SHOCK ON PRODUCTION VOLUMES IN MALTA

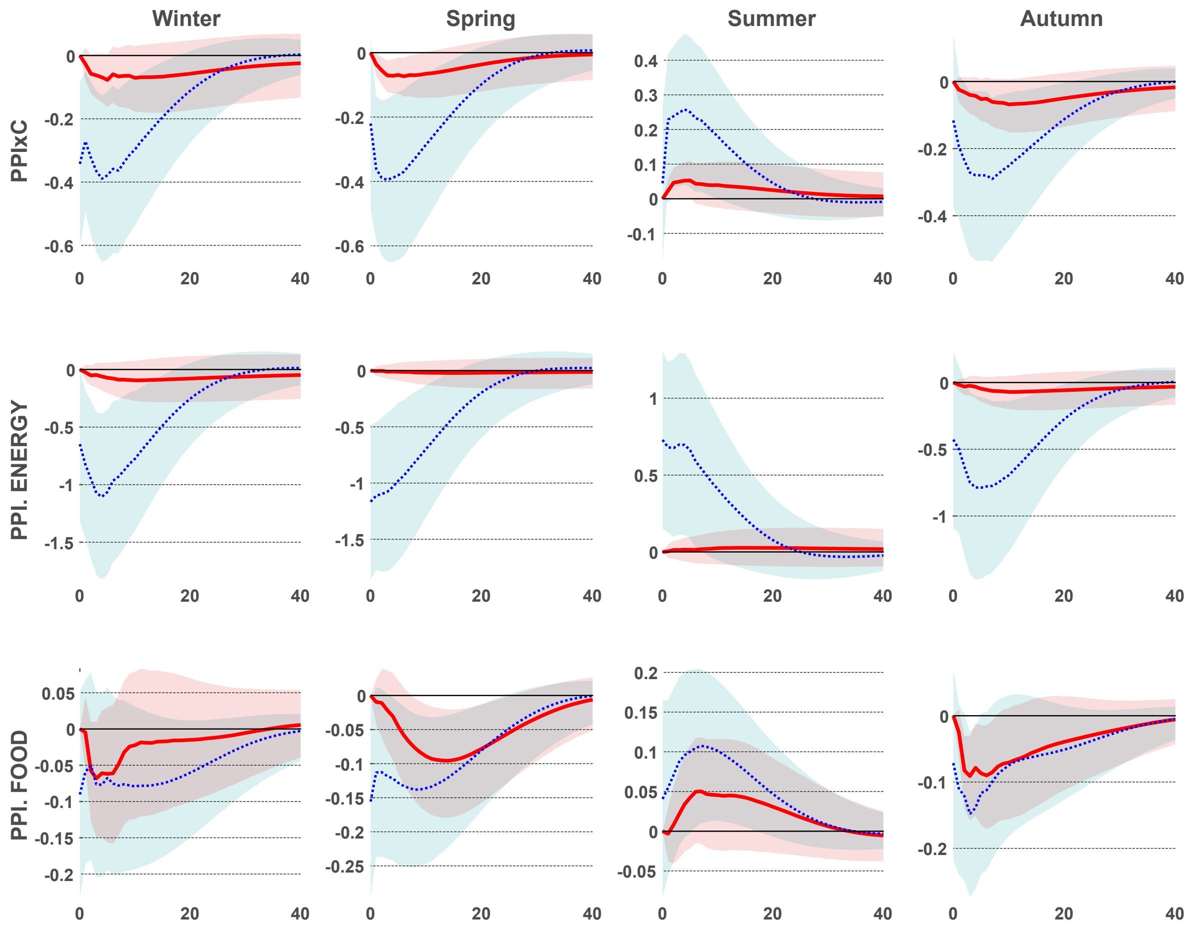


Note: The figure displays IRFs for selected Italian (blue) and Maltese (red) macroeconomic variables, with 68% credibility bands shown around the median responses. The temperature shock is normalised to represent an increase equal to the 90th percentile of the seasonal temperature distribution, capturing the effect of an extreme temperature event within each season.

