

“El Niño” and “La Niña”: Revisiting the Impact on Food Commodity Prices and Euro-Area Consumer Prices*

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This paper challenges the assumption that the intensification of El Niño and La Niña generally exert upward and downward pressures, respectively, on international food commodity prices that, in turn, affect consumer prices even in Europe. We show that the impact is weaker nowadays and, in some cases, may even change sign. Indeed, our results suggest that El Niño may not have contributed to the upward inflation pressures in the euro area during the most recent inflationary episode. Considering domestic agricultural policies is key for the results. We construct two databases: (i) a comprehensive granular database covering both euro-area consumer prices and European Union food commodity prices; (ii) a new database of EU prices from 1972 onward, which allows us to test the effect of these events on a larger sample. We assess the impact of these climatic events by means of local projections techniques. Our bottom-up approach, which factors in disaggregated effects on

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specific food components to assess the overall effect of El Niño and La Niña on aggregated prices, provides a more nuanced understanding of these phenomena. Furthermore, armed with our databases, we can replicate most of the existing evidence on international food commodity prices, thereby validating our approach and indirectly testing the robustness of our main results based on the euro area.

JEL Codes: C32, F62, F64, O13, Q54.

1. Introduction

The 2023–24 El Niño peaked as one of the strongest events on record, comparable to the extraordinary El Niño episode of 1997–98, according to the World Meteorological Organization (WMO) and in line with predictions by the National Center for Atmospheric Research (Yeager et al. 2022).¹ El Niño is a cyclically occurring climate phenomenon associated with warming of the ocean surface in the central and eastern tropical Pacific Ocean.² It induces anomalous temperatures, precipitation, and speeds and strength of ocean currents, leading to extended episodes of drought and floods in tropical countries.³

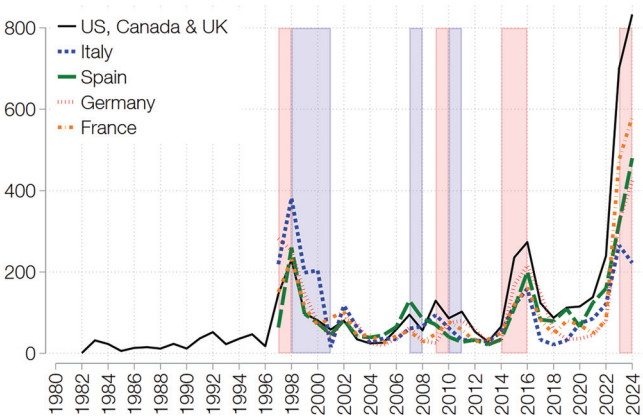
The counterpart phenomenon to El Niño, La Niña, induces the opposite effect, i.e., cooler sea surface temperatures across the central and eastern equatorial Pacific. La Niña sometimes follows El Niño events. Together, El Niño and La Niña represent the “warm” (El Niño) and “cold” (La Niña) phases of the El Niño–Southern Oscillation (ENSO). These climate alterations significantly affect agricultural yields in affected regions (e.g., Iizumi et al. 2014, Hsiang and Meng 2015, Smith and Ubilava 2017). In addition, indirect effects on the economy may stem from trade and relate to global value chain production and food commodity market competitiveness. Thus, ENSO has recently attracted significant attention from policymakers and central bankers because of its possible adverse (upward) effects on prices. In particular, in the last two years this

¹The National Center for Atmospheric Research (NCAR) is supported by the National Science Foundation. More information can be found here.

²It occurs every two to seven years on average and typically lasts 9 to 12 months.

³See Zebiak et al. (2015) and the literature therein.

Figure 1. Newspaper-Based ENSO Popularity Indices



Note: The figure shows newspaper-based ENSO popularity indicators for specific countries at a yearly frequency. These indicators are constructed following the procedure described in Appendix M. Red-shaded (blue-shaded) areas indicate strong El Niño (La Niña) episodes, which are declared when average sea surface temperatures in the equatorial Pacific are at least 1.5° Celsius warmer (cooler) than normal. Strong El Niño episodes occurred in 1997–98, 2009–10, 2014–16, and 2023. Strong La Niña episodes occurred in 1998–2001, 2007–08, and 2010–11. For more details, see Table 2 in Section 7.

phenomenon has been in the spotlight in the press as never before. Figure 1 shows newspaper-based indicators that capture the popularity of ENSO phenomena in the press in several developed countries.⁴ As expected, the press draws attention to ENSO events when they occur. However, the tremendous peak corresponding to the last El Niño event (2023–24) stands out. This confirms that the public is now extremely interested in this topic.

This paper investigates the effect of El Niño and La Niña events on euro-area inflation. This issue is particularly of interest today since most economies are getting back on track after the 2022–23 inflationary crisis. In this context, we find it extremely important to properly present and discuss the implications of ENSO events for the euro area. For instance, the European Central Bank (ECB) has

⁴The United States, Spain, Italy, Germany, and France. Note that these European countries are not directly affected by ENSO events, yet they talk about them when they occur.

regularly mentioned El Niño as a risk factor in its inflation forecasts. To give an example, in July 2023 the ECB stated: “It was observed that, while food inflation had started to come down somewhat, it remained elevated overall, and geopolitical risks and weather and climate-related factors, including El Niño, pointed to upside risks.”⁵ Moreover, in its December 2023 macroeconomic projections, the ECB warns about the “combination of climate change-related risks and the El Niño phenomenon which might amplify the frequency of extreme weather events resulting from climate change in general.” See Box 4 in ECB (2023).

This conjecture is supported by rich evidence on the impact of El Niño events, both from a global perspective (e.g., Brunner 2002; Hsiang and Meng 2015; Cashin, Mohaddes, and Raissi 2017; Adolfson and Lappe 2023) and also based on developing countries, which are directly affected by these phenomena (e.g., Martín 2016; Abril-Salcedo, Melo-Velandia, and Parra-Amado 2020). This evidence supports the broad consensus that El Niño raises food commodity prices, although country-specific consumer price impacts may differ depending on a country’s exposure to these climate patterns, its openness to global commodity trade, and its food commodity trade orientation (e.g., Cashin, Mohaddes, and Raissi 2017). These results are reported in detail in Table C.2 in Appendix C. Thus, there are differences in the impact of El Niño events among countries (e.g., Cashin, Mohaddes, and Raissi 2017; Andrian et al. 2024) and among food items (e.g., Ubilava 2011, 2017; Ubilava and Holt 2013; Iizumi et al. 2014; Smith and Ubilava 2017) that should be taken into account. However, to our knowledge, the literature has not yet studied the impact of ENSO events on euro-area consumer prices. Only a few studies focus on prices in specific European countries or some form of European aggregate, but not the euro area.⁶ This paper aims to fill this gap.

⁵See “Account of the Monetary Policy Meeting of the Governing Council of the ECB of 14–15 June 2023.”

⁶Brunner (2002) focuses on the G7 aggregate; Cashin, Mohaddes, and Raissi (2017) consider an ad hoc definition of the European region that includes the following 13 countries: Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, Turkey, and the United Kingdom; Laosuthi and Selover (2007) study a sample of developed countries that includes France, Italy, and Germany.

Our main finding is twofold. First, we find that El Niño shocks increased commodity prices in the 1980s, in line with previous aforementioned results, while La Niña entailed a weaker inflationary effect on food commodity prices.⁷ Second, from 1997 onward, ENSO shocks have led to asymmetric effects on euro-area inflation. Specifically, La Niña exerts an inflationary effect both on (international and EU) food commodity prices and euro-area inflation. In contrast, El Niño shocks negatively affect EU food commodity prices, and this effect passes through (partially) to euro-area consumer prices. Hence, El Niño shocks have disinflationary effects when considering the most recent sample. These results are novel given that the literature on ENSO shocks tends to focus on earlier periods, when the aggregate effect of El Niño shocks on commodity prices is inflationary.

In Section 7, we put forward a number of possible explanations which may help rationalize these results. For instance, we discuss that the decrease in euro-area consumer prices during El Niño events in the most recent period can be attributed to factors such as the reform of the EU Common Agricultural Policy, which reduced the volatility of EU food commodity prices, and the increased trade diversification and integration, which mitigated the impact of international commodity price shocks on the euro area. Additionally, the substitution of food commodities, where providers switch to less expensive sources not affected by El Niño, could help explain the disinflationary effect of El Niño on euro-area consumer prices in the most recent period. We remind the reader that the primary aim of this paper is to provide empirical evidence on the impact of El Niño and La Niña on euro-area prices, rather than to offer comprehensive explanations for all our findings. Nevertheless, we present a range of possible channels that may contribute to understanding the results.

Our results are related to the recent study by Peersman (2022), who investigates the causal effects of international food commodity price shocks on euro-area inflation by means of instrumental structural vector autoregressions. He uses a series of unanticipated harvest shocks as an instrument to identify exogenous international food

⁷In the 1980s, El Niño shocks increased both international and EU commodity prices, while La Niña shocks increased EU commodity prices but had no significant effects on international commodity prices.

commodity price shocks. This instrument is estimated as the residual from a harvest equation that controls for a number of possible determinants of food production, including global weather phenomena—represented by ENSO events.⁸ He finds that exogenous food commodity price shocks (a 1 percent increase in international commodity prices) have a strong impact on international consumer prices (1.18 percentage points (pp) after eight quarters) and on European Union commodity prices (1.07 pp). This inflationary result is in line with our finding for La Niña, over a similar sample. However, we find a deflationary impact of El Niño on the same sample. In any case, our results are not directly comparable to those of Peersman (2022) for a number of reasons: (i) we consider the direct impact of ENSO shocks, distinguishing between El Niño and La Niña shocks, while Peersman (2022) uses shocks to global harvests of corn, wheat, rice, and soybeans outside of Europe and unrelated to global economic developments to identify exogenous international food commodity price shocks; (ii) he focuses on a narrower set of components for food prices in the EU (cereals, meat, and dairy); (iii) he applies a weighting scheme for EU food commodity prices based on production (Eurostat economic accounts for agriculture), whereas we consider a harmonized index of consumer price (HICP) weights.

We contribute to the existing literature along a number of dimensions. First, we study the impact of El Niño and La Niña on euro-area inflation using both euro-area consumer prices (which are the target of the ECB's monetary policy) and European Union (EU) food commodity prices, given the relevance of EU commodity prices for assessing the pass-through from international food commodity prices to the relevant prices within the euro area (for a detailed discussion, see Ferrucci, Jiménez-Rodríguez, and Onorante 2012 and Borrallo et al. 2026). This is key, since the international and EU food commodity baskets differ both in terms of their composition and weight. This implies that changes in global prices for specific commodities induced by El Niño should not translate one-to-one to the euro-area

⁸In the harvest equation, a global food production index excluding European harvests is regressed on a set of variables reflecting a trend, ENSO shocks, and a vector of control variables that could affect global food production. The variables measuring ENSO shocks represent global weather phenomena that may simultaneously affect European and non-European harvests.

commodity prices, because that commodity may not be as relevant for the European region.

Second, we rely on local projections à la Jordà (2005), in line with the most recent literature on the economic effects of ENSO events (e.g., Cashin, Mohaddes, and Raissi 2017; Atems and Sardar 2021; Adolfsen and Lappe 2023). In this context, most of the existing evidence employs a top-down approach (estimating the impact of El Niño/La Niña on aggregate prices directly) or a disaggregated approach (the impact of El Niño/La Niña on specific components). Our methodological contribution is that we rely on a bottom-up approach, in which disaggregated effects on specific food components are correctly factored in to assess the overall effect of El Niño on aggregated prices. This is important because direct effects on prices of specific components may offset each other, and this may bias top-down results (Ferrucci, Jiménez-Rodríguez, and Onorante 2012).

Third, although our main results refer to the period from 1997 onward, i.e., since the existence of the euro area, we complement them by constructing a new database of EU prices spanning from 1972 onward, which allows us to test the effect of ENSO events on a larger sample that includes quite extreme ENSO episodes dating back to the 1970s.

Fourth, we show that our methodology allows for the replication of most of the existing evidence focusing on international food commodity prices.⁹ This reassures us about the validity of our method and is an indirect test to show the robustness of our main results based on the euro area.

The rest of the paper is organized as follows. Section 2 provides a review of the relevant literature. In Section 3, we describe the data. Section 4 outlines the empirical framework, and in Section 5 we present our results. Finally, in Section 6 we present a number of robustness exercises, while in Section 7 we discuss a number of possible channels that can explain our findings. Section 8 concludes with final observations and remarks.

⁹International food commodity prices are measured by the World Bank's Commodity Price Index, in the World Bank (WB) Pink Sheet Database.

2. Literature Review

The literature on the impact of El Niño events suggests heterogeneous GDP growth and inflation responses to El Niño shocks depending on the country. As regards economic growth, tropical countries experience economic losses (mostly in the agriculture, infrastructure, and energy sectors) to the extent that they are directly affected by weather anomalies. By contrast, El Niño shocks benefit economic activity in countries in temperate regions, which are not directly exposed to these weather-related anomalies. The latter can be explained by, among other factors, trade and aggregate demand resulting from weather disruptions (Brunner 2002; Laosuthi and Selover 2007; Martín 2016; Cashin, Mohaddes, and Raissi 2017; Smith and Ubilava 2017; Beltran, Hadzi-Vaskov, and Stepanov 2023). Whenever asymmetries are considered, GDP growth responds negatively to El Niño shocks, while La Niña shocks do not affect economic activity (Smith and Ubilava 2017). This literature is summarized in Table C.1 in Appendix C. The inflationary effects of El Niño shocks are also heterogeneous across countries (e.g., Brunner 2002; Laosuthi and Selover 2007; Ubilava and Holt 2013; Martín 2016; Cashin, Mohaddes, and Raissi 2017; Abril-Salcedo, Melo-Velandia, and Parra-Amado 2020; Atems and Sardar 2021; Adolfsen and Lappe 2023; Romero and Saldarriaga 2024) and are summarized in Table C.2 in Appendix C. Thus, a disaggregated perspective is crucial to correctly gauge the transmission of weather shocks to aggregate prices, as such heterogeneity can stem from the following several dimensions.

First, from a global perspective, specific food commodity prices respond differently to the same shock: for instance, palm and coconut oil prices increase after El Niño shocks, whereas soybeans and maize are not affected (Atems and Sardar 2021).¹⁰ Second, while weather anomalies are, in principle, a local phenomenon (they directly affect production and the prices of food commodities grown in specific regions/countries), in some cases their effects may spread globally

¹⁰When accounting for asymmetry in the weather anomaly, La Niña shocks increase aggregate food commodity prices while El Niño shocks have ambiguous results, with some food commodities being positively affected and others being negatively affected (Atems and Sardar 2021).

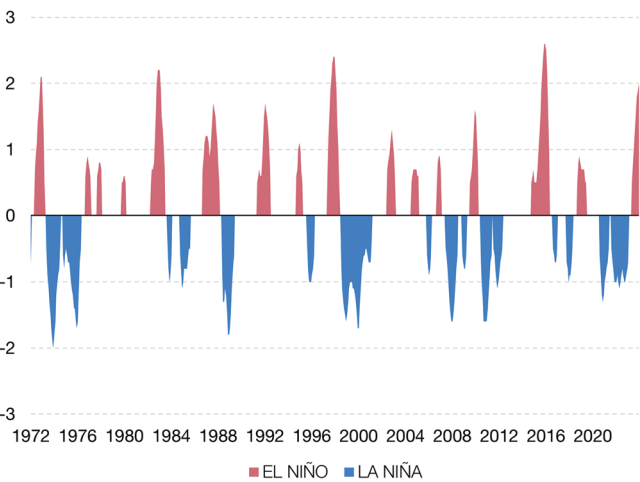
to prices of highly substitutable commodities (as in the case of oils and cereals). Hence, the transmission depends on the degree of substitutability of the affected commodity goods (Ubilava and Holt 2013; Ubilava 2023). Third, responses differ according to the region (tropical regions are more affected, as opposed to temperate regions) and the country. For example, a shock may be transmitted to local food commodity prices, depending on the degree of diversification of the country and its size (Laosuthi and Selover 2007), or the shock may be diluted in temperate countries since food commodities account for only a fraction of the cost of finished goods (Brunner 2002). Fourth, the transmission to consumer prices depends, among other factors, on the share of the exposed food that is present in a country’s consumer price index (CPI) basket (Cashin, Mohaddes, and Raissi 2017). In total, the existing evidence on the transmission to CPI inflation in Europe amounts to 0.07 percentage points (Cashin, Mohaddes, and Raissi 2017) or has been found to have only a marginally significant effect (for the G7 countries) (Brunner 2002).

3. Data

Our variable of interest is the Oceanic El Niño Index (ONI), the main indicator for monitoring the seasonal El Niño–Southern Oscillation climate pattern, from the U.S. National Centers for Environmental Information. It indicates the extent to which the three-month average sea surface temperature of a region of the Pacific Ocean (120°W–170°W) is significantly warmer (El Niño $> 0.5^{\circ}\text{C}$) or colder (La Niña $< -0.5^{\circ}\text{C}$) than a historical average. Five consecutive index values above (below) the threshold of $+0.5^{\circ}\text{C}$ (-0.5°C) are considered to represent an El Niño (La Niña) episode (see Figure 2).

To measure international food commodity, we use the global food commodity price index, as available from the World Bank’s Commodity Price “Pink Sheet.” Database, which is available at a monthly frequency from 1960 onward, as well as the price of its food commodity components: cereals, oils and meals, and other food and beverages. In the aggregate index the latter components are weighted according to the export value of each item relative to the total exports of low-income countries. In this paper all indices are converted from U.S. dollars to euros. Further information on the data composition and sources is available in Appendix B.

Figure 2. Episodes of El Niño and La Niña



Note: The Oceanic Niño Index shows the three-month average sea surface temperature in tropical Pacific Ocean compared to the 1981–2010 average.

As for food commodity prices for the euro area, we consider the food commodity prices of the European Union, as the euro-area countries trade within the single market of the EU for products. This is an important contribution to the literature, which often studies the impact of El Niño events on international food commodity prices, based on the criterion that El Niño is a global phenomenon that affects prices worldwide. By contrast, to the extent that our object of analysis is euro-area prices, we explicitly consider EU food commodities. This allows us to enhance the existing literature in two directions. First, we can take into account the role of the EU’s Common Agricultural Policy (CAP). The CAP smooths the transmission of shocks from international food commodity prices to European farm-gate prices. Due to this policy, European farm-gate prices have been less volatile than international food commodity prices. Second, there is an important difference between aggregate EU and international food commodity prices, which stems from changes in terms of (i) composition—different food items entering into the computation of the aggregate index—as well as in terms of (ii) weights. As shown in Table 1, both the composition of the index and its weights can differ substantially, especially the “vegetable oils” component.

