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HOW DO FUTURES CONTRACTS ON AGRICULTURAL COMMODITIES RESPOND TO EL NINO WEATHER EVENTS?

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Abstract

This study examines how futures contracts on wheat, soybeans, corn and sugarcane respond to El Nino weather events over the period March 2010 to April 2024. We use the monthly ENSO forecast data from the Climate Prediction Center of the National Oceanic and Atmospheric Administration to benchmark the start of an El Nino forecast, which we define as the first reporting month in which a current or forecasted El Nino probability exceeds 50%. We examine two periods around each event: the six months leading up to the El Nino forecast, and the six months following the event date. We find that El Nino weather events have significant effects on commodity futures prices. Wheat, soybean and corn futures prices (expressed in dollars) generally decline after an El Nino forecast, consistent with improved harvests due to an increase in rain. We also find that El Nino events are associated with increased volatility in commodity futures markets. Our study can inform hedgers and speculators who participate in the agricultural derivatives markets, as well as policymakers who may be interested in initiating or adjusting any subsidies granted to farmers or food consumers, as compensation for price pressures.

JEL Classification

G13, G14, Q02, Q14, Q51, Q54

Keywords

Commodities, Futures, El Nino, Weather, Agriculture, ENSO, Hedging, Crops, Wheat, Soybeans, Corn, Sugarcane

I. Introduction

This study examines how futures contracts on agricultural commodities respond to El Nino weather events. The El Nino-Southern Oscillation (ENSO) cycle is a recurring climate pattern linked to temperature fluctuations in the central and eastern tropical waters of the Pacific Ocean. Every three to seven years, the surface waters warm or cool by 1 – 3 degrees Celsius. The oscillating warming and cooling affects the distribution of tropical rainfall and impacts the weather in the U.S. and other parts of the world. El Nino and La Nina are the extreme phases of the ENSO cycle. During an El Nino period, the ocean surface waters warm and surface winds which normally blow from east to west along the equator weaken.

El Nino weather events have economic and statistically significant effects on world real commodity prices. Brunner (2002) finds that ENSO cycles explain 20% of the time-series variation in world food prices. Cashin, Mohaddes and Raissi (2017) explore the effects on country-level macro variables, such as growth, inflation and non-fuel commodity prices. They find that Japan, India, Indonesia, New Zealand, Australia, Chile, and South Africa experience short-term declines in economic activity, while Europe and the U.S. enjoy short-term increases. However, most countries experience short-term inflationary pressures resulting from price increases in energy and non-fuel commodity prices. Cai and Sakemoto (2022) find a strong relationship between ENSO cycles and real commodity prices. They find the relationship is stronger post-2000, which they attribute to the financialization of commodity markets.

The derivative markets for commodities have grown considerably over the last twenty years. Hedgers and speculators have always participated in these markets, but increasingly institutional investors (hedge funds, commodity trading accounts, exchange traded funds, etc.) are taking large, leveraged positions in commodity futures and options (Arburn and Harper, 2019). In this paper, we explore the links between El Nino weather events and commodity futures to better inform hedgers and speculators who participate in these markets. We also believe our study can inform policymakers who may be interested in initiating or adjusting any subsidies they award to farmers or food consumers, as compensation for price pressures.

II. Methodology

Each month the Climate Prediction Center (CPC) of the National Oceanic and Atmospheric Administration (NOAA) updates its ENSO cycle forecast. The forecast details the probabilities of La Nina, Neutral and El Nino events for three-month intervals centered around the current month and extending nine months into the future. An example appears below in Exhibit I.

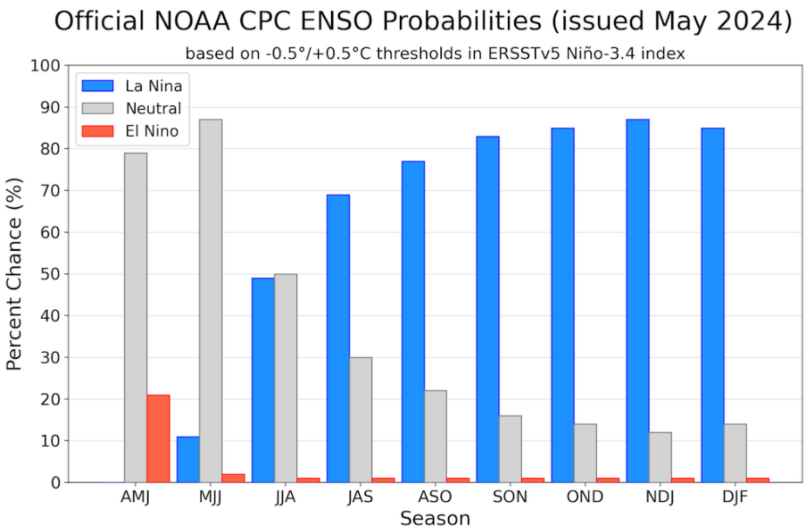

Exhibit I: Sample ENSO cycle forecast
Source: NOAA/CPC ENSO Forecast Graphic, courtesy of NOAA/CPC