Consumer prices in the **service** sector exhibit pronounced seasonal effects that align with the patterns observed in the energy and food sectors. This is not surprising, given the interconnected nature of these components – energy, food, and goods all serve as fundamental inputs into the service sector. Specifically, a positive temperature shock tends to lower service prices during the colder months, while driving them higher during the warmer months. For Italy, the magnitude and persistence of these effects are closely aligned with those observed in processed food prices, suggesting similar underlying transmission mechanisms. Nonetheless, it should be acknowledged that a substantial portion of the seasonal variation may also be influenced by other driving forces, which deserve consideration alongside input-related factors.

Examining the spillover effects, Malta's service price responses follow a comparable shape but are marked by some overshooting in some seasons. A spring/summer temperature shock in Italy results in a slightly more pronounced increase in Maltese service prices than in Italy itself. This difference is likely attributable to structural differences in the composition of the service sector across the two countries. Insights from the services index decomposition

Figure 3
SPILLOVER EFFECTS OF A TEMPERATURE SHOCK ON PRODUCER PRICES IN MALTA



Note: The figure displays IRFs for selected Italian (blue) and Maltese (red) macroeconomic variables, with 68% credibility bands shown around the median responses. The temperature shock is normalised to represent an increase equal to the 90^{th} percentile of the seasonal temperature distribution, capturing the effect of an extreme temperature event within each season.

suggest that the stronger response in Maltese service prices can be associated to a higher sensitivity of the accommodation and catering sector to external shocks, such as the temperature shocks considered here.[6]

The response of **NEIG** in Italy, shows a seasonal behaviour in line with the narrative of an energy pass-through to goods inflation. Furthermore, temperature shocks have smaller but longer lasting effects on goods prices than in the other sectors in winter and summer, and negligible effects in other seasons. Results also find evidence for limited yet statistically significant spillover of temperature shocks to NEIG prices. Nonetheless, Malta's responses seem to be more gradual, showing an element of imperfect passthrough in the very short run.

Looking at **real activity,** the study finds that aggregate production in Italy increases in the winter and autumn months, which appear to be the seasons where the spillover effects induce significant movements in the business cycle conditions index in Malta.

6 An IRF decomposition, available on request, shows that Italian unprocessed food was the largest contributor to the observed response in service prices of Figure 1, and their relative high share in Maltese imports, may explain the strong spillover to service prices in Malta.