**Table 1. International vs.
EU Food Commodity Price Index**

Group	Item	WB Weight	EU Weight
Food		100.0	100.0
Cereals		28.2	25.0
	Rice	8.5	
	Wheat/Durum	7.1	8.3
	Maize	11.5	
	Barley	1.2	8.3
	Rye		8.3
Vegetable Oils		40.8	5.0
	Soybeans	10.1	
	Soybean Oil	5.3	1.3
	Soybean Meal	10.7	
	Palm Oil	12.3	
	Coconut Oil	1.3	
	Groundnut Oil	1.1	
	Olive Oil		1.3
	Rapeseed Oil		1.3
	Sunflower Oil		1.3
Dairy and Eggs		0.0	21.0
	Raw Milk		5.3
	Skim Milk Powder		5.3
	Edam Cheese		5.3
	Eggs		5.3
Other Food		31.0	49.0
	Sugar	9.8	9.0
	Bananas	4.9	
	Meat, Beef (Cows, Steers)	6.8	18.0
	Meat, Chicken	6.0	9.0
	Meat, Pork		9.0
	Oranges	3.6	
	Coffee		4.0
Note: This table compares the composition and weights of the international food commodity price index, as available from the World Bank Pink Sheet Database, and the European Union food commodity price index (own calculations).			

We construct two data sets to test the impact of both El Niño and La Niña events on euro-area inflation in different time periods. The baseline sample starts from 1997, which coincides with the establishment of the euro area.¹¹ This is our natural first choice, since we are interested in the impact of ENSO events on euro-area inflation. In addition, we construct a larger sample that tracks euro-area prices from 1970, covering a period in which the euro area did not yet exist. This larger sample gives us an additional tool to check the robustness of our results along three directions: first, comparing with the existing literature, which typically considers periods including at least the 1980s; second, including more ENSO events; third, discussing the implications of the CAP on euro-area prices. In the rest of this section, we describe in detail which variables we consider and how we construct the relevant series of interest.

3.1 Baseline Sample: European Food Prices since 1997

This database contains monthly food prices at different levels of the food production process (food consumer, food producer, and food commodity prices) from January 1997 to December 2023 for the euro area and for the four largest European countries (France, Germany, Italy, Spain). Food consumer prices and food producer prices are obtained from Eurostat, while for food commodity prices we rely on the European Commission's Directorate-General for Agriculture and Rural Development (DG Agri) database.

Specifically, we compile data on food prices for six food groups: cereals, dairy, fats and oils, meat, sugar, and coffee, representing close to 70 percent of the food consumption basket. We exclude fruit and vegetable prices as they are highly volatile, as well as fish prices as there is no reference for its commodity price at the European Union level.¹² In any case, despite data unavailability, the

¹¹The euro zone was born with its first 11 member states on January 1, 1999. However, euro-area data are gathered since 1997.

¹²Commodity prices are unavailable in the European Union for fish, and there are very few items for fruits and vegetables, which raises concerns about the representativeness of the resulting food category. This is the key reason why we considered their exclusion from the analysis, as we cannot guarantee the same quality standards in the data, and in some cases we cannot even run the same model.

exclusion of fish, vegetables, and fruits should not affect our results significantly, as the EU imports fish from diversified sources and is largely self-sufficient in vegetables and nearly independent in fruits. In particular, the EU is a net importer of fish, as it produces only 60 percent of its consumption needs domestically, but the import part is sourced from highly diversified providers.¹³ The EU is self-sufficient to produce vegetables, and close to independent for fruits, as just 14 percent of its consumption depends on imports (Cuadro-Sáez, Pérez, and Viani 2025).

Food consumer prices and food producer prices are obtained from Eurostat, using the corresponding category for each group (see Table A.1 in Appendix A). We then consider the European Union’s corresponding food commodity prices available from the European Commission’s DG Agri. This database provides highly detailed indices, allowing us to construct an index for each food group commodity as the simple average of its components. For instance, the cereal food commodity price index is the mean price of feed barley, malting barley, feed maize, bread wheat, feed wheat, durum wheat, feed rye, and bread rye (refer to Table A.1 for the composition and correspondences among food price indices). When data are not available for commodity prices, we use international commodity prices instead.¹⁴

As for control variables, we include as a proxy for economic activity the growth in the industrial production index (IPI) for the euro area, as available from Eurostat. We also control for oil price and fertilizer price indices as provided by the World Bank’s Pink Sheet, which we convert into euros using the spot exchange rate. Both variables are defined at the global level.

3.2 *Larger Sample: European Food Prices since 1972*

We construct a novel database from January 1971 onward. Data on consumer prices are not available for any of the six groups, so we

¹³Despite the significant weight of Norway, which contributes 35 percent of imports.

¹⁴ This relates to only a few components: prices of rapeseed oil, sunflower oil, and soybean oils (which belong to the fats and oils category) are taken from the International Monetary Fund (IMF) database; the sugar price is provided by the WB Pink Sheet; the coffee price is from the International Coffee Organization (see Table A.1).

focus on the available aggregates: “headline” and “food and non-alcoholic beverages” consumer prices. In contrast, food commodity prices for the European region are available for this longer period of time. To extend these series backwards, we combine monthly information available from Eurostat (for the 1971–95 period) and DG Agri from 1996 onward.¹⁵ Specifically, for data before 1996 we take the components that appear both in the DG Agri database and Eurostat and whose monthly growths have a correlation of 65 percent or more in the 1991–94 period, and extend DG Agri price levels backwards using the monthly growth implied in Eurostat data. Then, after 1996 we maintain the indices used in the previous section (see Table A.2 in Appendix A).

4. Methodology

We estimate the impact of an intensification of El Niño on prices by using the local projections (LPs) method of Jordà (2005), in line with the most recent literature (e.g., Atems and Sardar 2021 and Adolfsen and Lappe 2023). The LPs estimator is attractive since it directly projects an outcome at the future horizon h on current covariates and does not require specification and estimation of the unknown true underlying multivariate system. For this reason, we believe that in our setting LPs is the most suitable methodology.

We consider the following specification:

$$\begin{aligned} \pi_{t+h} = & \alpha + \sum_{i=1}^j \beta^h \cdot \pi_{t-i} + \gamma^h \cdot \text{niño}_t + \sum_{i=0}^j \nu^h \cdot \text{fuel}_{t-i} \\ & + \sum_{i=0}^j \delta^h \cdot \text{fert}_{t-i} + \sum_{i=0}^j \kappa^h \cdot \text{IPI}_{t-i} + \epsilon_t, \end{aligned} \quad (1)$$

where $h = 0, \dots, 18$, $j = 6$, and h and i refer to months. The variable of interest, El Niño, equals the Oceanic El Niño Index (ONI) during an El Niño event and takes the value 0 otherwise (that is,

¹⁵We use monthly data from Eurostat from 1971 to December 1995, and we link these with monthly data from DG Agri from January 1996 onward for all available components since 1971, except for egg prices, which are available from 1997 onward.

during La Niña events and when neither of the two take place). When we consider La Niña, we construct the same variable for these events, taking the absolute value of the resulting indicator.¹⁶ Control variables include oil prices ($fuel_t$), fertilizer prices ($fert_t$), and the industrial production index (IPI_t) as a proxy for economic activity. All variables in the model refer to log month-on-month changes.¹⁷ The dependent variable is a measure of the euro-area price inflation, which can be defined as consumer prices or commodity prices, and can be set at the aggregate level or disaggregated at a more granular level, depending on the specification. Additionally, we suppose that industrial production and fuel and fertilizer prices are exogenous to food commodity prices.

The shock considered in the analysis is the effect of an intensification of an El Niño event, i.e., an increase of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño event is already taking place. Since the *niño* variable takes the ONI value when an El Niño event is taking place and 0 otherwise, the intensification of an El Niño event implies a rise of γ percentage points in price growth. This interpretation applies also for La Niña shocks, since intensifications of this event enter with the absolute value in the equation. Note, the *niño* variable enters into the equation contemporaneously, as the estimation structure of local projections allows us to calculate how it affects future values of the target variable through the impulse response function (IRF).

For each specification, we choose the optimal lag structure according to the following two-step strategy.¹⁸ First, we estimate the model including the same number of lags—from one to six lags—for all control variables except for the El Niño variable, which enters only contemporaneously. For each specification, we compute the Hannan-Quinn information criterion, and then we choose the number of lags that corresponds to the model that performs best according to the Hannan-Quinn criterion. In a second step, for each

¹⁶In Appendices J and K we show that our results are robust to considering them simultaneously.

¹⁷Oil, fertilizer, euro-area industrial production, and food commodity and consumer prices are seasonally adjusted by using X-13 ARIMA-SEATS.

¹⁸For all cases, in order to find the optimum specification we apply this procedure to the first-horizon regression of the LP exercise and then keep the resulting specification for all horizons.

model we exclude the non-significant lags from the regression (aside from the contemporaneous and the first lag, which always remain).¹⁹ Finally, our linear projection estimations account for heteroskedasticity by using Huber-White corrected standard errors, as suggested in Montiel Olea and Plagborg-Moller (2021).

We run our estimations from different perspectives. First, we run the analysis at the disaggregated level and provide the corresponding IRF of each of the six specific food groups. Second, we estimate the model on the aggregate price indices, which are weighted averages of the group-specific food components. This top-down approach is what is commonly reported in the literature. This method may lead to composition bias since direct effects on prices of specific components may be offsetting each other, as pointed out by Ferrucci, Jiménez-Rodríguez, and Onorante (2012). We solve this issue by means of a bottom-up approach. That is, we first estimate the response of each specific component to an El Niño shock and then group responses to an aggregate level (Ferrucci, Jiménez-Rodríguez, and Onorante 2012). In the aggregation, the median responses are aggregated by means of a weighted average. The construction of the confidence bands of the aggregate IRFs in the bottom-up approach is based on a block bootstrap procedure with fixed regressors. We jointly resample the estimated residuals of the 12 models (one model for each of the six food commodity price components plus one model for each of the food consumer price components) via a block bootstrap and combine the resampled residuals with the fixed regressors. This gives us a bootstrapped series of commodities and consumer food price values on which we reestimate the models and the IRFs. We repeat the bootstrap procedure 1,000 times and construct the

¹⁹For all cases, the optimum number of lags is one lag, except for the models of dairy consumer prices (two lags), coffee consumer prices (two lags), and sugar consumer prices (three lags). Hence, step two of the procedure applies only to these latter specifications. It turns out that for the model of dairy consumer prices, we keep the second lag of the dependent variable and the economic activity variable and drop the second lag of oil and fertilizer prices. For the model of coffee consumer prices, we keep only the second lag of the dependent variable and drop the second lag for all other controls; for the model of sugar consumer prices, we include up to the third lag of the dependent variable and the third lag of the activity indicator, while the rest of the controls enter with the first lag only.

respective confidence bands for the aggregated IRFs by aggregating the IRFs for each individual bootstrap run and then extracting the corresponding percentiles. This allows us to compute confidence bands that take into account the cross-sectional correlation of the error terms across distinct food commodity and consumer price components. For a general description of bootstrapping methods, see Kreiss and Lahiri (2012).

5. Results

All figures and the discussion below should be read as referring to the effects of shocks defined as an increase of 1°C in the ocean surface temperature during an El Niño event (ONI) and a decrease of 1°C in the ocean surface temperature during a La Niña event (ONI)—thus, an intensification of either an El Niño or La Niña episode.

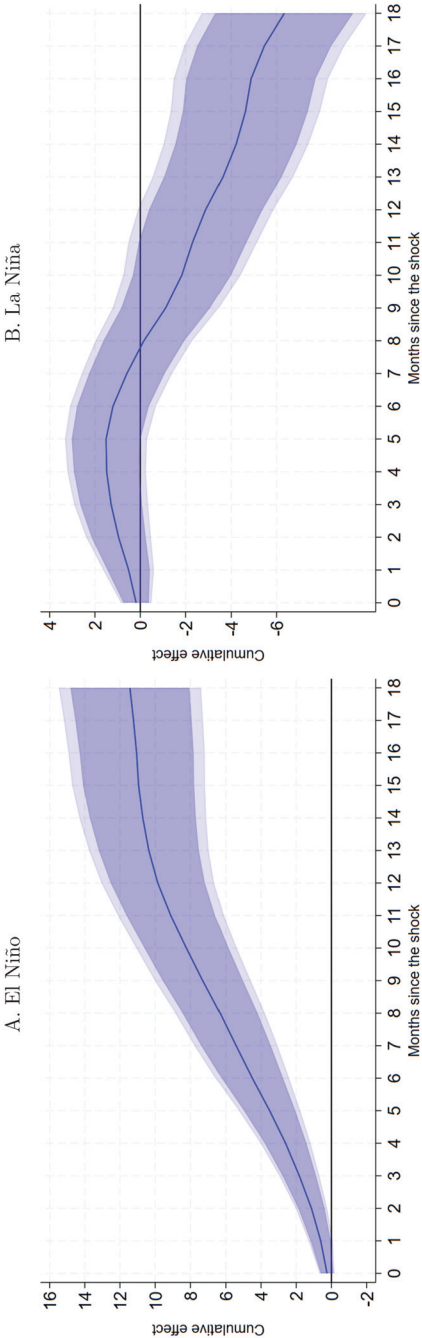
5.1 *Impact on International Food Commodity Prices*

Results of both El Niño and La Niña shocks on international food commodity prices over the longer sample period (1972–2023) are in line with the existing evidence (e.g., Brunner 2002; Cashin, Mohaddes, and Raissi 2017; Adolfsen and Lappe 2023) that currently shapes discussions about the risks implied by these climate-related phenomena.

Our results show that the intensification of an El Niño event leads to a significant increase in global food commodity price growth of about 9 percentage points one year after the shock and that this cumulative effect remains significant for at least 18 months after the shock. In contrast, the impact of La Niña is barely significant in the fourth month after the shock, causing an increase in international food commodity prices somewhat below 2 percentage points (see Figure 3) and is otherwise not significant.

Appendix D reports food-group-specific effects of ENSO shocks. For the case of El Niño, most of the spike in the aggregate food commodity index is due to the response of vegetable oils, and to a lesser extent sugar and cereals. Results for El Niño are broadly consistent with the previous literature. For example, Smith and Ubilava (2017) document a decrease in global production, which then implies an increase in the price. Other studies find a positive impact on the

Figure 3. International Commodity Price Responses to an Intensification of El Niño/La Niña



Note: Monthly cumulative response of international commodity prices to an El Niño/La Niña shock along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1 °C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

price of cereals (Brunner 2002; Laosuthi and Selover 2007; Ubilava 2017; Adolfsen and Lappe 2023), on the global prices of vegetable oils (Ubilava and Holt 2013), and on the price of sugar (Cashin, Mohaddes, and Raissi 2017). However, for a few specific items we find it hard to reconcile our results with previous ones, essentially because the existing evidence is not clear-cut, i.e., Brunner (2002), Martín (2016), and Cashin, Mohaddes, and Raissi (2017) show a positive impact of El Niño on coffee, while Ubilava (2011) demonstrates that the impact of El Niño depends on the type of coffee, finding a positive impact of El Niño on robusta coffee beans and a negative impact on arabica coffee beans.

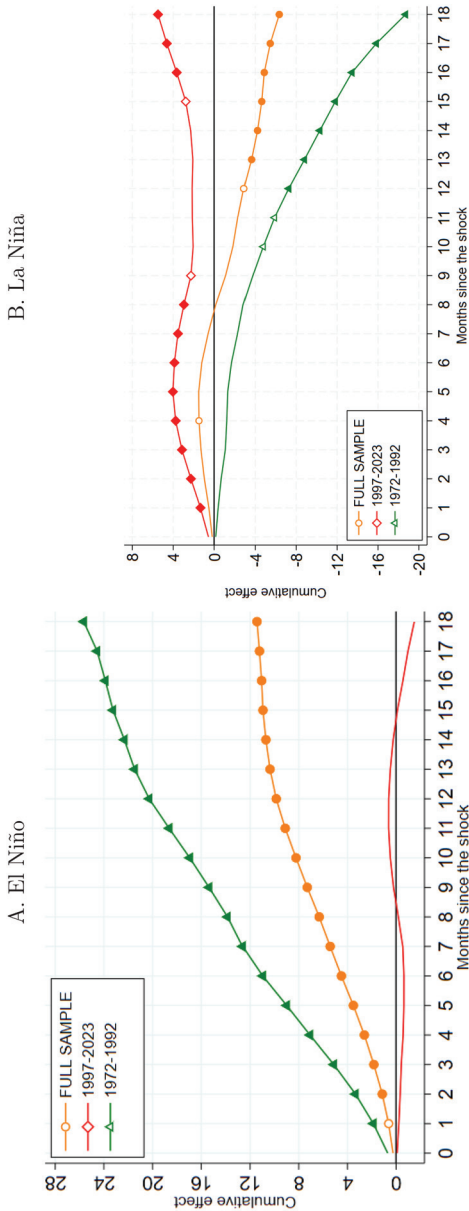
Given our aim of studying the impact of the intensification of ENSO events on euro-area inflation, we split the sample into two periods. The first spans from 1972 to the Common Agricultural Policy reform in 1992, known as MacSharry’s reform, by which the EU moves from indirect support to farmers via guaranteed prices to direct support via income transfers.²⁰ The second period starts in 1997, shortly before the launch of the euro.

Splitting the sample reveals two striking results (see Figure 4). First, the impact of El Niño on international commodity prices is very intense in the former period (1972–92), i.e., an intensification of El Niño causes an increase of about 20 percentage points in international food commodity prices after 12 months. Second, and more importantly, this impact completely fades away when considering the more recent euro-area sample (1997–2023). One possible explanation is that during the former period, which includes the 1980s, four strong El Niño events occurred consecutively in a closely spaced manner. In contrast, the most recent period features strong El Niño events that occurred with more time between each occurrence. Section 7 presents a discussion of further additional economic explanations.

In the case of La Niña, the sample split shows that the former period is consistent with existing findings along two dimensions:

²⁰In the guaranteed prices system (before 1992), excessively high food commodity prices generate an excess of production (sustained also by excessive stocks and export subsidies) which, in turn, creates negative consequences such as the fall of farm income and soaring budget expenditure, while consumption increases at a slower pace than production (Garzon 2006).