We use the monthly ENSO data to benchmark the start of an El Nino forecast, which we define as the first reporting month in which a current or forecasted El Nino probability exceeds 50%. Examining the data from March 2010 through April 2024, we obtain 3 El Nino forecasts for the following months: March 2014, June 2018 and March 2023. El-Nino events formed and dissipated during the following periods: May 2014 – June 2016, December 2018 – August 2019 and June 2023 – April 2024. Within our sample period, there were no false, positive forecasts for El Nino weather events.

We examine two periods around each event: the six months leading up to the El Nino forecast, and the six months following the event date. We examine three staple crops – wheat, soybeans and corn, as well as sugarcane, with 2023 estimated global market values of $196 billion, $193 billion, $297 billion and $66 billion respectively.[1] These are among the most actively traded agricultural futures contracts. We use Bloomberg Agriculture Index data to measure wheat, soybean, corn and sugarcane futures contract prices. Generally, the series roll every 1 - 3 months, and the index captures the prices of the most liquid commodity futures contracts.

III. Results

In Exhibit II, we plot wheat futures prices before and after the El Nino forecasts for 2014, 2018-2019 and 2023. For each series, prices are scaled relative to the closing wheat futures price on the event date, which we define as the first day on which the El Nino current or future forecast probability exceeds 50%. Wheat is a staple crop produced around the globe, but no one country has a dominant share of the market. China, India and Russia are the largest producers with 17%, 13% and 13% of 2022 global production, respectively.[2] Wheat is an annual crop, harvested in early summer (as winter wheat) or fall (as spring wheat).

[1] Source: www.grandviewresearch.com
[2] Source: The Food and Agriculture Organization (FAO) of the United Nations.