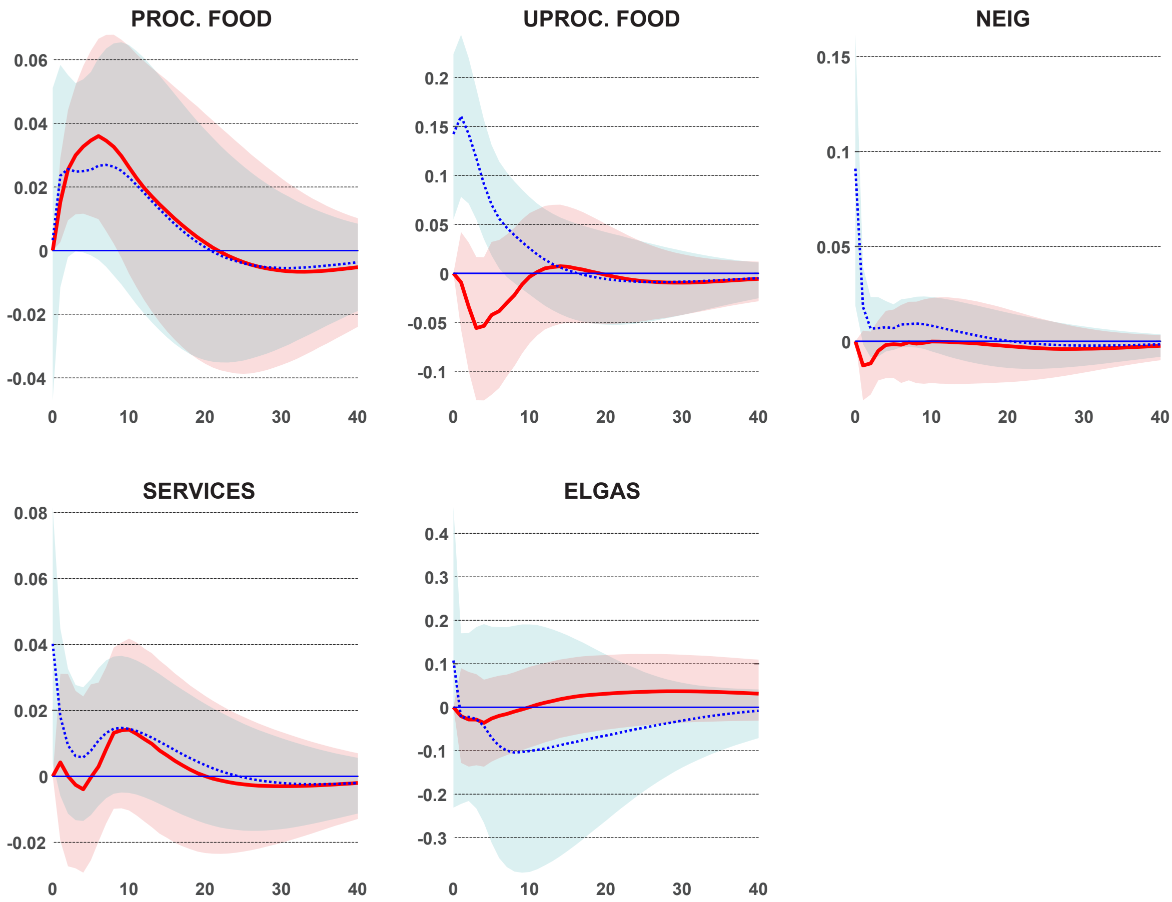
Impulse response functions to droughts

Figures 4 and 5 show the sectoral responses in Italy and Malta to a drought originating in Italy. As explained in the previous sections this exercise abstracts from seasonal considerations by setting the proxy, Z_t, to a binary column vector with 1 indicating the presence of a drought and 0 otherwise.

A drought leads to an immediate increase in energy production in Italy, suggesting heightened energy consumption across the economy, in particular in manufacturing processes. Conversely, and differently from temperature shocks, consumer prices for electricity and gas (ELGAS) remain largely unaffected by drought conditions. As for spillover effects, Malta experiences a slight decline in energy production, likely linked to the role of the Malta-Italy interconnector, as previously discussed.

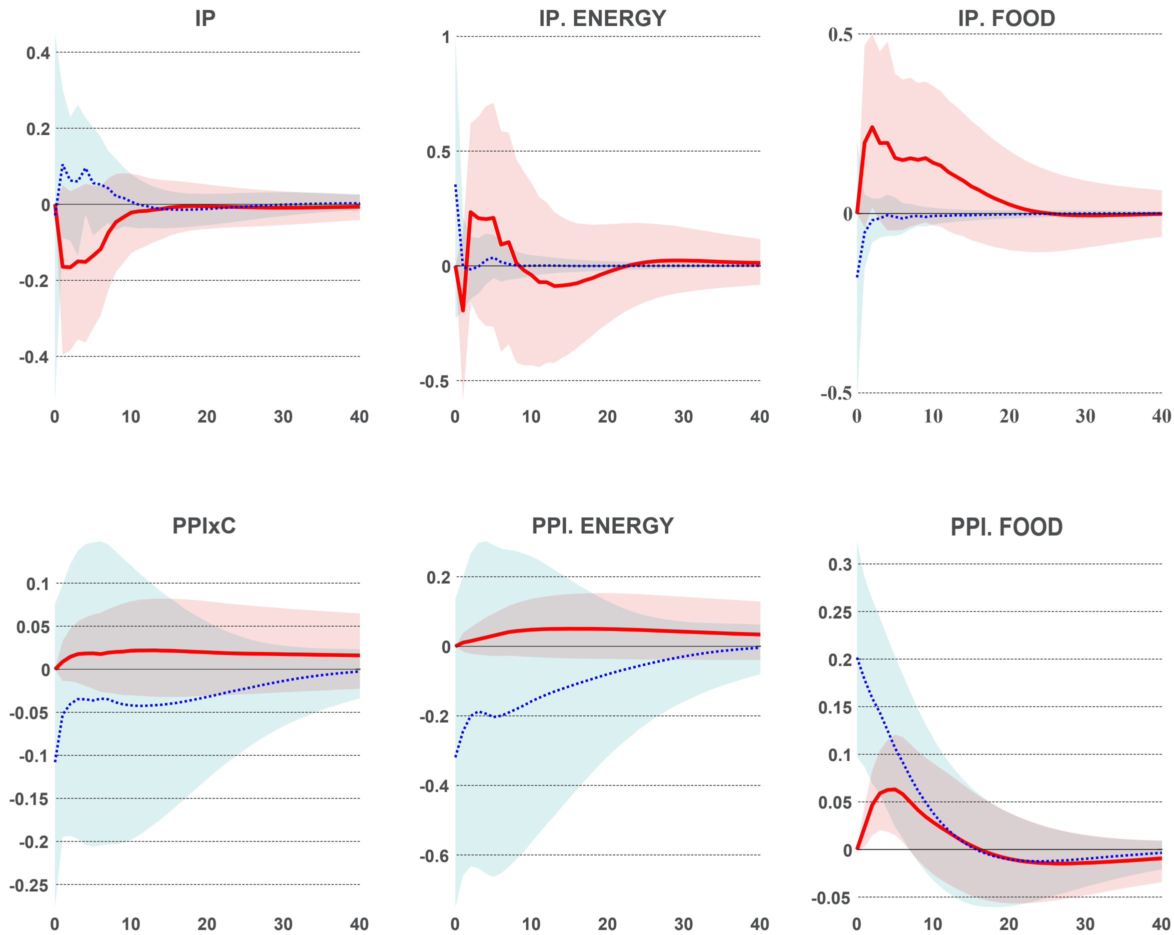
Both processed and unprocessed food prices increase, along with the producer prices of food while Italian food production decreases. Strikingly, the response in producer prices is approximately two times greater than that observed for a summer temperature shock, underscoring the extreme nature of drought events. Overall, the results demonstrate that a drought strongly influences food producer prices, which in turn contribute to upward pressure on consumer inflation. With regards to the magnitude and persistence of the effects on consumer prices, the latter