Figure 4. International Commodity Price Responses to an Intensification of El Niño/La Niña: Split Sample



Note: Monthly cumulative response of international commodity prices to an El Niño/La Niña shock. Full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations using a bottom-up approach. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

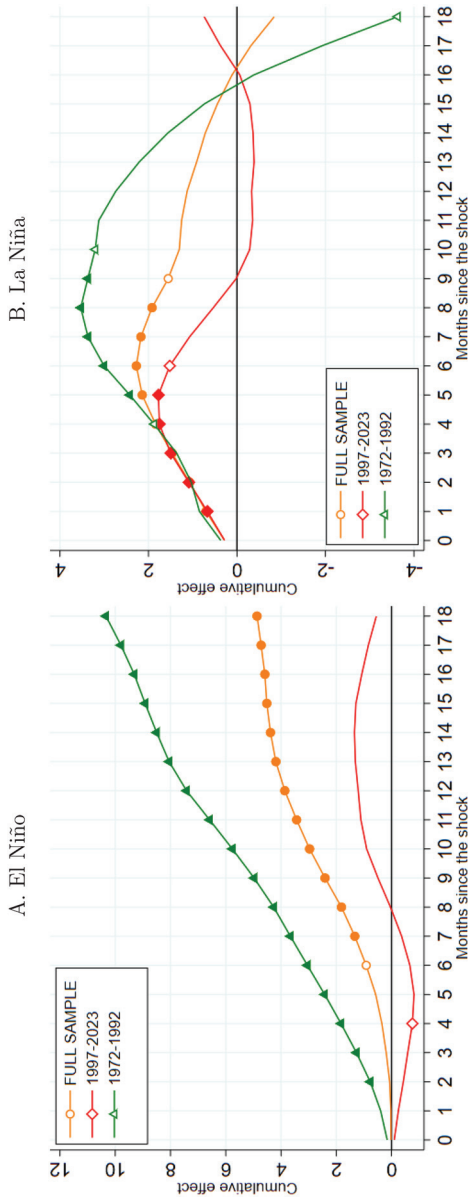
(i) La Niña tends to exert a softer effect on prices than El Niño, and (ii) if anything, La Niña slightly reduces international commodity prices. In any case, the maximum impact takes place around the fifth month after the shock, with an increase in international food commodity prices of about 4 percentage points, which is still well below the estimated impacts of El Niño on food commodity prices. This confirms that La Niña has softer effects than El Niño. The positive effect found in the most recent period might be explained by the fact that the 2000–12 period featured four strong La Niña events that happened consecutively in a closely spaced manner.

5.2 Impact on EU Food Commodity Prices

Turning to the impact on EU food commodity prices, and maintaining the sample divided into two periods, results show that in 1972–92 El Niño significantly affected EU food commodity prices by about 7 percentage points 12 months after the shock. This effect vanishes when considering the most recent period (see Figure 5). Notably, in the most recent period, the effect of El Niño on food prices turns negative, although the coefficients are small and only marginally significant. Disaggregated responses by food groups reveal that El Niño has a clear disinflationary effect on some commodities, such as meat and cereals, which is offset by the responses of other food groups. Moreover, the disinflationary impact of El Niño is confirmed and becomes even stronger when taking into account the pass-through along the value chain (see Appendix F). While we do not aim to explain the reaction of each food group, in the rest of this section and in Section 7 we propose some possible explanations that may help rationalize the disinflationary effect of El Niño on EU food prices. A more detailed discussion on these disaggregated effects is provided in Appendix E.

Note that during the first period, food commodity prices were guaranteed in the European Union, such that agricultural producers had an incentive to overproduce. As long as El Niño adversely affected international production, European producers (supported by export subsidies) had an incentive to export their surpluses at international prices. The CAP reform in 1992 entailed direct support to farmers via income. The removal of the incentives for EU farmers to overproduce and export as of 1992 is consistent with the

Figure 5. EU Commodity Price Responses to an Intensification of El Niño/La Niña: Split Sample



Note: Monthly cumulative response of EU food commodity prices to an El Niño/La Niña shock. Full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations using a bottom-up approach. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

hypothesis that El Niño no longer had any effect on EU commodity prices.

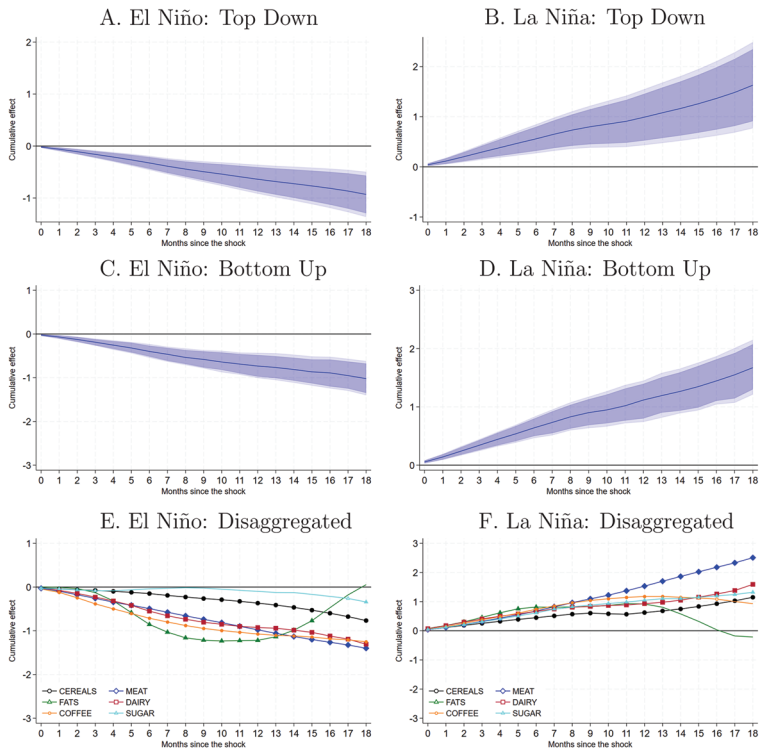
By contrast, La Niña induces a moderated and short-lived (up to five months after the shock) inflationary effect on EU food commodity prices, an effect that is robust over time. This apparent inconsistency between the response of international (not significant in the short term and turning negative afterward) and EU commodity prices (positive) in the case of a La Niña shock in the former period (until 1992) can be explained looking at the disaggregated effects (see Figure D.2 in Appendix D and Figure H.2 in Appendix H). In both price indicators, the positive impact comes from meat and sugar, while the negative one is due to vegetable oils. What drives the difference is the different weighting schemes used to aggregate food components: vegetable oils have a large weight in the international commodity index and a small weight the EU one. Conversely, meat counts much more in the EU commodity weighting scheme than in the international scheme (see Table 1).

5.3 *Consumer Price Results*

In this section, we focus on the target of our analysis, i.e., the impact of ENSO events on food inflation in the euro area, for which we consider the euro-area sample since 1997. We consider a restricted definition of the HICP food price index consistent with our EU commodity price index, in which we retain six food groups that amount to 70 percent of the food consumer basket (see Figure A.1 in Appendix A).²¹ In particular, we consider cereals, dairy, fats and oils, meat, sugar, and coffee and leave aside the other food groups (mineral water and juices, fruits and vegetables, and fish) due to their high volatility and the lack of consistent price data available. This approach results in a negative and significant impact of an intensification of El Niño of about 0.6–0.7 (top-down/bottom-up) percentage points on food inflation 12 months after the shock, as the impact on commodity prices passes through to food inflation and to headline inflation. The impact is positive and more pronounced in the case of

²¹Results based on the aggregate HICP food price index are in line with our findings for our restrictive definition of the HICP food price index and are available to the reader upon request.

Figure 6. Response of Euro-Area Food Consumer Price Inflation to an Intensification of El Niño/La Niña



Note: Monthly cumulative response of the euro-area food HICP based on our own six food group aggregate to an El Niño shock (left panels) and La Niña shock (right panels) along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. In the third row, full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

the intensification of a La Niña event (1–1.1 percentage points) (see Figure 6).

The impact on food inflation passes through to headline inflation in a significant way. Contrary to common belief, we find that an intensification of El Niño weakly reduces euro-area inflation by

0.3 percentage points. Besides, the effect of an intensification of La Niña events is positive and of about 0.6 percentage points in cumulative terms 12 months after the shock (see Figure 7). These two results are crucial in the current circumstances as (i) El Niño might not have been pushing inflation upward as believed and, more importantly, (ii) one should take into account the risks to inflation due to an intensification of La Niña events.²²

6. Robustness

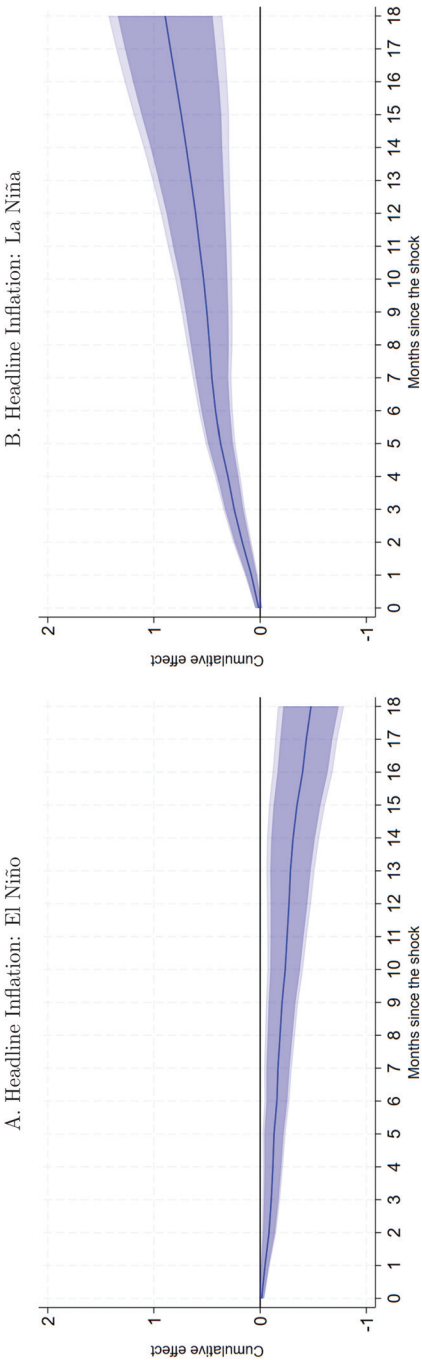
We provide a number of robustness exercises. First, we check the robustness of the baseline results by expanding our model to follow the value chain perspective of Ferrucci, Jiménez-Rodríguez, and Onorante (2012). We do so by adding at least one lag of food producer prices and of food consumer prices in the food commodity equation, and at least the first lag of food producer prices and food commodity prices in the model for food consumer prices (Equation (1)). Results are reported in Appendix F and are very similar to our main results.

Second, we carry out the analysis at the country level for the most important euro-area countries: Italy, France, Germany, Spain (see Appendix G). The responses of food inflation to intensifications of El Niño and La Niña for each of those countries are quite similar to the responses of the euro area as a whole.

Third, we reestimate the analysis for consumer prices using the larger sample (from the 1970s), for the euro area (see Appendix H). Unfortunately, data for each of the six consumer prices were not available from 1971, so we estimate the effects of El Niño and La Niña shocks on the food component of the HICP, the headline component, and commodity prices. The response of food inflation to both shocks was similar to the top-down and bottom-up results of the main exercise. However, headline inflation in the euro area does

²²On a conjunctural note, at the time of writing, the El Niño–Southern Oscillation is likely to turn into a La Niña phase this summer: there is a 65 percent chance that La Niña is declared between July and September 2024 and persists into the Northern Hemisphere winter of 2024–25 (85 percent chance during November–January), according to the National Oceanic and Atmospheric Administration’s (NOAA’s) Climate Prediction Center. See the “ENSO: Recent Evolution, Current Status and Predictions” report of June 24, 2024.

Figure 7. Response of Euro-Area Headline Consumer Price Inflation to an Intensification of El Niño/La Niña



Note: Monthly cumulative response of the euro-area headline HICP to an El Niño/La Niña shock along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

not react significantly to El Niño, although it still reacts significantly to La Niña, and commodity prices increase significantly after both phenomena.

Fourth, as an additional robustness analysis, we run the baseline model for the international food commodity prices adding, on one hand, the one-month change in the dollar-to-euro exchange rate and, on the other hand, changing the number of lags for food commodity, fertilizer, and oil prices and activity to 12. The resulting figures are shown in Appendix I. For El Niño shocks, adding the exchange rate to the baseline model does not change the results, but including more lags reduces their effects on food commodity price growth by around 20 percent relative to the baseline model. However, for La Niña, adding the exchange rate makes the short-run positive effect of the phenomenon on commodity price growth not statistically significant, while no meaningful change happens when adding 12 lags to the baseline model.

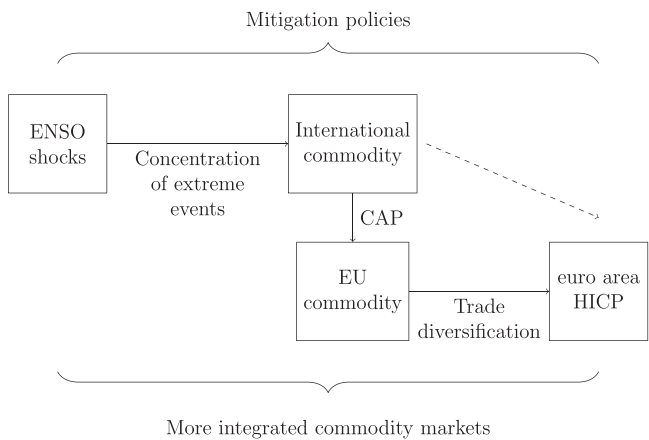
Fifth, we included both El Niño and La Niña variables in the same regression model, rather than analyzing them separately. This approach acknowledges that El Niño and La Niña are interrelated phases of the ENSO climate phenomenon. Our findings indicate that the baseline results are robust when both events are treated simultaneously (see Appendix J).

Finally, we include in the same regression El Niño and La Niña, exploiting all variation in the ONI variable. Hence, we consider the complete variation of the ONI variable, not only the excess from the normal value. This allows us to take into account other dimensions of the ONI events, such as duration and intensity. Results are reported in Appendix K and are in line with our baseline conclusions.

7. Discussion

With respect to food commodity prices, we show that there are nuances that have to do with composition effects (type of commodity) and sample periods (with more recent decades presenting smaller effects than the former period observed). With respect to consumer price inflation in the euro area, we show that it is crucial to account for the role of domestic agricultural policies (for the euro area, the CAP) and trade patterns. In particular, focusing on the euro-area

Figure 8. Channels Layout



Note: For mitigation policies, see Section 7.2; for the concentration of extreme events, see Section 7.1; for the CAP, see Section 7.4; for trade diversification, see Section 7.5; for more integrated commodity markets, see Section 7.3.

(EA) sample, an intensification of El Niño decreases EU food commodity prices by 1 pp, which in turn decreases EA headline inflation by about 0.3 pp after 12 months.

As for La Niña shocks, these increase EU food commodity prices by 1.8 pp, which passes through to EA headline inflation (+0.6 pp after 12 months). While the impact of the intensification of La Niña on EU food commodity prices is stable over time,²³ the impact of El Niño shocks on international commodity prices changes over time. These are positive and large when including the 1970s and 1980s in the analysis, whereas they fade away (for international commodity prices) or even switch signs (for EU commodity prices) when restricting to the EA sample.

Our findings can be explained by the combination of a number of factors. For the convenience of the reader, we represent these arguments in the following diagram (see Figure 8) and explain them one by one.

²³The effect of an intensification of La Niña on international food prices is negative in the '70s–'80s and becomes inflationary in the most recent period. We do not have an explanation for that.

7.1 Concentration of Extreme Phenomena in the 1980s

A possible explanation for the smaller impact of El Niño shocks in the most recent sample might be a change in the distribution of ENSO events. In Table 2, we report descriptive statistics for all ENSO events included in this analysis. Strong ENSO events are shown in bold. For El Niño, we note that in the former period, and especially during the 1980s, there was an extreme concentration of strong El Niño phenomena (three strong El Niño events in a row within the decade from 1982 to 1992). Moreover, these events are associated with a striking variation in commodity prices. These episodes took place in a time when food inflation volatility was high and market integration was not as developed as it later became. As a consequence, the combination of a high concentration of strong El Niño events in the 1980s and the strong food price variation in that decade may have driven the results for the former sample, and hence in part explain our findings.

7.2 Mitigation Policies and the Financialization of Food Commodities

Early warning systems allow farmers to frontload or delay the planting and harvesting of crops when the formation of an El Niño event is detected, thereby mitigating potential losses (see, for instance, Adams et al. 2003; Paz et al. 2007; Raj, Kumar, and Ramesh 2020). This channel could help explain our results. Indeed, fully fledged policies for anticipating, responding to, and mitigating the effects of the ENSO phases have been called for by the Food and Agriculture Organization (FAO). For instance, FAO (2023) points to policies that help fishers protect their boats ahead of storms or reinforced river embankments ahead of floods. The organization also calls for responding to harvest damage by distributing drought-tolerant seeds to rainfed farmers and protecting livestock health, among other strategies. The FAO also emphasizes capitalizing on the positive spillover effects of El Niño and offsetting its losses, for instance, by supplying seeds to flood-affected farmers so they can plant and regain a harvest as flood waters recede. A third step the FAO calls for is the fast delivery of the most-needed products for farmers in case of devastation, such as veterinary medicines, seeds,

Table 2. Characteristics of ENSO Phenomena

El Niño				
Start	End	Length [†]	EU Comm. [§]	Int. Comm. [¶]
May-72	Mar-73	12	13.9	37.8
Sep-76	Jan-77	6	4.9	3.2
Sep-77	Dec-77	5	2.7	9.4
Oct-79	Jan-80	5	3.8	1.1
Apr-82	Jun-83	16	9.4	11.9
Sep-86	Feb-88	19	-1.5	12.7
May-91	Jun-92	15	2.0	-4.8
Sep-94	Mar-95	8	-0.7	-2.0
May-97	May-98	14	-9.9	-2.8
Jun-02	Feb-03	10	5.0	-4.2
Jul-04	Feb-05	9	0.6	-6.4
Sep-06	Jun-07	6	1.7	8.4
Jul-09	Mar-10	10	4.6	4.2
Oct-14	Apr-16	20	-5.6	-0.7
Sep-18	Jun-19	11	1.2	6.2
May-23	Dec-23	9	-5.4	-5.9
Avg. All Events		10.9	1.7	4.3
Avg. Strong Events (*)		14.4	1.0	6.6
La Niña				
Start	End	Length [†]	EU Comm. [§]	Int. Comm. [¶]
Jan-71	Jan-72	14	11.1	-6.1
May-73	Jul-74	16	36.6	38.5
Oct-74	Apr-76	20	-16.2	-33.8
Sep-83	Jan-84	6	-0.6	1.8
Oct-84	Aug-85	12	-7.1	-20.6
May-88	May-89	14	16.8	28.1
Aug-95	Mar-96	9	-4.5	8.8
Jul-98	Feb-01	33	3.5	0.1
Nov-05	Mar-06	6	9.7	4.6
Jun-07	Jun-08	14	13.6	38.7
Nov-08	Mar-09	6	-4.8	-0.1

(continued)

Table 2. (Continued)

La Niña				
Start	End	Length [†]	EU Comm. [§]	Int. Comm. [¶]
Jun-10	May-11	13	23.6	17.9
Jul-11	Apr-12	11	−4.7	7.8
Aug-16	Dec-16	6	5.2	4.9
Oct-17	Apr-18	8	−7.2	3.9
Aug-20	May-21	11	19.0	36.3
Aug-21	Jan-23	19	28.8	15.6
Avg. All Events		12.8	7.2	8.6
Avg. Strong Events (*)		18.3	14.9	17.9
Note: The table shows the month and year in which events of El Niño (La Niña) start and end, the number of months for which these events took place, and the change in both the European and international food commodity prices during each event. Rows in bold refer to strong El Niño and La Niña events. A strong El Niño (La Niña) is defined as an event where the average sea surface temperature in the equatorial Pacific is at least 1.5°C warmer (colder) than normal. [†]Length: Number of months since the start of the event. [§]EU commodity price. We report the rate of change between the final month of the event and the initial month of the event. [¶]International commodity price. We report the rate of change between the final month of the event and the initial month of the event. (*) We compute the average considering only strong events, which are listed in bold in the table.				

and water bladders, while providing cash to severely affected families to meet their most immediate needs.