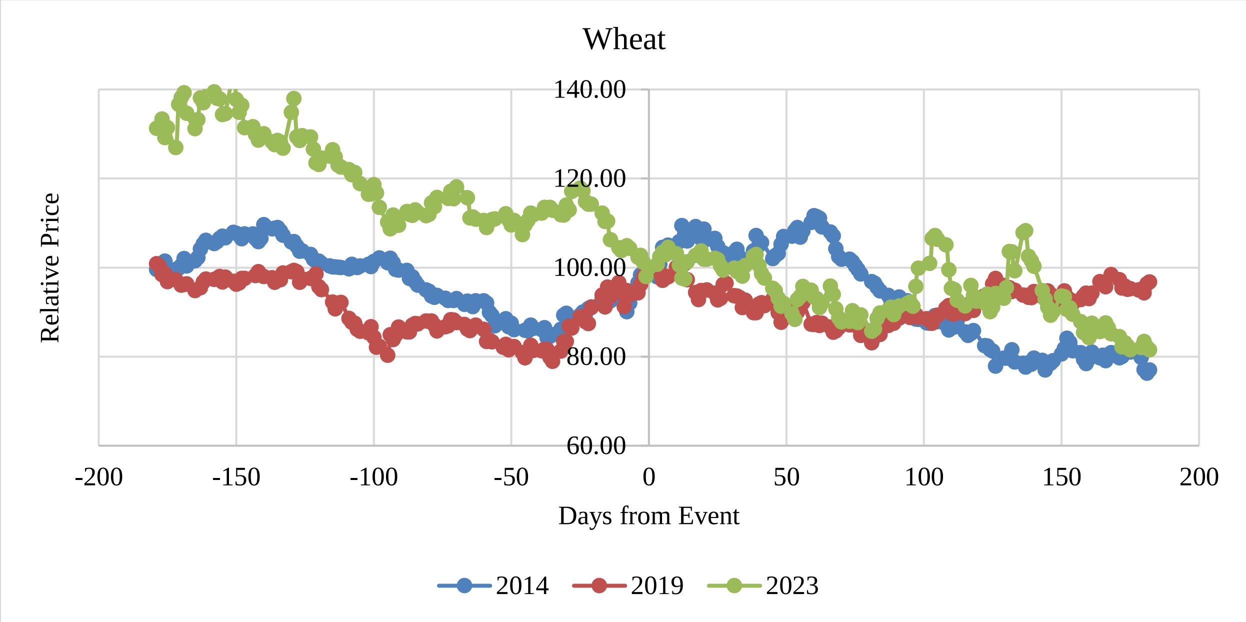

Exhibit II: Wheat futures prices (scaled) before and after 3 El Nino forecasts

Wheat futures prices were generally declining in the lead up to the 2023 El Nino forecast. The series for 2014 and 2019 exhibit flatter trajectories, with prices first falling then reversing course about 40 days before the El Nino forecasts materialized. Unexpectedly, all three series exhibit declining wheat futures prices in the six-month period following the event date.

In Exhibit III, we report the mean and standard deviation of daily wheat futures returns before and after the event dates. Long wheat futures positions generated negative average daily returns in all three post-event cycles, though none of the means are statistically distinguishable from zero. More interesting are the volatility measures before and after the event dates. Here we observe that volatility increased in 2014 and 2023. In both cases, the increase in volatility is statistically significant at the 5% level.

Year	Pre-event Mean Return t-stat (p-val)	Post-event Mean Return t-stat (p-val)	Test for mean return equivalence (p-val)	Pre-event Return Standard Deviation	Post-event Return Standard Deviation	Test for volatility equivalence (p-val)
2014	0.01% 0.09 (0.93)	-0.20% -1.31 (0.19)	1.12 (0.26)	1.19%	1.66%	1.95 (0.00)***
2019	0.01% 0.05 (0.96)	-0.04% -0.27 (0.79)	0.21 (0.83)	1.69%	1.47%	0.76 (0.07)*
2023	-0.20% -1.09 (0.28)	-0.13% -0.60 (0.55)	-0.23 (0.82)	2.03%	2.46%	1.47 (0.02)**

Exhibit III: Wheat futures returns and volatilities before and after 3 El Nino forecasts

*(**)[***] denotes statistical significance at the 10%(5%)[1%] level.

In Exhibit IV, we plot soybean futures prices before and after the El Nino forecasts for 2014, 2018-2019 and 2023. Soybeans are produced around the world, but two countries dominate the market: Brazil and the United States, with 35% and 32% of 2022 global production respectively (Source: FAO of the United Nations). Soybean harvests benefit from hot summers.

Soybean futures prices started rising around 40 days before the 2014 El Nino forecast. They were mostly flat in the 2023 cycle and falling before rising in the 2019 cycle. Post the event dates, soybean futures prices generally trended lower.

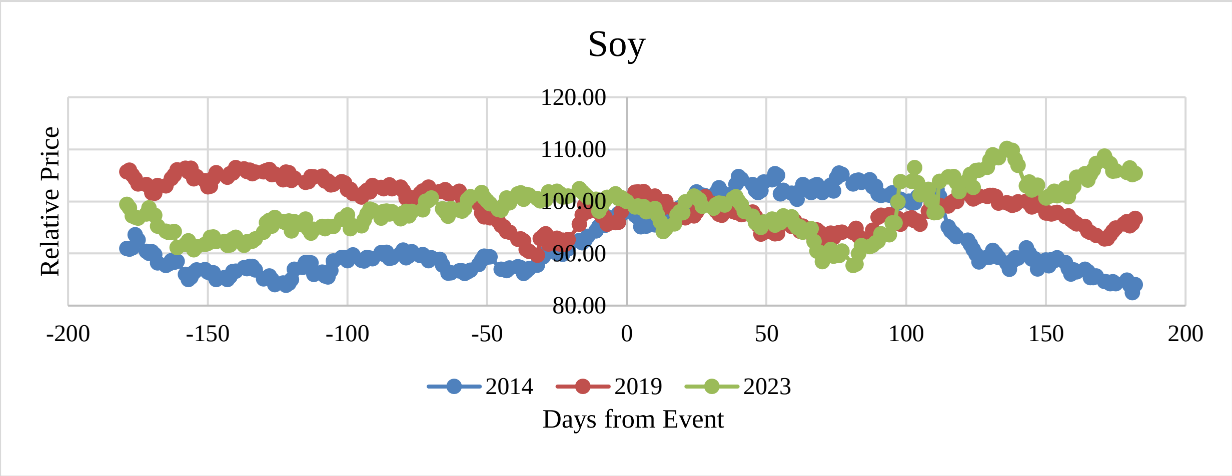

Exhibit IV: Soybean futures prices (scaled) before and after 3 El Nino forecasts

In Exhibit V, we report the mean and standard deviation of daily soybean futures returns before and after the event dates. Long soybean futures positions generated negative average daily returns in both the 2019 and 2023 post-event cycles, but the means are not statistically distinguishable from zero. Comparing the average daily returns pre-event to those observed post-event, we find no statistically significant differences. However, as we observed with wheat futures, volatility increased in both the 2014 and 2023 post-event cycles.