Figure 4
SPILLOVER EFFECTS OF A DROUGHT ON HICP COMPONENTS IN MALTA
(per cent)



Note: The figure displays IRFs for selected Italian (blue) and Maltese (red) macroeconomic variables, with 68% credibility bands shown around the median responses. The shock is normalised to represent the appearance of a drought and is normalised to 1 on impact.

Figure 5
SPILLOVER EFFECTS OF A DROUGHT ON PRODUCER PRICES AND REAL ACTIVITY IN MALTA
(per cent)



Note: The figure displays IRFs for selected Italian (blue) and Maltese (red) macroeconomic variables, with 68% credibility bands shown around the median responses. The shock is normalised to represent the appearance of a drought and is normalised to 1 on impact.

categories display comparable responses to those of temperature shocks in summer (see Figure 1). This similarity holds for both the local effect in Italy and the spillover effects to Malta, highlighting the connectedness of the two economies in terms of consumer food prices.

Service prices in Italy rise sharply following a drought. This effect is less persistent compared to a temperature shock; however, it aligns with previous explanations of the interconnectedness with other sectors such as food and energy. Interestingly, contrary to the response to a temperature shock, responses for service prices in Malta are actually less pronounced than in Italy, highlighting the distinct nature of drought shocks.[7]

NEIG experience price increases in Italy following a drought, with an effect comparable to that of a summer temperature shock. However, there is no evidence of spillover effects to Malta in this sector nor on **aggregate real activity**.

[7] Linking these IRFs to the service index decomposition, the results indicate that the primary pass-through channel for a drought operates through the catering sector due to a pass through of food prices.

Conclusions

This study contributes to the climate–macroeconomy literature by proposing a two-country empirical framework to analyse cross-border spillovers. Using Italy–Malta as a case study, the results show that temperature shocks and droughts in a large economy can transmit to a small open economy through sector-specific channels.

Temperature shocks display seasonal asymmetries: milder winters ease inflationary pressures, while hotter summers increase them, mainly through food and energy. Droughts, by contrast, exert concentrated effects on agriculture and food prices. Both shocks generate spillovers to Malta, but their sectoral manifestation might differ slightly

"Policymakers in small open economies should account for the possibility that foreign climate shocks may materialise domestically in different sectors, depending on country-specific structures"

These findings have clear policy implications. Policymakers in small open economies should account for the possibility that foreign climate shocks may materialise domestically in different sectors, depending on country-specific structures. Incorporating such cross-border transmission mechanisms into macroeconomic and financial stability assessments will improve the targeting of policy responses and enhance resilience to climate-related risks.

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