Another factor that might have mitigated the impact of the El Niño–Southern Oscillation over the most recent decades is the hedging strategies on food commodity derivative markets that have developed markedly since early 2000 and which have proven to be effective in lowering risks (see, for instance, Jiang and Fortenbery 2019; Ferreira, Tonin, and Alves 2022; Pantoja-Robayo and Rodriguez-Guevara 2023). This is probably related to the more intense participation of institutional investors providing further liquidity to the food commodity derivative markets since the late 1990s, known as the financialization of commodity markets, as these traders tend to adopt higher risk-return positions that generate

broader hedging opportunities for commercial investors (ECB 2011; Tang and Xiong 2012; Cheng and Xiong 2014).

We remind the reader that the most likely effect of mitigation policies is to reduce the ONI-induced price increases. However, these policies could also lead to a decrease in prices in certain cases, although this is something we cannot test for. For instance, mitigation policies may enable farmers to anticipate or delay certain cultivation phases in response to an impending El Niño event. If these adjustments result in an increased supply, the resulting harvest could potentially lead to a decrease in food commodity prices.

7.3 The Volatility of Food Commodity Prices in the 1980s

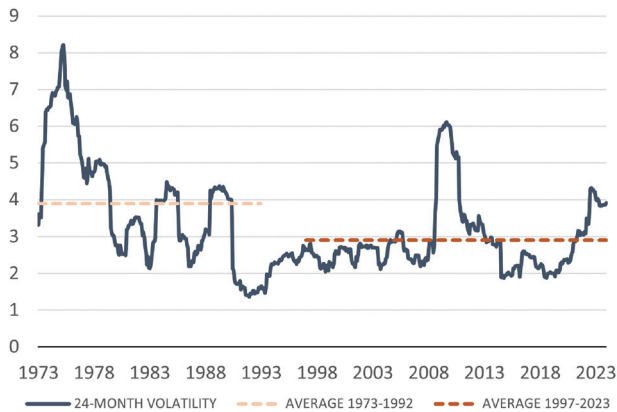
Increased globalization and economic integration may also partly explain why the impact of ENSO phenomena has decreased over time. As is shown in Figure 9, food commodity price volatility has decreased since the middle of the 1980s. Jacks, O'Rourke, and Williamson (2009) shows that world market integration is associated with less commodity price volatility.²⁴ This means that a higher degree of globalization could reduce food price volatility. This argument suggests that food commodity prices have become less reactive to shocks, and hence the effects of ENSO climate phenomena may have become weaker.

7.4 EU's Common Agricultural Policy

The reform of the Common Agricultural Policy (CAP) in 1992, known as MacSharry's reform, may also help explain our findings, i.e., the differences in the inflationary effects of El Niño in different samples. Until 1992, the CAP guaranteed minimum food commodity prices for farm production, and farmers were offered subsidies to export. This combination encouraged excess production and trade out of Europe. Hence, in this setting, when international food commodity prices increased due to El Niño shocks, European farmers had an incentive to export to international markets. As a consequence, food commodity supply decreased in the European market

²⁴The paper studies 300 years of data for commodity prices and links it to periods of high and low globalization.

Figure 9. 24-Month Volatility of International Food Commodity Prices



Note: Own calculations. The figure shows the 24-month standard deviation of the international food commodity index. The horizontal lines show the average from 1973 to 1992 and from 1997 to 2023.

and EU food commodity prices increased due to competition effects. After 1992 this policy changed, such that support to farmers became direct—through rents—and minimum prices and export subsidies were no longer guaranteed.

7.5 Trade Diversification in the Euro Area

The working hypothesis here is that trade patterns may have helped mitigate the effect of ENSO events on EU food commodity prices over time. To shed light on this potential channel, we provide some facts on the evolution of EU trade by food group, in line with our main analysis.²⁵ For this descriptive exercise, we focus on three food groups, namely cereals, meat, and dairy, which together represent 50 percent of the EU consumer food basket.

For each food group and year, we compute the import share, defined as the sum of shares of EU imports coming from countries that are affected or not by ENSO phenomena (either El Niño or La Niña) out of the total EU imports, for the corresponding

²⁵For details on the data and methodology, see Appendix L.

food category. We also compute the Herfindahl-Hirschman Index (HHI) in order to measure the degree of import concentration across trade partners, distinguishing between the import concentration from countries that are affected by ENSO phenomena and the import concentration from other countries that are not directly affected by ENSO phenomena.

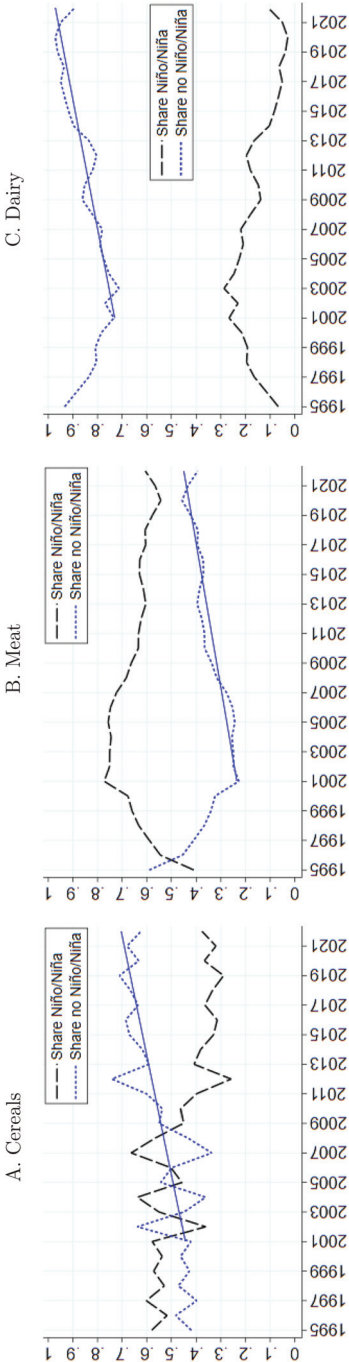
The following dynamics stand out. For each food group, the share of imports from ENSO-affected countries has decreased since 2000 to the benefit of the import share from ENSO-neutral countries, which has increased (see Figure 10). This means that since the 2000s, the EU has traded more intensively with ENSO-neutral countries, shifting imports away from ENSO-affected countries. In terms of concentration, for dairy and cereals we observe an increase in the overall concentration index since the 2000s, resulting from both the increased concentration within the market segment of imports from ENSO-neutral countries and the broader gap in import shares to the benefit of this group of countries (see Figure 11).²⁶

Instead, for meat the overall concentration index has remained broadly stable since the 2000s, as a result of two offsetting trends: the increase in concentration within the segment of ENSO-neutral countries and the narrowing of the import share gap to the benefit of this group of countries, which lowers the concentration.

All in all, this descriptive evidence is consistent with the working hypothesis that EU countries may have implemented trade strategies that protect the EU market from the food price volatility implied by ENSO shocks along two dimensions: (i) by shifting the import share from countries affected by ENSO shocks toward countries not affected by these phenomena and (ii) by concentrating within the segment of the import market of countries not affected by ENSO shocks, i.e., importing more from fewer ENSO-neutral countries. This may help explain our findings. However, this conclusion has to be taken with a grain of salt, as trade data cover only the most

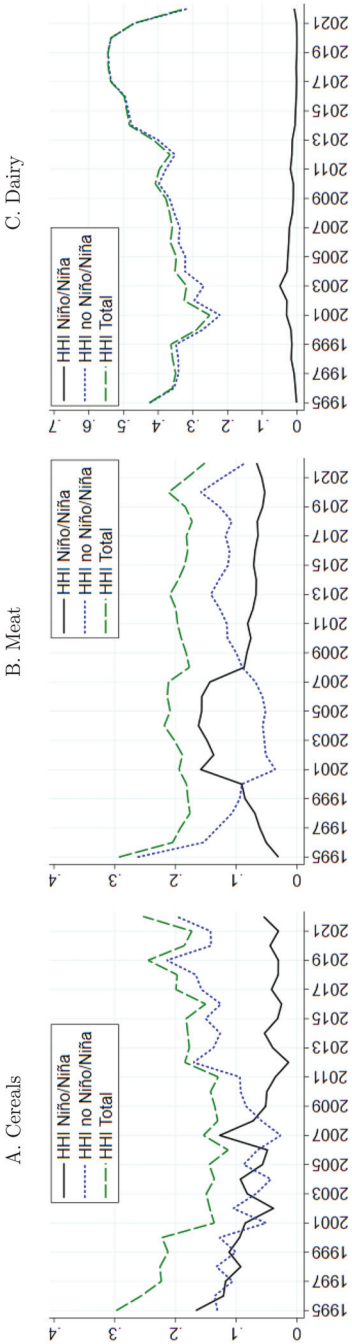
²⁶This follows from the fact that the increase in the overall concentration index is coupled, firstly, with the increase in import shares from ENSO-neutral countries and, secondly, with the rise in concentration in this segment of countries in the period when concentration in the ENSO-affected group remains virtually stable.

Figure 10. Import Share by Food Group



Source: BACI International Trade Database at the Product-Level by CEPII (BACI-CEPII).
Note: These figures display import share indices as described in Appendix L. The solid thin blue line depicts the linear trend of the import share from ENSO-affected countries since 2001, to facilitate the reading of the graph.

Figure 11. Import Concentration by Food Group



Source: BACI-CEPII.

Note: These figures display import concentration indices as described in Appendix L.

recent period and, hence, we are extrapolating the trade dynamics backwards.

8. Conclusions

This paper investigates the effect of El Niño and La Niña events on euro-area inflation. We focus on a comprehensive granular database covering both euro-area consumer prices and European Union (EU) food commodity prices. We also construct a new database of EU prices from 1972 onward, allowing us to test the effect of ENSO events on a larger sample. We assess the impact of these climatic events by means of local projections techniques, following the methodology of Jordà (2005).

Our findings based on data from 1997 onward show that an intensification of an El Niño event actually results in a decrease in euro-area headline inflation of approximately 0.3 percentage points 12 months post-shock. In stark contrast, a La Niña event leads to an increase in headline inflation of 0.6 percentage points 12 months after the shock. When we extend our analysis to include data dating back to the 1970s, we identify the 1980s as a pivotal decade demonstrating a significant positive impact of El Niño on both global and European Union food commodity prices. This finding aligns with the existing literature. Interestingly, this trend reversed post-1997.

All in all, our results suggest that El Niño may not have been a key driver of upward inflation pressures in the euro area during the most recent episode of high inflation. Nevertheless, policymakers should remain alert to the inflation risk associated with an intensification of the impending La Niña event.

This paper contributes to the existing literature by filling a gap in the study of the impact of ENSO events on euro-area prices. Our bottom-up approach, which factors in disaggregated effects on specific food components to assess the overall effect of El Niño and La Niña on aggregated prices, provides a more nuanced understanding of these phenomena. Furthermore, our methodology allows us to replicate most of the existing evidence on international food commodity prices, thereby validating our approach and indirectly testing the robustness of our main results based on the euro area.

Appendix A. Food Components across Sources

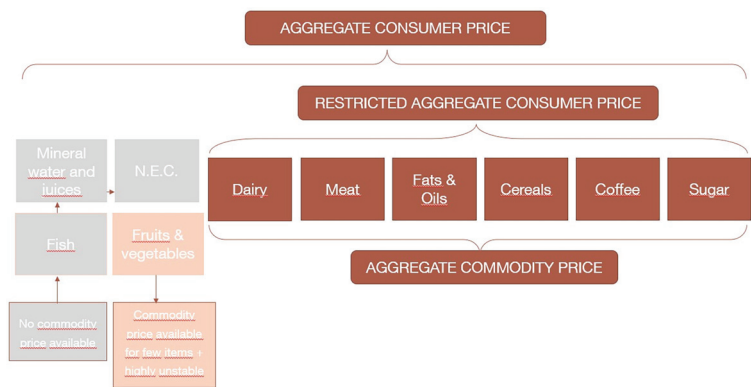
Table A.1. Food Prices: Definitions and Subcomponents across Food Groups and Production Processes

	Commodity Price	Producer Price	Consumer Price
Cereals	Feed barley, malting barley, feed maize, bread wheat, feed wheat, durum wheat, feed rye, and bread rye	Cereals: manufacture of grain mill products, starches, and starch products	Cereals: bread and cereals
Dairy	Skim milk powder, raw milk, butter, cheddar, edam, and eggs	Manufacture of dairy products	Dairy: milk, cheese, and eggs
Fats and Oils	Rapeseed oil, sunflower oil, soybean oil—the three of them from the IMF—and olive oil	Manufacture of oils and fats	Oils and fats
Meat	Cows, steers, pigs class E, and chicken	Production of meat and poultry meat products	
Sugar	White sugar (from WB Pink Sheet since May 2023)	Manufacture of sugar	Sugar: sugar, jam, honey, syrups, chocolate, and confections
Coffee	Coffee (from the International Coffee Organization)	Processing of tea and coffee	Coffee, tea, and cocoa

Table A.2. Food Commodity Price Indices Before and After 1996

	Components of Commodity Prices Before 1996	Components of Commodity Prices After 1996
Cereals	Feed rye, durum wheat, feed barley, and feed maize (before 1991, feed maize comes from the Pink Sheet)	Feed barley, malting barley, feed maize, bread wheat, feed wheat, durum wheat, feed rye, and bread rye
Dairy	Skim milk powder, raw milk, edam, and eggs	Skim milk powder, raw milk, butter, cheddar, edam, and eggs
Fats and Oils	Soybean oil until 1980, then also rapeseed oil and sunflower oil	Rapeseed oil, sunflower oil, soybean oil—all three from the IMF—and olive oil
Meat	Cows, pigs class E, and chicken	Cows, steers, pigs class E, and chicken
Sugar	Sugar (from the International Financial Statistics up to 1979 and IMF commodity prices from 1980 onward)	White sugar (from WB Pink Sheet since May 2023)
Coffee	Coffee (robusta, from the Pink Sheet)	Coffee (from the International Coffee Organization)

Figure A.1. Correspondence of EU Commodity Prices and Euro-Area Consumer Prices



Note: Own elaboration. N.E.C. means not elsewhere classified.

Appendix B. Detailed Commodity Food Price Data Since 1972

This appendix describes in detail the sources and procedures used to construct the variables since 1972.

Global Food Commodity Prices. Monthly data on global food commodity price indices are obtained from the World Bank’s Pink Sheet. We include in the database the food aggregate as well as each of the food groups and items. Food items are aggregated into groups and the total food aggregate according to the average export value weights in emerging economies in the 2002–04 period. All indices are converted from U.S. dollars to euros.

European Union Food Commodity Prices. To construct this aggregate price index, we proceed as follows:

- We consider monthly data for cereals, meat, and dairy from 1972 to 2023. We concentrate on these three food groups due to data availability restrictions for their components: cereals (rye, durum, feed barley), meat (heifers, chicken, cows, pigs), and dairy and eggs (raw milk, skimmed milk powder, edam cheese, and eggs). We use DG Agri monthly data on food commodity prices from 1991 onward, and we complete the

database with the equivalent Eurostat monthly prices, available on a monthly basis from 1971 to 1995/99 depending on the specific food item. All prices are expressed in euros.

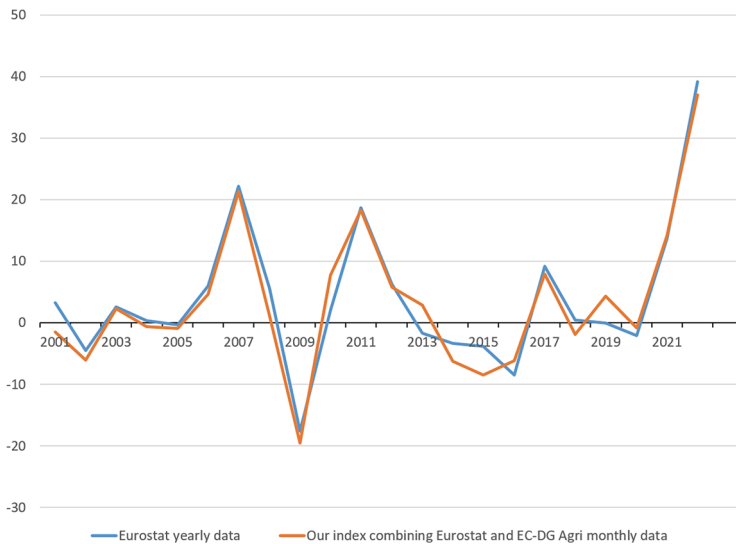
- We include in our database the food items showing a correlation between growth rates from the two data sources higher than 0.65 during the overlapping period (1991–94). For instance, edam cheese prices show the lowest correlation of 0.66 between the growth rates available in Eurostat and DG Agri. Cows’ meat shows the highest (0.95).
- For each food item, we use the Eurostat price index from January 1971 to December 1995 normalized to 100 in January 1971.²⁷ Then, we continue the series, applying to the last observation available from the Eurostat data the corresponding growth rate in DG Agri.
- Each food group price index is calculated as the simple average across its food items’ prices. The aggregate food commodity price for the European Union is the weighted average of the food group price indices, according to the weight of each category in the food consumption basket in 2021 (0.31 for cereals, 0.43 for meat, and 0.26 for dairy and egg products).
- To ensure that this procedure is correct, we compare the resulting food commodity aggregate price index growth rate to the equivalent price series in Eurostat (available at a yearly frequency from 2000 onward). Figure B.1 shows that the two series are very similar over the last two decades, ensuring that our procedure is valid.

Euro-Area Consumer Prices. The Harmonised Index of Consumer Prices (HICP) is obtained from Eurostat, whereas food consumer prices are obtained from the OECD (Organisation for Economic Co-operation and Development), starting in 1971, and we link these with Eurostat data from 1996 onward.

- First, we construct a long time series of the energy component of the consumer price index for the European region by aggregating the energy indices of France, Germany, and Italy, which are available from the OECD database. This series is

²⁷For eggs, we use the Eurostat data until 1996.