Year	Pre-event Mean Return t-stat (p-val)	Post-event Mean Return t-stat (p-val)	Test for mean return equivalence (p-val)	Pre-event Return Standard Deviation	Post-event Return Standard Deviation	Test for volatility equivalence (p-val)
2014	0.08% 0.91 (0.36)	-0.13% -1.24 (0.22)	1.54 (0.12)	1.00%	1.20%	1.45 (0.02)**
2019	-0.04% -0.46 (0.64)	-0.03% -0.40 (0.69)	-0.05 (0.96)	0.96%	0.95%	0.97 (0.44)
2023	0.01% 0.11 (0.91)	0.05% 0.40 (0.69)	-0.27 (0.79)	1.02%	1.48%	2.10 (0.00)***

Exhibit V: Soybean futures returns and volatilities before and after 3 El Nino forecasts

*(**)[***] denotes statistical significance at the 10%(5%)[1%] level.

In Exhibit VI, we plot corn futures prices before and after the El Nino forecasts for 2014, 2018-2019 and 2023. Corn is produced around the world, but two countries dominate the market: the United States and China with 30% and 24% respectively of 2022 global production (Source: FAO of the United Nations). In the northern hemisphere, corn must be planted in the spring because it is cold intolerant.

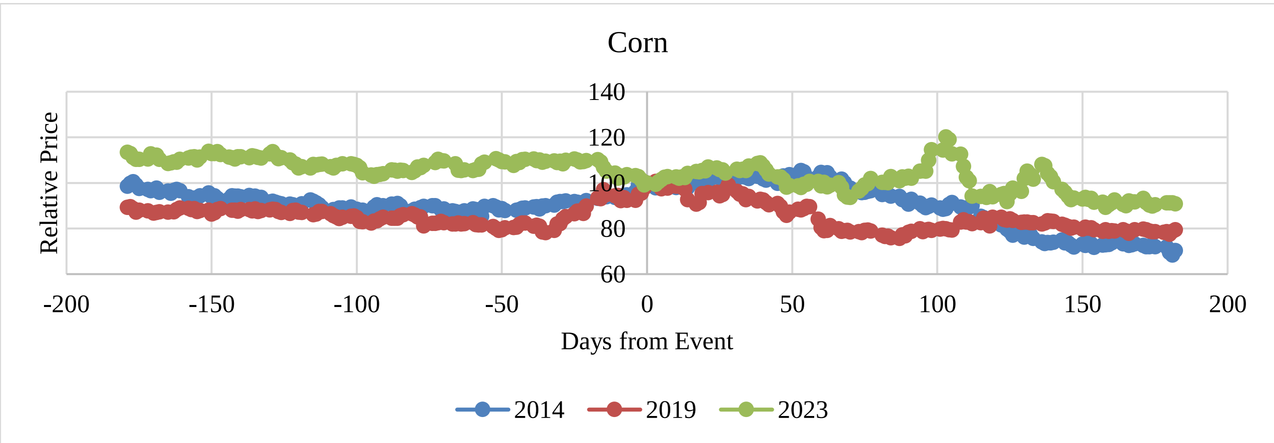

Exhibit VI: Corn futures prices (scaled) before and after 3 El Nino forecasts

Corn futures prices started rising about 30 days before the 2019 El Nino forecast. They were mostly flat in the 2023 cycle and falling before rising in the 2014 cycle. Post the event dates, corn futures prices generally trended lower.

In Exhibit VII, we report the mean and standard deviation of daily corn futures returns before and after the event dates. Long corn futures positions generated negative average daily returns in all three post-event cycles, but only the 2014 average is statistically significant. In that cycle, the mean returns before and after the El Nino forecast are statistically different at the 5% level. In all three cycles, volatility increased significantly after the El Nino forecast.