Figure B.1. Comparison between Our Price Index and Eurostat Data



Note: The comparison starts from 2000 onward, since this is when Eurostat started reporting annual data. We show that our price index, which combines monthly data from Eurostat and the European Commission's DG AGRI, when aggregated at a yearly frequency, shows a very similar evolution to the original yearly price index of Eurostat.

considered a proxy for the energy index of the euro area. In the aggregation, we implement the Eurostat methodology.

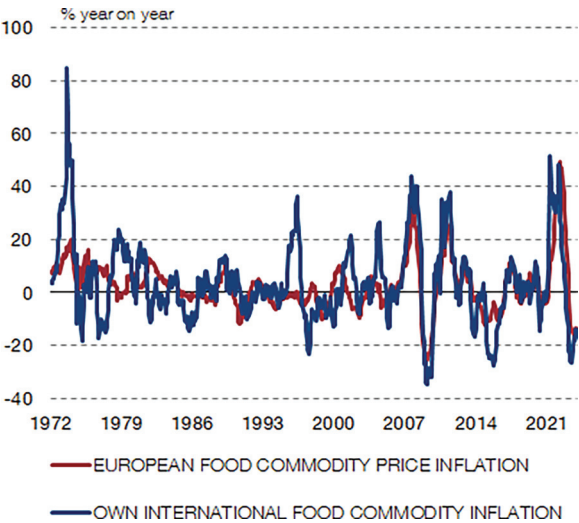
- Second, we construct a long time series of the HICP energy component for the euro area by exploiting all available data. Data for the energy component of the consumer price index for the euro area are available from the OECD database from 1977 onward and from Eurostat from 1990 onward. To stretch the Eurostat series back to 1971, we proceed as follows. We extend the Eurostat energy index for the euro area backwards until 1977 by applying the growth rate of the OECD energy index for the euro area. Then, we extend the resulting series back to 1971 by applying the growth rate of the aggregate energy index based on OECD data for Italy, France, and Germany computed in the previous step.

- Then, once we have long time series for the (i) headline HICP, (ii) food HICP, and (iii) energy HICP for the euro area since 1971, we construct the core HICP index for the euro area by first adding up (ii) and (iii) and then subtracting the resulting sum from the headline HICP. Note, for these operations we implement the Eurostat methodology.

Other Control Variables. The following are additional control variables:

- **Crude Oil Prices and the Fertilizer Price Index.** These are obtained from the World Bank’s Pink Sheet and converted into euros.
- **Economic Activity for the Euro Area.** In the European region-based estimations, we also control for the economic activity in the European region by including as a regressor the monthly industrial production index (IPI) growth in the region. Since we need a large time series from the 1970s

Figure B.2. European and World Food Commodity Price Inflation



Note: Own calculations.

onward, we construct our own variable by combining different data. Most of the data are provided by the OECD, except for the most recent data (December 2023), which are obtained from the Eurostat database. In all cases, we consider industrial production excluding construction. For January 1971 to July 1974, we use the IPI for Europe (OECD), and we link this with the IPI for the euro area for August 1975 to November 2023. For the last data point (December 2023), which at the time of writing has not yet been released in the OECD database, we use industrial production excluding construction, obtained from Eurostat.

Table B.1. Components of the Global Food Commodity Price Index (WB)

Commodity Component	Time Availability
Rice	1960:M1–2023:M12
Wheat	1960:M1–2023:M12
Maize	1960:M1–2023:M12
Barley	1960:M1–2020:M8
Soybeans	1960:M1–2023:M12
Soybean Oil	1960:M1–2023:M12
Soybean Meal	1960:M1–2023:M12
Palm Oil	1960:M1–2023:M12
Coconut Oil	1960:M1–2023:M12
Groundnut Oil	1960:M1–2023:M12
Sugar	1960:M1–2023:M12
Bananas	1960:M1–2023:M12
Beef	1960:M1–2023:M12
Chicken	1960:M1–2023:M12
Oranges	1960:M1–2023:M12
Cocoa (*)	1960:M1–2023:M12
Coffee, Robusta (*)	1960:M1–2023:M12
Tea, Average Three Auctions (*)	1960:M1–2023:M12
Fish Meal (**)	1979:M1–2023:M12
Palm Kernel Oil (**)	1996:M1–2023:M12
Rapeseed Oil (**)	2002:M2–2023:M12
Sunflower Oil (**)	2002:M2–2023:M12
Lamb (**)	1971:M1–2023:M10
Mexican Shrimp (**)	1960:M1–2023:M10
Sorghum (***)	1960:M1–2020:M08
Groundnuts (***)	1980:M1–2023:M12

Note: These are the food commodity prices that compose the global food commodity price index as provided by the World Bank. (*) denotes subcomponents that are part of the World Bank Beverage Commodity Price Index. (**) denotes subcomponents that are not part of either the Food or the Beverage Commodity Index. (***) indicates weights considered in the Food Commodity Price Index.

Table C.1. Literature Review: Impact of El Niño on GDP Growth

	Results	Coverage	El Niño	Method	Sample	Controls
Beltran, Hadzi-Vaskov, and Stepanov (2023)	Heterogeneous effect on GDP across countries: negative for CAPDR(*), Colombia, Ecuador, Peru; positive for Argentina, Paraguay, Uruguay; ambiguous on Bolivia, Brazil, Chile, Mexico	Latin America	Oceanic Niño Index (ONI)	Local projections in cross-country panel	Not mentioned	Account for other shocks (but do not mention which ones)
Cashin, Mohaddes, and Raissi (2017)	Heterogeneous responses across countries: negative but short-lived for Australia, Chile, Indonesia, India, Japan, New Zealand, South Africa; positive for the U.S., Europe, China	Global: 21 countries/regions in an interlinked model	Southern Oscillation Index (SOI)	GVAR model	1979–2013	Inflation, real exchange rate, short-term and long-term interest rates, real equity prices, real energy and non-fuel commodity prices
Martín (2016)	GDP loss that ranges between 0.5 and 1.5 pp depending on the country, mostly concentrated in agriculture, infrastructure, and energy sector.	Bolivia, Peru, Ecuador, Colombia, Venezuela	Southern Oscillation Index (SOI)	Country-level AR models	Not defined, but includes 1982–98	Economic crisis dummies
Brunner (2002)	Positive effect of 0.5 pp on GDP growth in the G7 countries, significant at the 10 percent level. Possible explanations: increase in investment spending or in aggregate demand from other countries devastated by El Niño (e.g., food, housing materials, machinery, equipment).	Global: aggregate G7 countries	SST or SOI anomaly measure	VAR models	1963–98	Average CPI inflation rate, average GDP growth rate, international real commodity price inflation

(continued)

Table C.2. Literature Review: Impact of El Niño on Inflation

	Results	Coverage	Prices	El Niño	Method	Sample	Controls
Ubilava and Holt (2013)	Palm oil is directly affected by El Niño/La Niña (since it is produced in Oceania and Southeast Asia). Other vegetable oils (soybean oil, sunflower seed oil, rapeseed oil produced in not directly affected regions) are indirectly affected due to strong substitutability in consumption between vegetable oils. El Niño (La Niña) yields a vegetable oil price increase (decrease). A three-standard-deviation ENSO shock, 0.7 °C sea surface temperature (SST) anomaly, yields a 6–10 percent change in vegetable oil prices.	Global	Global vegetable oil prices: palm, soybean, rapeseed, and sunflower seed	SST anomalies	STAR	Monthly data, 1972–2010	Month dummies to control for seasonal effects
Cashin, Mohaddes, and Raissi (2017)	Non-fuel commodity prices increase after El Niño. Energy prices increase due to higher demand from Asia, to compensate for (i) lower electricity output and (ii) an increase in water demand for irrigation. This translates into a global oil demand shock (both oil prices and global output increase). CPI inflation increases in most countries (in the U.S. and Europe this increases by 0.12 and 0.07 pp, respectively). Responses are larger in economies that have a higher share of food in their CPI baskets.	21 countries/ regions (*)	National CPI inflation; global energy and non-fuel commodity prices	Southern Oscillation Index (SOI)	Country-specific local projections and GVAR	1979–2013	GDP growth, CPI inflation, exchange rate, short-term and long-term interest rates, equity prices, energy and non-fuel commodity prices

(continued)

Table C.2. (Continued)

	Results	Coverage	Prices	El Niño	Method	Sample	Controls
Martín (2016)	El Niño increases CPI inflation from 1 pp (Colombia) to 5 pp (Ecuador) depending on the country.	Bolivia, Peru, Ecuador, Colombia, and Venezuela	National CPI inflation	Southern Oscillation Index (SOI)	Country-level AR models	Includes the 1982–98 period; sample period not mentioned	Change in monetary aggregate as proxy for monetary policy
Romero and Saldarriaga (2024)	El Niño directly affects food inflation, which in turn increases inflation expectations (second round of effects).	Colombia	Inflation expectations, local food prices	Oceanic Niño Index (ONI)	BVARx	Monthly data, 2003–20	International food price index, real exchange rate, local food prices, industrial production, inflation expectations
Brunner (2002)	A one-standard-deviation positive surprise in ENSO raises real commodity price inflation by 3.5–4 pp. Qualitatively similar effects are observed on G7 overall prices, although much weaker and only marginally significant. This is because primary commodities account for only a fraction of overall finished good costs.	Global aggregate G7 countries	Global real non-oil primary commodity prices and G7 consumer price inflation	SST or SOI anomaly measure	VAR	Quarterly data, 1963–98	Average CPI inflation rate, average GDP growth rate, international real commodity price inflation

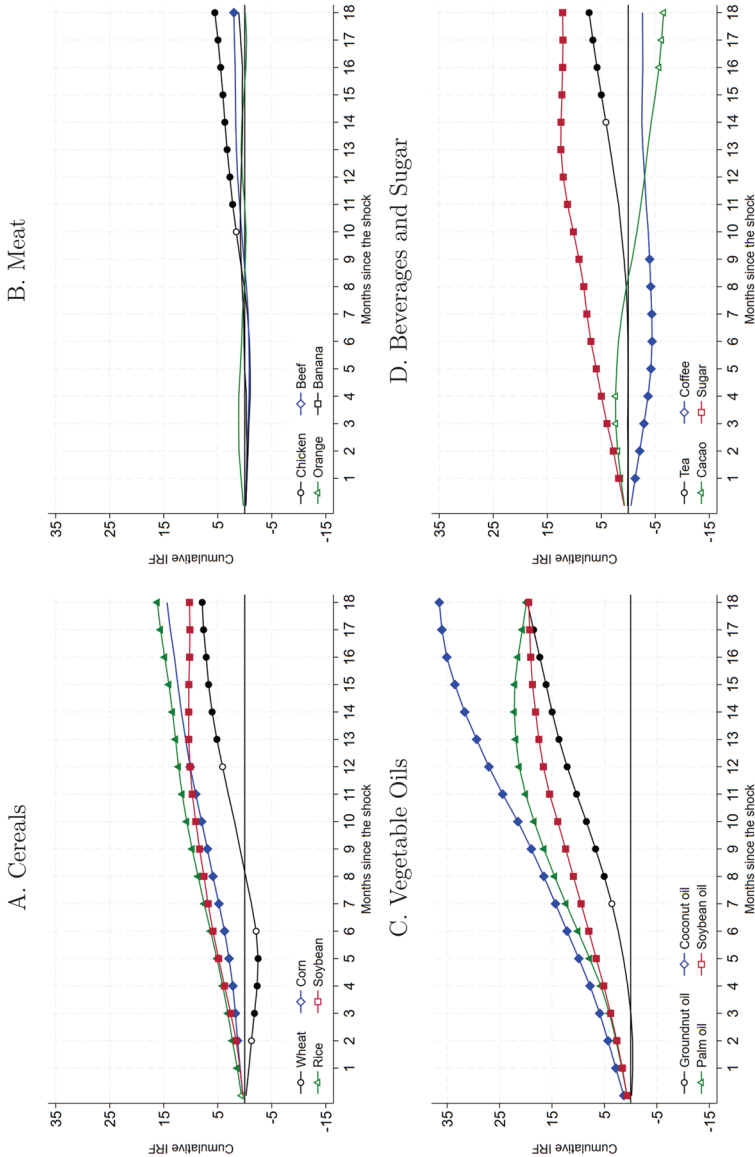
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Table C.2. (Continued)

	Results	Coverage	Prices	El Niño	Method	Sample	Controls
Abril-Salcedo, Melo-Velandia, and Parra-Amado (2020)	Cumulated effect of El Niño is a 600 bp increase in food inflation nine months after the shock. Over 1962–2018, no evidence emerges of changes in the size of food inflation responses over time. A La Niña shock yields ambiguous effects.	Colombia	National food price inflation	SST anomaly measure	Nonlinear smooth transition regression model (STR)	Monthly data, 1962–2018	No
Atems and Sardar (2021)	Heterogeneous effects between La Niña and El Niño. (**) La Niña shocks lead to positive responses to overall agriculture commodity prices. This is because agricultural output decreases after La Niña events, which increases prices in the following period. El Niño shocks do not affect overall agriculture commodity prices. Results for stocks are similar: La Niña shocks are beneficial to stock prices of agricultural companies, while El Niño shocks are detrimental or insignificant.	U.S.	Stock prices of 12 U.S. food and agricultural companies and global food commodity prices	SST anomaly measure	State-dependent local projections	Weekly/monthly data, 1990–2019	CPI price index, industrial production index

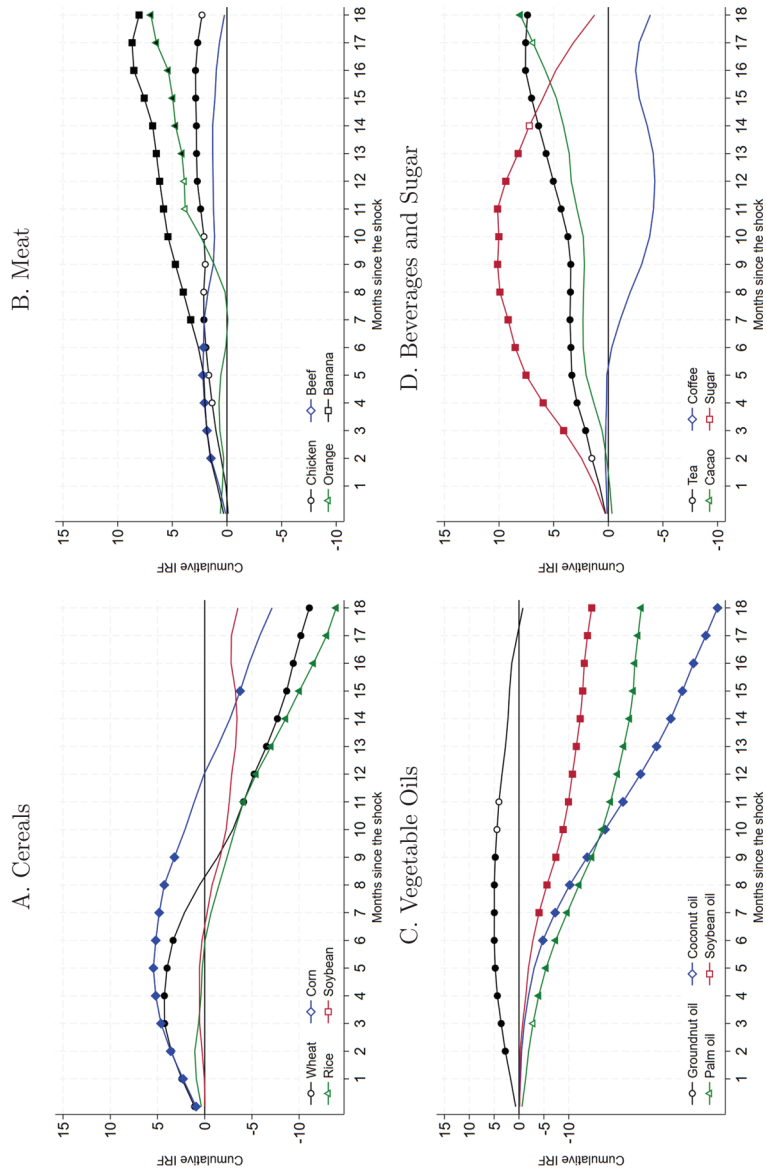
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Figure D.1. Response of International Commodity Prices to an Intensification of El Niño



Note: Monthly cumulative response of international food commodity prices to an El Niño shock. Full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño, i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño event is already taking place.

Figure D.2. Response of International Commodity Prices to an Intensification of La Niña

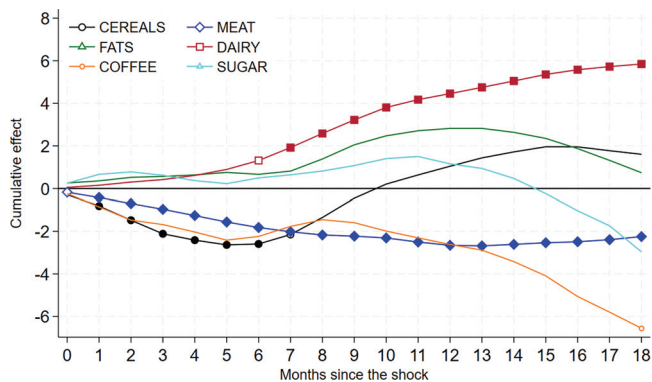


Note: Monthly cumulative response of international food commodity prices to a La Niña shock. Full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations. The shock considered is an intensification of a La Niña, i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when a La Niña event is already taking place.

Appendix E. Disaggregated Effect of El Niño Shocks on EU Commodity and Consumer Prices

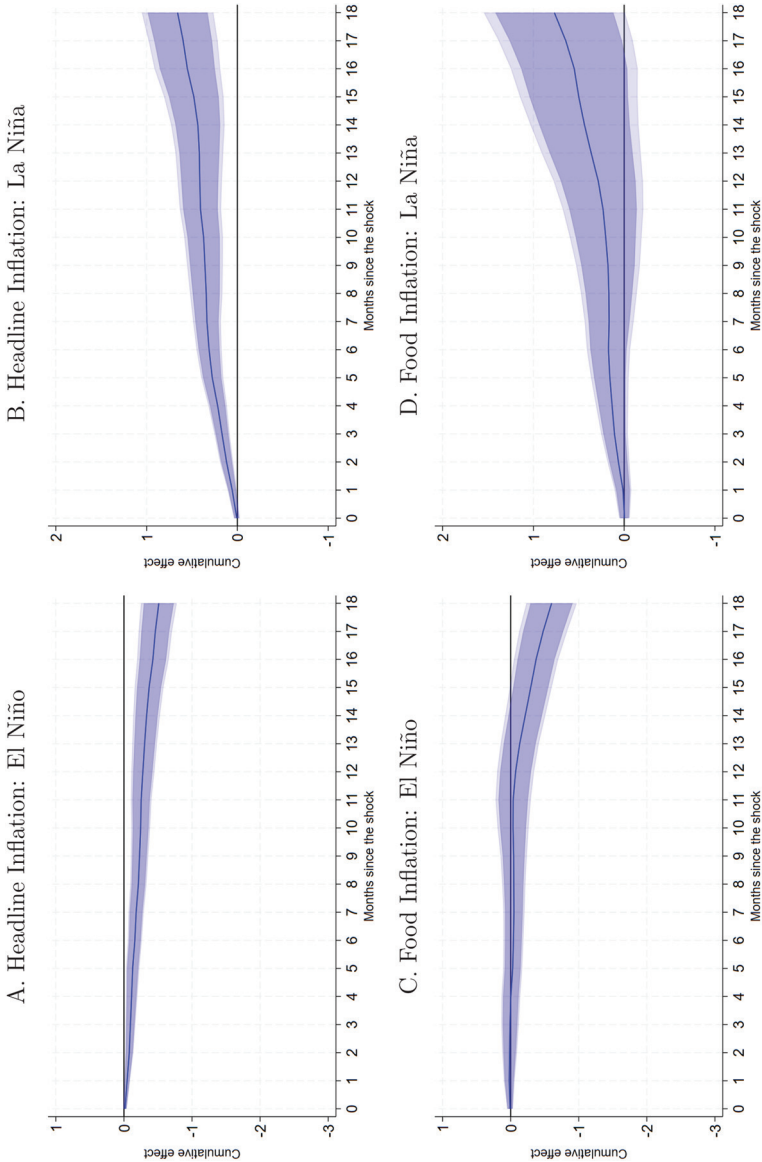
In this appendix, we analyze the disaggregated effects of El Niño shocks on EU commodity prices for the most recent period (1997–2023). While the aggregated impact is presented in Section 5.2 of the main text, here we delve into the disaggregated effects to demonstrate that the overall impact is disinflationary, despite being barely significant at the aggregate level. This disinflationary effect is primarily due to composition effects. In particular, meat and cereals are negatively and significantly affected by the intensification of El Niño, while dairy products are positively affected. We find no significant impacts on oils and fats, sugar, and coffee. Thus, the food aggregate containing the six food groups masks important impacts on the products with the greatest weight in the shopping basket. When we run the robustness exercise considering the entire value chain in Appendix F, these results become clearer. The negative impacts on meat and cereals become more pronounced, while the positive impact on dairy products diminishes and appears much later. Therefore, the disinflationary impact of El Niño is confirmed when taking into account the pass-through along the value chain.

Figure E.1. Disaggregated Response of EU Food Commodity Prices by Food Groups



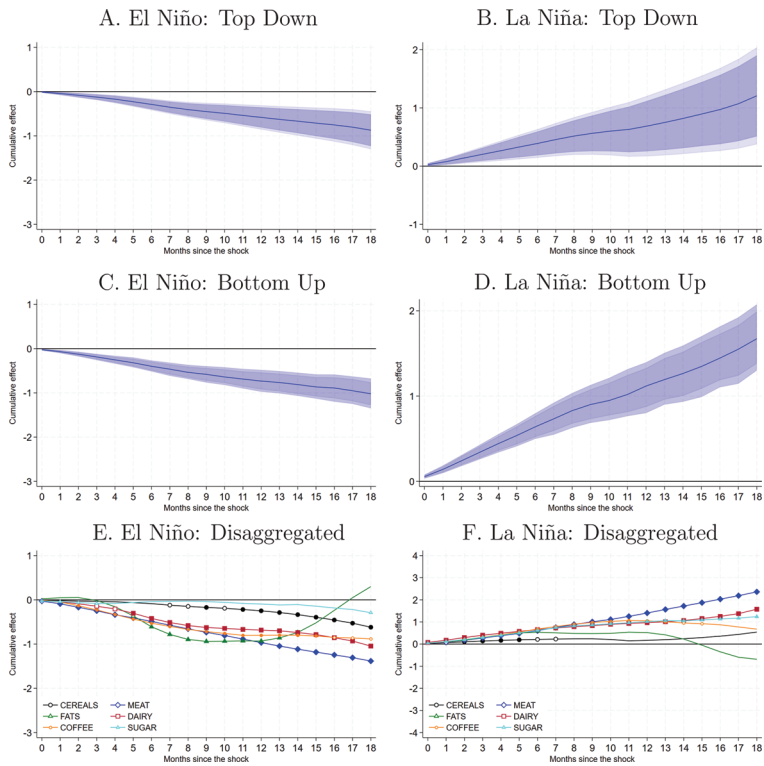
Note: Monthly cumulative response of EU commodity prices according to our own six food group aggregate to an El Niño shock. Full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations. The shock considered is an intensification of an El Niño, i.e., an increase of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño event is already taking place.

Figure F.1. Response of Euro-Area Inflation: Value Chain (Eurostat aggregates)



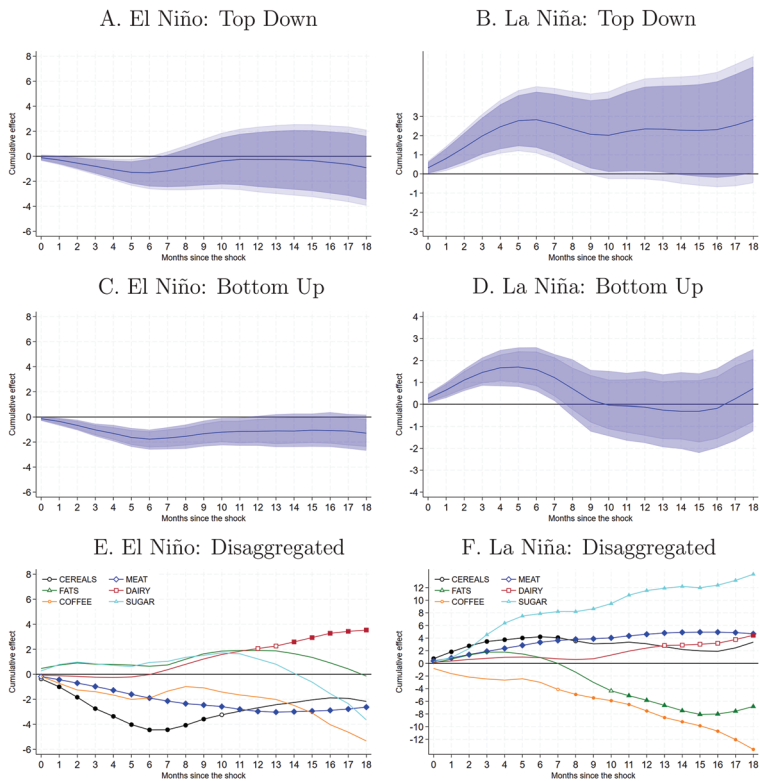
Note: Monthly cumulative response of euro-area headline inflation and food inflation—Eurostat aggregate—to an El Niño shock (left panel) and a La Niña shock (right panel) along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1 °C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

Figure F.2. Response of Euro-Area Food Inflation: Value Chain (own aggregate)



Note: Monthly cumulative response of euro-area food HICP according to our own six food group aggregate to an El Niño shock (left panel) and a La Niña shock (right panel) along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. In the third row, full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

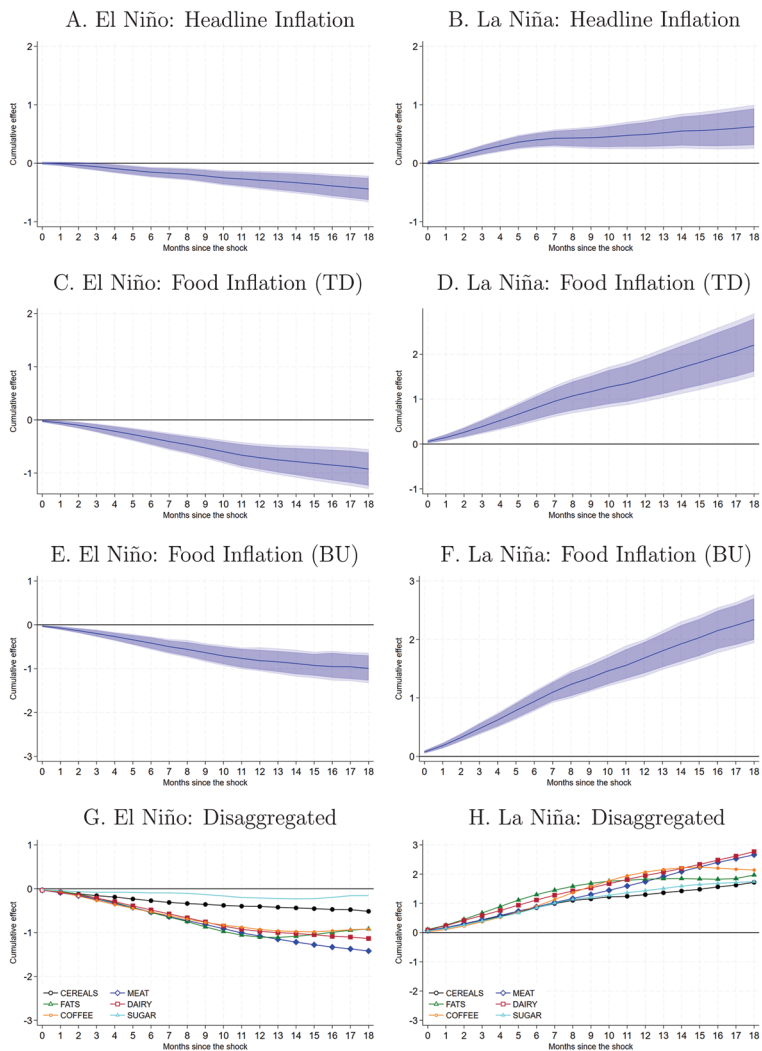
Figure F.3. Response of EU Food Commodity Prices: Value Chain



Note: Monthly cumulative response of European Union food commodity prices to an El Niño shock (left panel) and a La Niña shock (right panel), along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. In the third row, full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

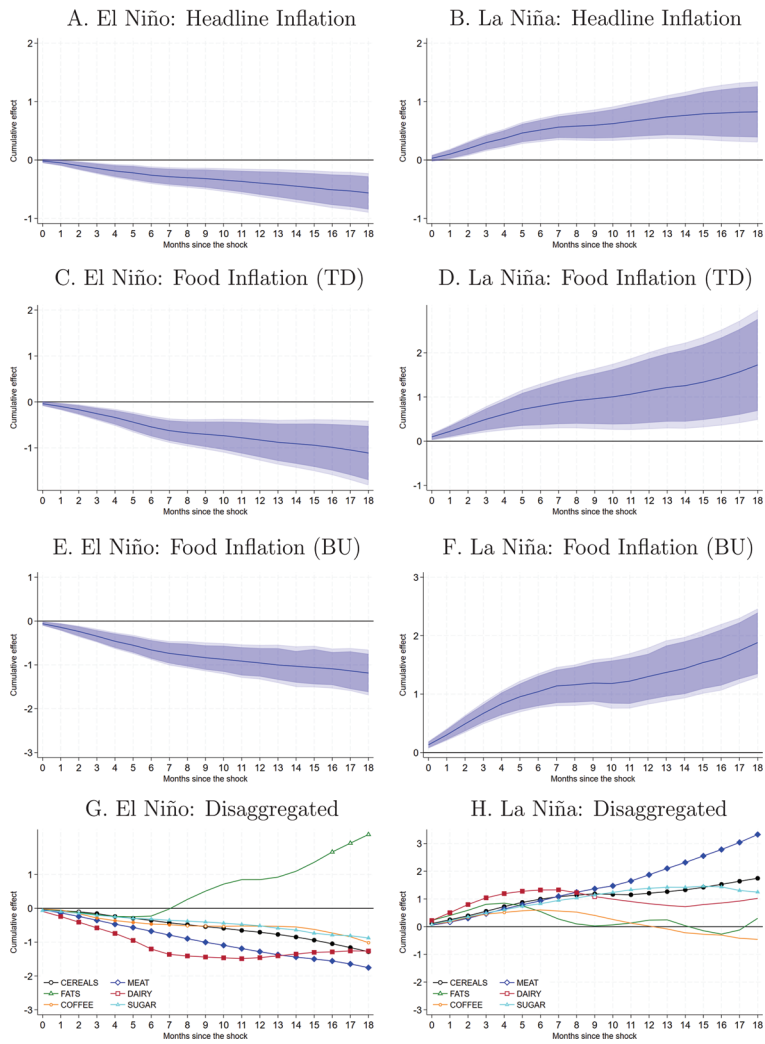
Appendix G. Robustness: Results for France, Italy, Germany, and Spain

Figure G.1. France: Inflation Responses



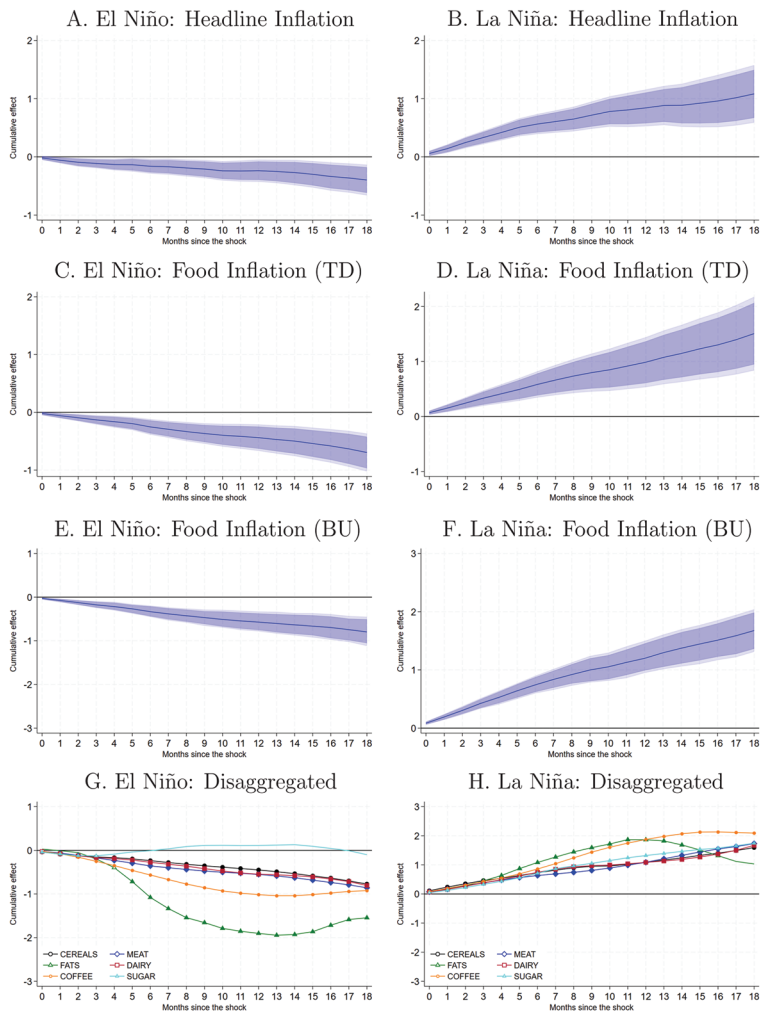
Note: Monthly cumulative response of France’s headline and food HICP to an El Niño/La Niña shock along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. Results are based on linear projection estimations. The shock considered is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

Figure G.2. Germany: Inflation Responses



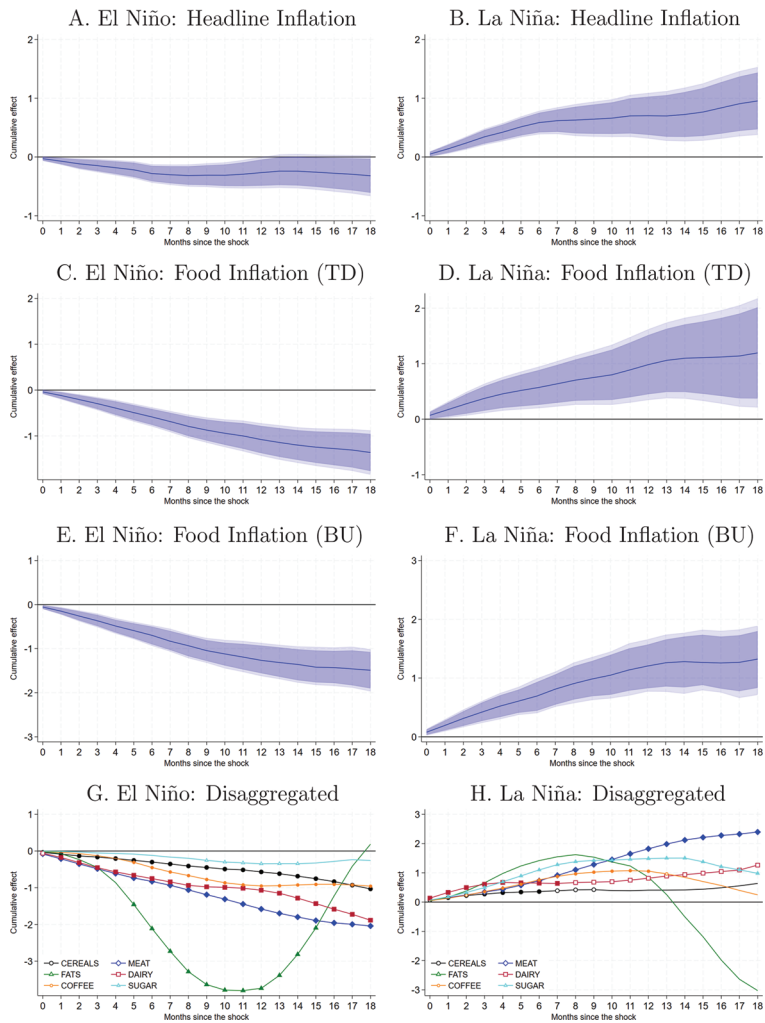
Note: Monthly cumulative response of Germany’s headline and food HICP to an El Niño/La Niña shock along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. Results are based on linear projection estimations. The shock considered is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

Figure G.3. Italy: Inflation Responses



Note: Monthly cumulative response of Italy’s headline and food HICP to an El Niño/La Niña shock along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. Results are based on linear projection estimations. The shock considered is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