Year	Pre-event Mean Return t-stat (p-val)	Post-event Mean Return t-stat (p-val)	Test for mean return equivalence (p-val)	Pre-event Return Standard Deviation	Post-event Return Standard Deviation	Test for volatility equivalence (p-val)
2014	0.02% 0.18 (0.86)	-0.28% -2.41 (0.02)**	1.96 (0.05)*	1.11%	1.31%	1.41 (0.03)**
2019	0.10% 0.87 (0.39)	-0.19% -1.38 (0.17)	1.61 (0.11)	1.29%	1.56%	1.47 (0.02)**
2023	-0.10% -1.11 (0.27)	-0.06% -0.31 (0.76)	-0.20 (0.84)	0.97%	2.04%	4.43 (0.00)***

Exhibit VII: Corn futures returns and volatilities before and after 3 El Nino forecasts
***(**)[***] denotes statistical significance at the 10%(5%)[1%] level.**

In Exhibit VIII, we plot sugarcane futures prices before and after the El Nino forecasts for 2014, 2018-2019 and 2023. Sugar is produced around the world, but two countries dominate the market: Brazil and India with 40% and 20% respectively of 2020 global production (Source: FAO of the United Nations). Sugarcane only flourishes in tropical or subtropical climates.

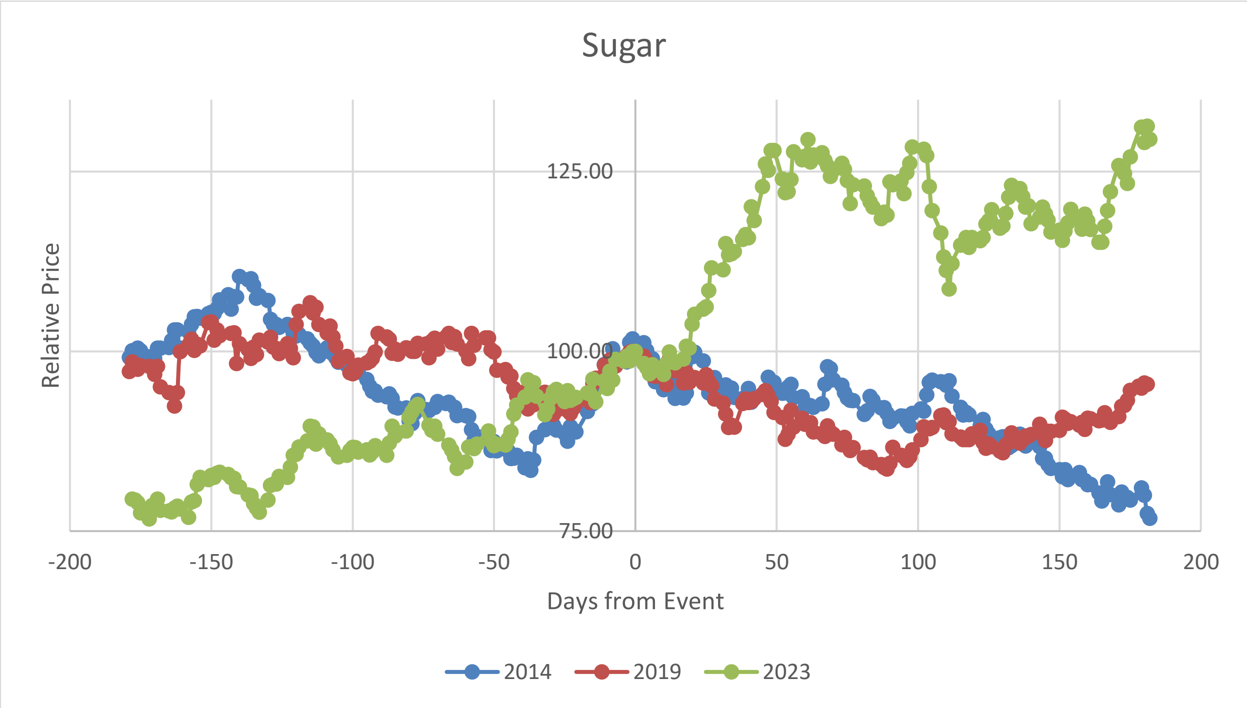

Exhibit VIII: Sugar futures prices (scaled) before and after 3 El Nino forecasts

Sugar futures prices rose before the 2023 El Nino forecast. They were mostly flat in the 2019 cycle and falling before rising in the 2014 cycle. Post the event dates, sugar futures prices trended lower in 2014 and 2019, but spiked higher in 2023.