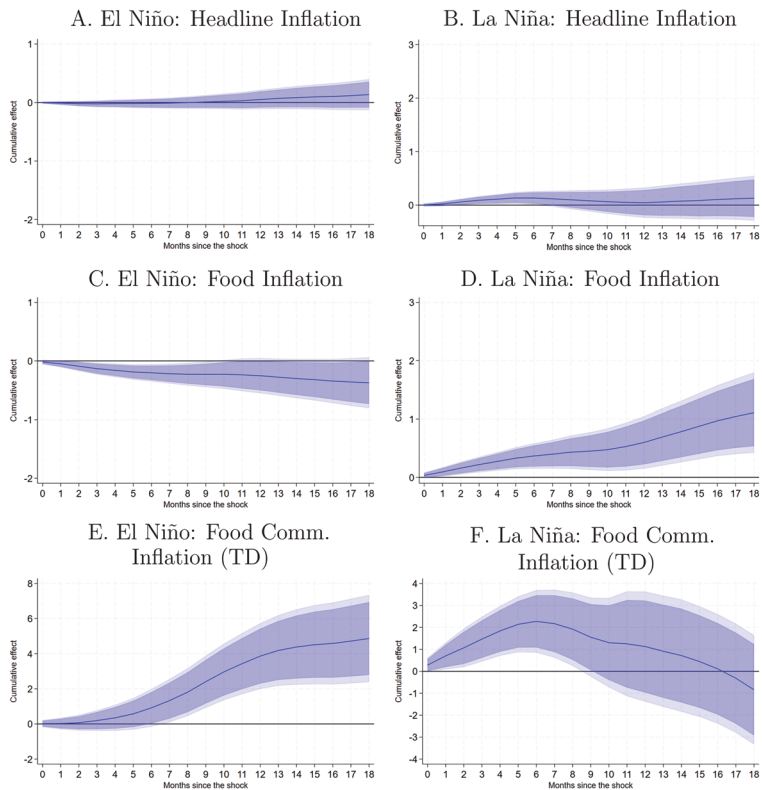
Figure G.4. Spain: Inflation Responses



Note: Monthly cumulative response of Spain’s headline and food HICP to an El Niño/La Niña shock along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. Results are based on linear projection estimations. The shock considered is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

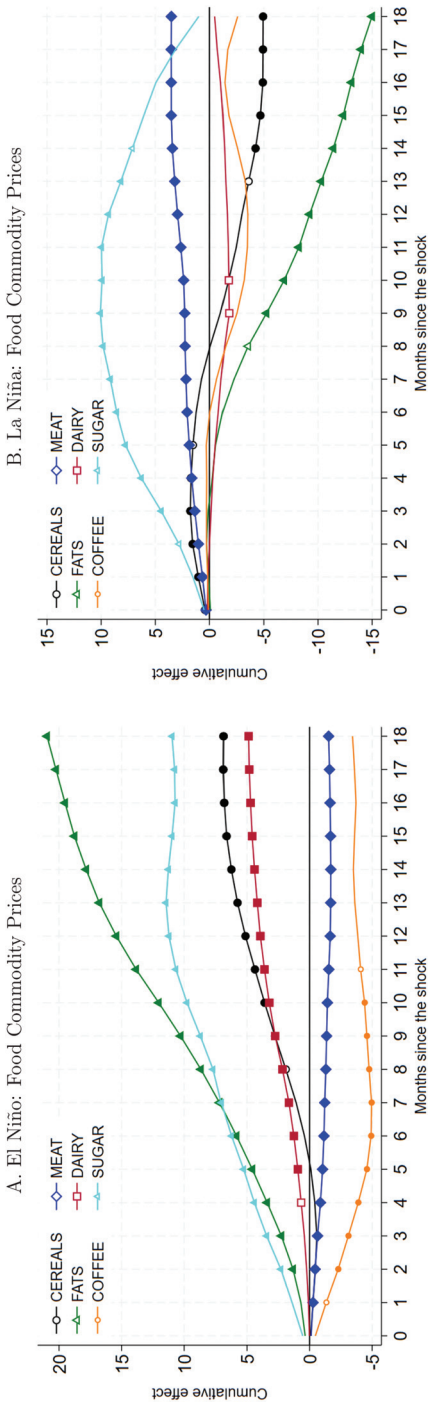
Appendix H. Robustness: Historical Evidence

Figure H.1. Response of Euro-Area Headline and Food and Food Commodity Inflation: Data since 1970



Note: Monthly cumulative response of euro-area headline and food HICP, as well as food commodity prices, to an El Niño shock (left panel) and a La Niña shock (right panel) along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

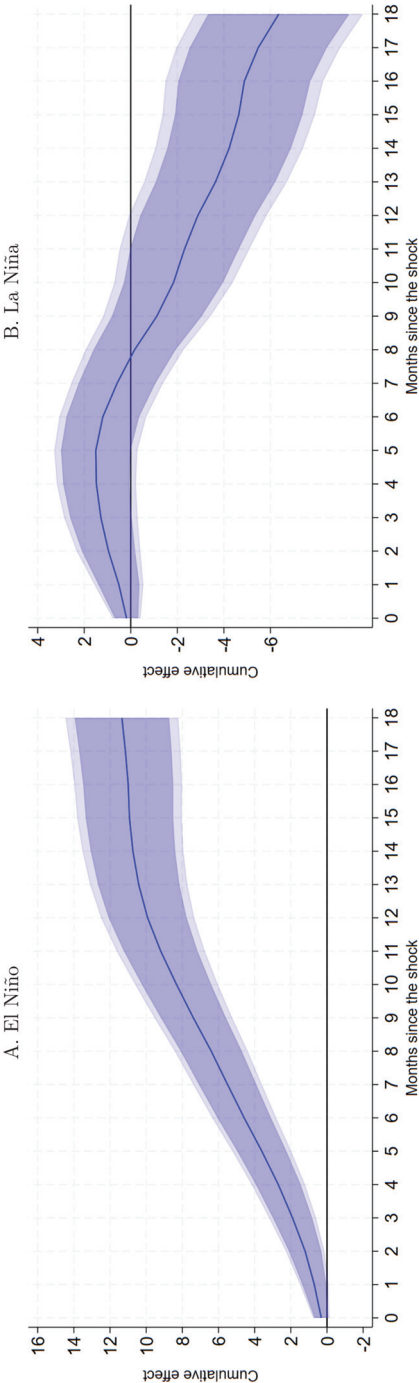
Figure H.2. Response of Disaggregated European Union Food Commodity Prices: Data since 1970



Note: Monthly cumulative response of European Union food commodity prices to an El Niño shock (left panel) and a La Niña shock (right panel). Full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

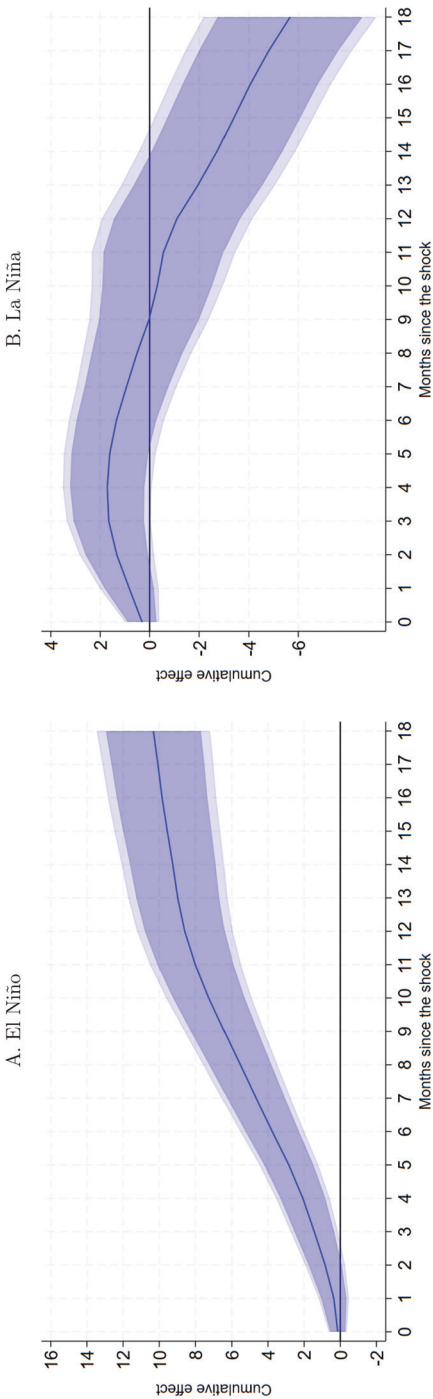
Appendix I. Robustness: Adding Controls and Lags

Figure I.1. Response of International Food Commodity Prices to Adding the Exchange Rate as a Control Variable



Note: Monthly cumulative response of international food commodity prices to an El Niño shock (left panel) and a La Niña shock (right panel) along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

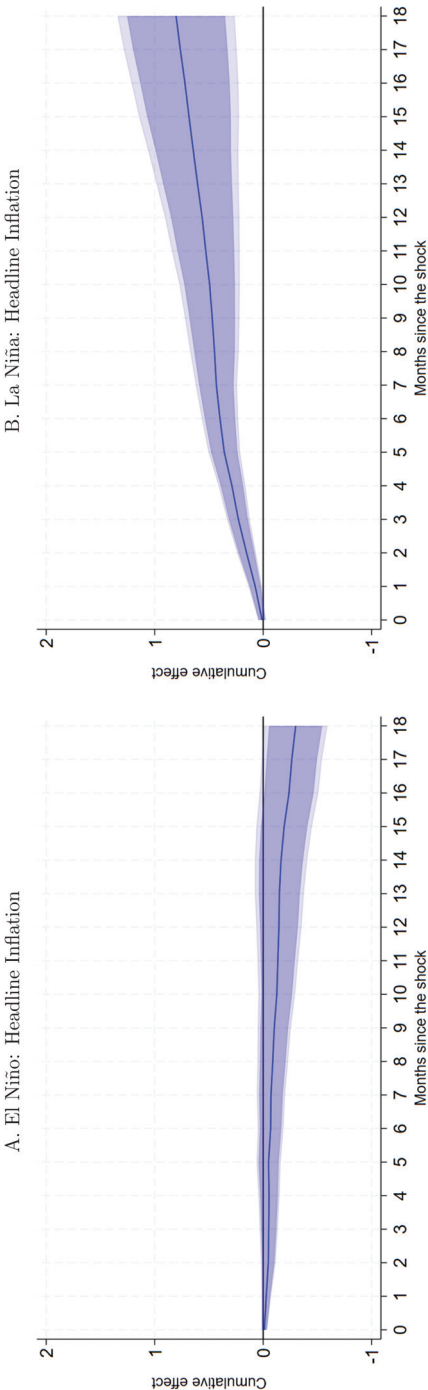
Figure I.2. Response of International Food Commodity Prices to Adding 12 Lags of Food Commodity, Fertilizer, and Oil Prices and Activity



Note: Monthly cumulative response of international food commodity prices to an El Niño shock (left panel) and a La Niña shock (right panel) along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place.

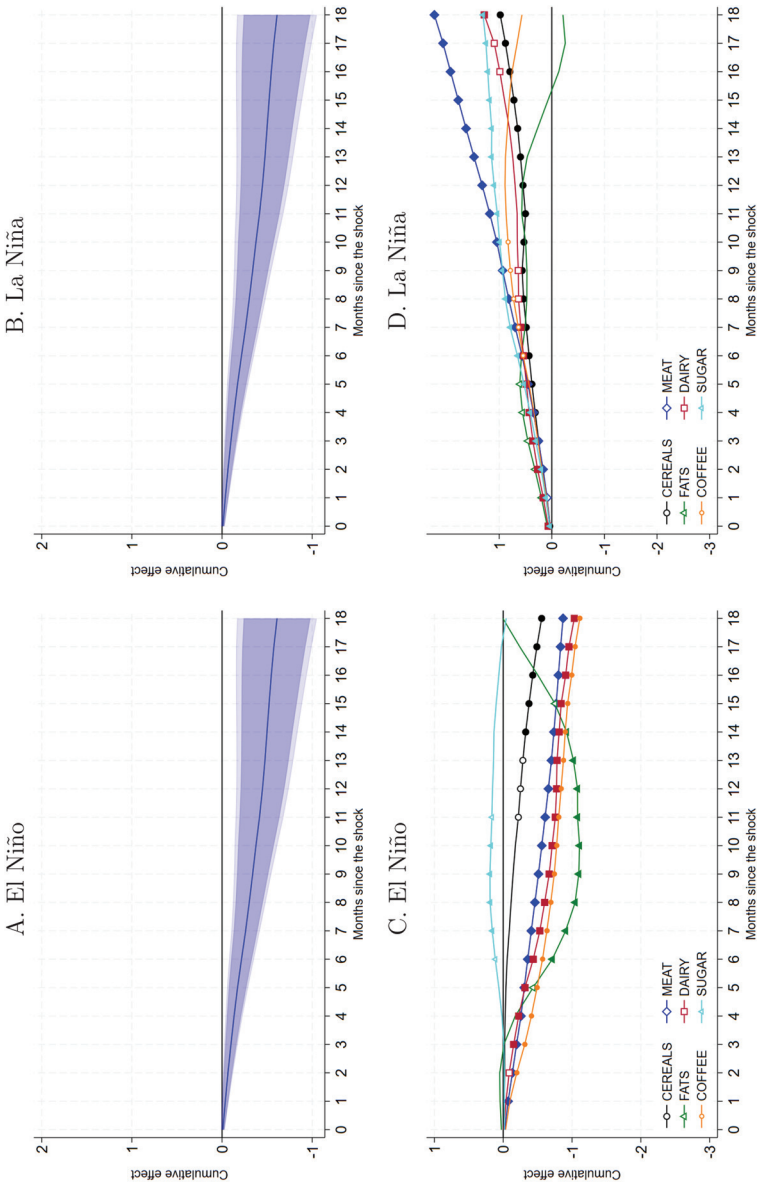
Appendix J. Robustness: Treating El Niño and La Niña Simultaneously

Figure J.1. Response of Euro-Area Headline Inflation:
Treating El Niño and La Niña Simultaneously



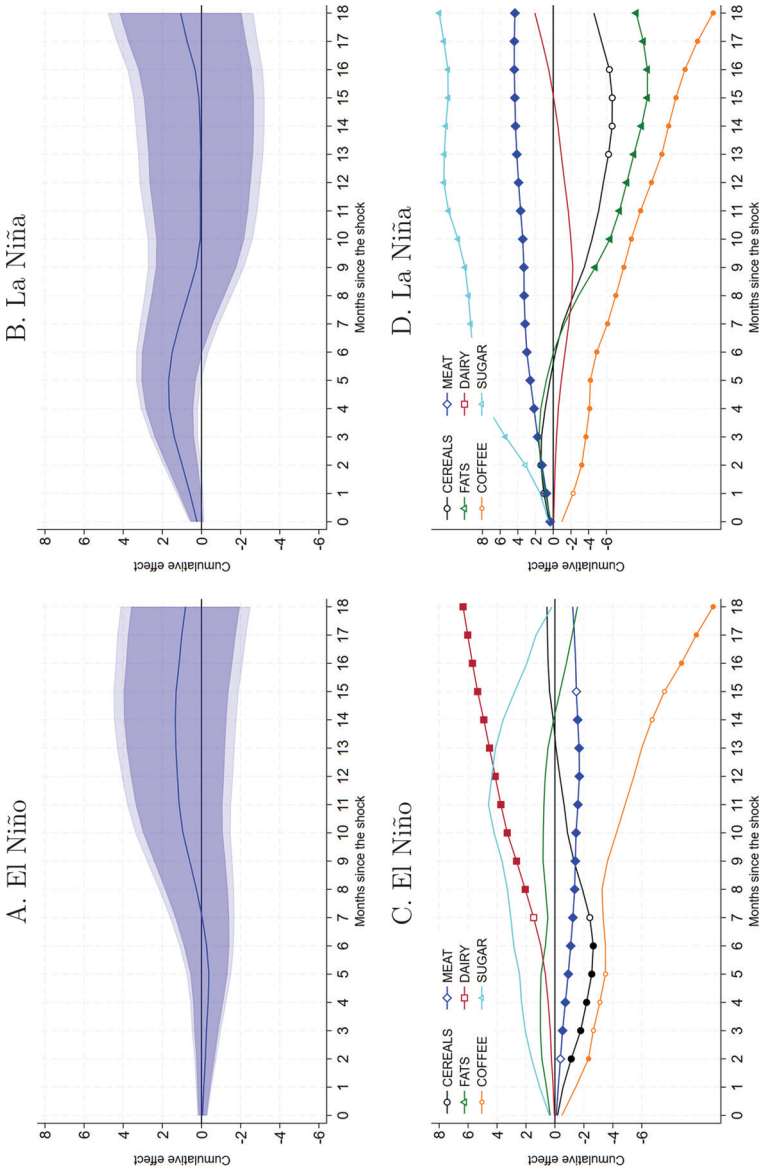
Note: Monthly cumulative response of euro-area headline HICP to an El Niño shock (left panel) and a La Niña shock (right panel) along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place. Both events are considered simultaneously, that is, we include both El Niño and La Niña variables in the model, as defined when we analyzed them individually.

Figure J.2. Response of Euro-Area Food Inflation:
Treating El Niño and La Niña Simultaneously



Note: Monthly cumulative response of euro-area food HICP to an El Niño shock (left panel) and a La Niña shock (right panel) along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. In the second row, full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place. Both events are considered simultaneously; that is, we include both El Niño and La Niña variables in the model, as defined when we analyzed them individually.

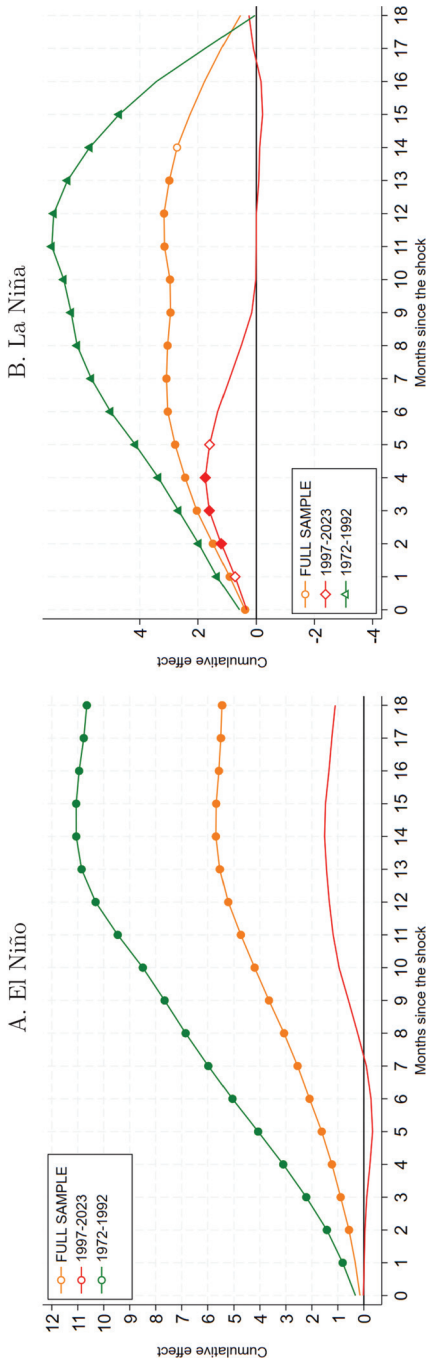
Figure J.3. Response of European Union Food Commodity Inflation: Treating El Niño and La Niña Simultaneously



Note: Monthly cumulative response of European Union food commodity to an El Niño shock (left panel) and a La Niña shock (right panel) along with 5 percent (lighter blue area) and 10 percent (darker blue area) confidence bands. In the second row, full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place. Both events are considered simultaneously, that is, we include both El Niño and La Niña variables in the model, as defined when we analyzed them individually.

Appendix K. Robustness: El Niño and La Niña Simultaneous and Complete

Figure K.1. Response of Disaggregated European Union Food Commodity Prices: El Niño and La Niña Simultaneous and Complete



Note: Monthly cumulative response of European Union food commodity prices to an El Niño shock (left panel) and a La Niña shock (right panel). Full (empty) symbols indicate statistical significance at the 5 (10) percent level; a solid line indicates no statistical significance. Results are based on linear projection estimations. The shock considered in the left (right) panel is an intensification of an El Niño (La Niña), i.e., an increase (decrease) of 1°C in the ocean surface temperature in the east-central tropical Pacific when an El Niño (La Niña) event is already taking place. Note, in this specification the original ONI variables for El Niño and La Niña are included as such, which means that (i) both types of events are considered simultaneously, and (ii) all original values of the ONI variable are considered, and no censoring is applied.

Appendix L. EU Trade Patterns over Time

For the purpose of this exercise, we rely on annual data from the “Base pour l’Analyse du Commerce International of the Centre d’études prospectives et d’informations internationales” (BACI-CEPII), at the HS-6 product level. The data set includes bilateral trade flow information about the import value of each trade partner over a 28-year period from 1995 to 2022.

We aggregate import data into the six food categories that we used in the rest of the study: cereals, coffee, meat, dairy products and eggs, oils and fats, and sugar. In addition, the Economic and Monetary Union (EMU) is considered as a single importer, so the import value of each product coming from each trading partner is aggregated among the member states. Only imports from extra-EU economies are considered. We compute two measures.

First, we use the Herfindahl-Hirschman Index (HHI) to represent the degree of import concentration across trade partners. It ranges between 0 and 1, with highly concentrated imports resulting in a higher value of the indicator.²⁸ For each food category c , the HHI index is constructed by adding up the squared shares of EMU imports coming from country j in the total EMU imports of food category c :

$$HHI_{EMU}^c = \sum_{j=1}^N (Share_{EMU,j}^c)^2. \quad (L.1)$$

This general measure of concentration, HHI_{Total} , can be disaggregated to focus only on specific trading partners. In particular, the concentration of imports coming from economies affected by El Niño or La Niña, $HHI_{Niñx}$, can be calculated by adding up the squared shares of EU imports coming only from countries affected by any of these climate phenomena. Similarly, the concentration of imports coming from the rest of the countries, $HHI_{no_Niñx}$, can be calculated by adding up the squared import shares coming only from economies not affected by El Niño or La Niña.²⁹

²⁸An index equal to 1 represents a case of extreme concentration: a product that is imported from one trade partner only. An index close to 0 represents a case of high diversification: a product that is imported from many trade partners.

²⁹The sum of $HHI_{Niñx}$ and $HHI_{no_Niñx}$ equals HHI_{Total} .

The second measure we consider is the import share, which is computed for each food category by adding up the shares of EMU imports coming from a specific group of countries in the total EU imports of the corresponding food category. Thus, the index *Share_Niñx* can be calculated as the share of EMU imports coming from countries affected by El Niño or La Niña and the index *Share_no_Niñx* as the share of EMU imports coming from the rest of the economies.³⁰ Results for import concentration and import shares are shown in Figures 11 and 10 of Section 7 in the main text, respectively.

Appendix M. Construction of Newspaper-Based Index of ENSO Popularity

This appendix explains the construction of the newspaper-based indices discussed in Section 1 of the main text. These indices capture the importance ENSO phenomena have gained in the press over time in the following countries: U.S., Germany, France, Italy, and Spain.

To construct these indices, we build upon the methodology of Baker, Bloom, and Davis (2016), who constructed the well-known economic policy uncertainty (EPU) indicator for a number of countries.

To access newspaper articles, we rely on the Factiva repository provided by Dow Jones. We focus on the printed editions of newspapers and ignore their online versions. For each country, we consider as many newspapers as possible to ensure that selected newspapers cover almost the entire ideological spectrum and hence minimize any ideological bias that may stem from analyzing the media. We consider the following newspapers, by country:

- U.S., Canada, and United Kingdom: the *Boston Globe*, the *Telegraph*, the *Economist*, the *Globe and Mail*, the *Guardian*, the *Wall Street Journal*, *Los Angeles Times*, the *New York Times*, the *Times*, *Chicago Tribune*, and the *Washington Post*.

³⁰The sum of *Share_Niñx* and *Share_no_Niñx* is 1.

- Germany: *Berliner Zeitung*, *Berliner Morgenpost*, *Die Welt*, *Frankfurter Allgemeine Zeitung*, *Handelsblatt*, *Süddeutsche Zeitung*, *Der Tagesspiegel*, and *Die Tageszeitung*.
- France: *La Tribune*, *L'Opinion*, *Le Monde*, *Libération*, *La Croix*, *Le Figaro*, and *Les Echos*.
- Italy: *Corriere della Sera*, *La Stampa*, *Il Sole 24 Ore*, *ItaliaOggi*, *La Repubblica*, *Il Giornale*, and *Il Fatto Quotidiano*.
- Spain: *ABC*, *Cinco Días*, *El Economista*, *El Mundo*, *El País*, *Expansión*, and *La Vanguardia*.

For the U.S., Canada, and United Kingdom, the time coverage is longer such that we can construct the indicator from 1980. For the considered European countries (*the big 4*), our indicator starts from January 1997 due to data availability. We construct our measure of ENSO popularity at a monthly frequency and aggregate it at the yearly level for graphical purposes.

In a nutshell, the ENSO popularity index is constructed as the proportion of newspaper articles that are about ENSO climate phenomena. To do this, we count the number of articles in each month and newspaper that contain either *El Niño* or *La Niña* and which are also on the topic of the *climate*. For each country, we adapt the language accordingly. In practice, we consider the following keywords for each country:

- U.S., Canada, and United Kingdom: (*El Nin** or *La Nin**) and *climat**
- Germany: (*El Nin** or *La Nin**) and *klima**
- France: (*El Nin** or *La Nin**) and *clima**
- Italy: (*El Nin** or *La Nin**) and *clima**
- Spain: (*El Nin** or *La Nin**) and *climático** not (*Jesus* or *Navidad* or *Greta*). Note, since in Spanish *El Niño* means boy and *La Niña* means girl, we need to add additional requirements to minimize false positives (i.e., counting articles that are not related to the ENSO phenomena). In particular, we need to exclude articles about the climate and Christmas, which can contain *El Niño Jesus* (which means *baby Jesus*) and articles about climate and the young climate activist Greta Thunberg, which may contain *La Niña Greta*.

The construction of the indices closely follows the procedure used by Baker, Bloom, and Davis (2016). First, for each newspaper we count the number of articles published in a given month that contain the aforementioned keywords. Second, we divide this count by the total number of published articles that month, in order to express this count as a proportion of articles published by the newspaper in that month. Third, we standardize each monthly series of scaled counts by dividing by the standard deviation. This makes the volatility of the series comparable across newspapers. Fourth, for each country we average the newspaper-based standardized series across newspapers to compute an aggregated index. Fifth, we rescale the resulting index to mean 100 to obtain a set of homogeneous country-based ENSO popularity indices. Finally, these indicators are aggregated at a yearly frequency and plotted in Figure 2.

Note, the huge peak corresponding to the last El Niño event (2023–24) is striking, especially for the U.S. We double-checked the articles selected to construct the indicators for this period, and the peak is indeed genuine, i.e., all articles selected refer to El Niño or La Niña climate events when discussing topics related to climate. This confirms that the public is now extremely interested in this topic.

References

- Abril-Salcedo, D. S., L. F. Melo-Velandia, and D. Parra-Amado. 2020. “Nonlinear Relationship between the Weather Phenomenon El Niño and Colombian Food Prices.” *Australian Journal of Agricultural and Resource Economics* 64 (4): 1059–86. <https://doi.org/10.1111/1467-8489.12394>.
- Adams, R. M., L. L. Houston, B. A. McCarl, M. Tiscareño, J. Matus, and R. F. Weiher. 2003. “The Benefits to Mexican Agriculture of an El Niño–Southern Oscillation (ENSO) Early Warning System.” *Agricultural and Forest Meteorology* 115 (3-4): 183–94. [https://doi.org/10.1016/s0168-1923\(02\)00201-0](https://doi.org/10.1016/s0168-1923(02)00201-0).
- Adolfson, J. F., and M.-S. Lappe. 2023. “Risks to Global Food Commodity Prices from El Niño.” *Economic Bulletin* (European Central Bank) 6/2023: Box 1. <https://ideas.repec.org/a/ecb/ecbbox/202300061.html>.

- Andrian, L., C. M. Álvarez, A. Chávez, E. Díaz, C. Larrahondo, L. F. Serrudo, M. Alzamora, and D. Cárdenas. 2024. “Efectos del fenómeno “El Niño” en la Región Andina.” Technical Report, Interamerican Development Bank. <https://sinia.minam.gob.pe/sites/default/files/archivos/public/docs/Efectos-del-FEN-en-la-Region-Andina-una-aproximacion-empirica.pdf>.
- Atems, B., and N. Sardar. 2021. “Exploring Asymmetries in the Effects of El Niño–Southern Oscillation on U.S. Food and Agricultural Stock Prices.” *Quarterly Review of Economics and Finance* 81 (August): 1–14. <https://doi.org/10.1016/j.qref.2021.04.013>.
- Baker, S. R., N. Bloom, and S. J. Davis. 2016. “Measuring Economic Policy Uncertainty.” *Quarterly Journal of Economics* 131 (4): 1593–1636. <https://doi.org/10.1093/qje/qjw024>.
- Beltran, P., M. Hadzi-Vaskov, and I. Stepanov. 2023. “Online Annex 2. El Niño’s Potential Impact on Latin America.” In *Regional Economic Outlook—Western Hemisphere*, Online Annex 2. Washington, D.C.: International Monetary Fund. <https://www.imf.org/-/media/Files/Publications/REO/WH/2023/October/English/onlineannex-2-en.ashx>.
- Borralló, F., L. Cuadro-Sáez, Á. Gras-Mirallés, and J. J. Pérez. 2026. “The Transmission of Shocks to Food and Energy Commodity Prices to Food Inflation in the Euro Area.” *Applied Economics Letters* 33 (3): 411–16. <https://doi.org/10.1080/13504851.2024.2369711>.
- Brunner, A. D. 2002. “El Niño and World Primary Commodity Prices: Warm Water or Hot Air?” *Review of Economics and Statistics* 84 (1): 176–83. <http://www.jstor.org/stable/3211747>.
- Cashin, P., K. Mohaddes, and M. Raissi. 2017. “Fair Weather or Foul? The Macroeconomic Effects of El Niño.” *Journal of International Economics* 106 (May): 37–54. <https://doi.org/10.1016/j.jinteco.2017.01.010>.
- Cheng, I.-H., and W. Xiong. 2014. “Financialization of Commodity Markets.” *Annual Review of Financial Economics* 6 (1): 419–41. <https://doi.org/10.1146/annurev-financial-110613-034432>.

- Cuadro-Sáez, L., J. J. Pérez, and F. Viani. 2025. "Food Commodity Production and Imports in Spain and the EU: How Much External Autonomy is There?" *Economic Bulletin* (Bank of Spain) 2025/Q2: Article 04. <https://doi.org/10.53479/39605>.
- European Central Bank. 2011. "Financialisation of Commodities." Box 4 in Financial Stability Review (December). https://www.ecb.europa.eu/press/financial-stability-publications/fsr/foqus/2011/pdf/ecb~6fdfdfce1c.fsrbox201112_04.pdf.
- . 2023. "Eurosystem Staff Macroeconomic Projections for the Euro Area." Technical Report. https://www.ecb.europa.eu/press/projections/html/ecb.projections202312_eurosystemstaff~9a39ab5088.en.html.
- Ferreira, G. L. M., J. M. Tonin, and A. F. Alves. 2022. "Impacts of El Niño Southern Oscillation on Hedge Strategies for Brazilian Corn and Soybean Futures Contracts." *Revista de Economia e Sociologia Rural* 60 (spe). <https://doi.org/10.1590/1806-9479.2021.250643>.
- Ferrucci, G., R. Jiménez-Rodríguez, and L. Onorante. 2012. "Food Price Pass-Through in the Euro Area: Non-Linearities and the Role of the Common Agricultural Policy." *International Journal of Central Banking* 8 (1, March): 179–218. <https://www.ijcb.org/journal/ijcb12q1a9.htm>.
- Food and Agriculture Organization (FAO). 2023. "El Niño: Anticipatory Action and Response Plan, October 2023–March 2024." Technical Report, Food and Agriculture Organization of the United Nations. <https://doi.org/10.4060/cc8496en>.
- Garzon, I. 2006. "The MacSharry Reform (1992)." In *Reforming the Common Agricultural Policy*, 61–75. Palgrave Macmillan UK. https://doi.org/10.1057/9780230626577_6.
- Hsiang, S. M., and K. C. Meng. 2015. "Tropical Economics." *American Economic Review* 105 (5): 257–61. <https://doi.org/10.1257/aer.p20151030>.
- Iizumi, T., J.-J. Luo, A. J. Challinor, G. Sakurai, M. Yokozawa, H. Sakuma, M. E. Brown, and T. Yamagata. 2014. "Impacts of El Niño Southern Oscillation on the Global Yields of Major Crops." *Nature Communications* 5 (1): 3712. <https://doi.org/10.1038/ncomms4712>.
- Jacks, D. S., K. H. O'Rourke, and J. G. Williamson. 2009. "Commodity Price Volatility and World Market Integration since

- 1700.” NBER Working Paper No. 14748. https://www.nber.org/system/files/working_papers/w14748/w14748.pdf.
- Jiang, J., and T. R. Fortenbery. 2019. “El Niño and La Niña Induced Volatility Spillover Effects in the U.S. Soybean and Water Equity Markets.” *Applied Economics* 51 (11): 1133–50. <https://doi.org/10.1080/00036846.2018.1524980>.
- Jordà, Ò. 2005. “Estimation and Inference of Impulse Responses by Local Projections.” *American Economic Review* 95 (1): 161–82. <https://doi.org/10.1257/0002828053828518>.
- Kreiss, J.-P., and S. N. Lahiri. 2012. “Bootstrap Methods for Time Series.” *Handbook of Statistics*, Vol. 30, ed. T. S. Rao, S. S. Rao, and C. R. Rao, 3–26. Elsevier. <https://doi.org/10.1016/B978-0-444-53858-1.00001-6>.
- Laosuthi, T., and D. D. Selover. 2007. “Does El Niño Affect Business Cycles?” *Eastern Economic Journal* 33 (1): 21–42. <https://doi.org/10.1057/ej.2007.2>.
- Martín, L. 2016. “¡Es Niño!: Impacto económico en la Región Andina.” <https://doi.org/10.18235/0000234>.
- Montiel Olea, J. L., and M. Plagborg-Møller. 2021. “Local Projection Inference is Simpler and More Robust than You Think.” *Econometrica* 89 (4): 1789–1823. <https://arxiv.org/pdf/2007.13888>.
- Pantoja-Robayo, J., and D. Rodríguez-Guevara. 2023. “The Climate Effect on Colombian Coffee Prices and Quantities Based on Risk Analysis and the Hedging Strategy in Discrete Setting Approach.” *Agris on-line Papers in Economics and Informatics* 15 (4): 97–107. <https://doi.org/10.7160/aol.2023.150407>.
- Paz, J. O., C. W. Fraisse, L. U. Hatch, A. García y García, L. C. Guerra, O. Uryasev, J. G. Bellow, J. W. Jones, and G. Hoogenboom. 2007. “Development of an ENSO-based Irrigation Decision Support Tool for Peanut Production in the Southeastern US.” *Computers and Electronics in Agriculture* 55 (1): 28–35. <https://doi.org/10.1016/j.compag.2006.11.003>.
- Peersman, G. 2022. “International Food Commodity Prices and Missing (Dis)Inflation in the Euro Area.” *Review of Economics and Statistics* 104 (1): 85–100. https://doi.org/10.1162/rest_a_00939.
- Raj, E. E., R. R. Kumar, and K. V. Ramesh. 2020. “El Niño–Southern Oscillation (ENSO) Impact on Tea Production and

- Rainfall in South India.” *Journal of Applied Meteorology and Climatology* 59 (4): 651–64. <https://doi.org/10.1175/jamc-d-19-0065.1>.
- Romero, J. V., and S. N. Saldarriaga. 2024. “Weather Shocks and Inflation Expectations in Semi-Structural Models.” *Latin American Journal of Central Banking* 5 (2): Article 100112. <https://doi.org/10.1016/j.latcb.2023.100112>.
- Smith, S. C., and D. Ubilava. 2017. “The El Niño Southern Oscillation and Economic Growth in the Developing World.” *Global Environmental Change* 45 (July): 151–64. <https://doi.org/10.1016/j.gloenvcha.2017.05.007>.
- Tang, K., and W. Xiong. 2012. “Index Investment and the Financialization of Commodities.” *Financial Analysts Journal* 68 (6): 54–74. <https://doi.org/10.2469/faj.v68.n6.5>.
- Ubilava, D. 2011. “El Niño, La Niña, and World Coffee Price Dynamics.” *Agricultural Economics* 43 (1): 17–26. <https://doi.org/10.1111/j.1574-0862.2011.00562.x>.
- . 2017. “The ENSO Effect and Asymmetries in Wheat Price Dynamics.” *World Development* 96 (August): 490–502. <https://doi.org/10.1016/j.worlddev.2017.03.031>.
- . 2023. “What This Year’s El Niño Means for Wheat and Global Food Supply.” *The Conversation*. <https://theconversation.com/what-this-years-el-nino-means-for-wheat-and-global-food-supply-209386>.
- Ubilava, D., and M. Holt. 2013. “El Niño Southern Oscillation and Its Effects on World Vegetable Oil Prices: Assessing Asymmetries Using Smooth Transition Models.” *Australian Journal of Agricultural and Resource Economics* 57 (2): 273–97. <https://doi.org/10.1111/j.1467-8489.2012.00616.x>.
- Yeager, S. G., N. Rosenbloom, A. A. Glanville, X. Wu, I. Simpson, H. Li, M. J. Molina, et al. 2022. “The Seasonal-to-Multiyear Large Ensemble (SMYLE) Prediction System Using the Community Earth System Model Version 2.” *Geoscientific Model Development* 15 (16): 6451–93. <https://doi.org/10.5194/gmd-15-6451-2022>.

Zebiak, S. E., B. Orlove, A. G. Muñoz, C. Vaughan, J. Hansen, T. Troy, M. C. Thomson, A. Lustig, and S. Garvin. 2015. “Investigating El Niño-Southern Oscillation and Society Relationships.” *WIREs Climate Change* 6 (1): 17–34. <https://doi.org/10.1002/wcc.294>.