In Exhibit IX, we report the mean and standard deviation of daily sugar futures returns before and after the event dates. Long sugar futures positions generated positive daily returns in all three pre-event cycles, but none of the averages are statistically significant. After the El Nino forecasts, the daily mean returns were positive in 2023 and negative in 2014 and 2019. However, none of the mean returns are statistically significant at the 10% level. In both 2014 and 2023, volatility rose after the El Nino forecast. However, in 2019, volatility declined after the El Nino forecast.

Year	Pre-event Mean Return t-stat (p-val)	Post-event Mean Return t-stat (p-val)	Test for mean return equivalence (p-val)	Pre-event Return Standard Deviation	Post-event Return Standard Deviation	Test for volatility equivalence (p-val)
2014	0.01% 0.13 (0.90)	-0.17% -1.48 (0.14)	1.16 (0.25)	1.24%	1.29%	1.09 (0.31)
2019	0.02% 0.16 (0.87)	-0.03% -0.32 (0.75)	0.32 (0.75)	1.54%	1.23%	0.63 (0.01)***
2023	0.18% 1.44 (0.15)	0.24% 1.59 (0.11)	-0.28 (0.78)	1.40%	1.65%	1.38 (0.04)**

Exhibit IX: Sugar futures returns and volatilities before and after 3 El Nino forecasts

*(**)[***] denotes statistical significance at the 10%(5%)[1%] level.

In Exhibit X, we report the average starting and ending commodity futures prices for wheat, soybeans, corn and sugarcane for the period (t – 180, t + 180), where t denotes the event date for each cycle. As before, for each series, we scale the prices relative to the closing commodity futures price on the event date. Generally, commodity futures prices for these crops decline over the one-year period surrounding the El Nino forecast. In 10 out of 12 cases, there was a price decline and in 8 out of 12 cases, the price decline exceeded 10%. The average price declines for wheat and corn are quite large, 23.04% and 20.14% respectively. In 2 out of 12 cases, there was a price increase. The price increase for sugarcane in 2023 is quite large. In the six-month period leading up to the El Nino forecast, wheat futures prices declined 9.60% and sugarcane futures prices increased 8.19%. Soybean and corn futures prices were nearly unchanged. Generally, commodity futures prices are flat over the six-month period leading up to the El Nino forecast. In 3 out of 12 cases, there is a price rise exceeding 10% and in 2 out of 12 cases, there is a price decline exceeding 10%. Generally, commodity futures prices decline over the six-month period after the El Nino forecast. In 10 out of 12 cases, there was a price decline and in 7 out of 12 cases, the price decline exceeded 10%.

Commodity Future	Mean Price (t – 180)	Mean Price (t + 180)	Price Change (t – 180, t + 180)	Price Change (t – 180, t)	Price Change (t, t + 180)
Wheat	110.62	85.13	-23.04%	-9.60%	-14.87%
Soybeans	98.67	95.36	-3.35%	1.35%	-4.64%
Corn	100.41	80.19	-20.14%	-0.41	-19.81%
Sugarcane	92.43	92.07	-0.39%	8.19%	-7.93%

Exhibit X: Commodity Futures Price Movements before and after the El Nino forecast

IV. Robustness checks

We obtain qualitatively similar results when we examine futures contracts with longer maturities, for example, the 2nd and 3rd to expire contracts. We also examined exchange traded products for wheat, soybeans, corn and sugarcane. These ETPs generally take multiple positions in futures contracts expiring up to 16 months in the future. We obtain qualitatively similar results when we examine the returns of these ETPs.

V. Conclusion

Our study aligns with the literature and confirms that El Nino weather events have significant effects on commodity futures prices. The inflationary pressures that Cashin, Mohaddes and Raissi (2017) document do not show up in the staple crops we examine. Wheat, soybean and corn futures prices (expressed in dollars) generally decline after an El Nino forecast, consistent with improved harvests due to an increase in rain. This result aligns with Merener (2015), who finds a negative relation between soybean futures prices and aggregate measures of daily rainfall.

Since staple crops are produced in multiple regions for global consumers, we might expect producers to move production to areas of the world that benefit from predictable and reoccurring weather events, such as El Nino cycles. However, some crops require specialized soil, temperature, and precipitation conditions and they cannot be grown globally. These would be more vulnerable to weather events, such as El Nino, and would likely experience inflationary pressures.

We also find that El Nino events are associated with increased volatility in commodity futures. It's possible that uncertainty about crop harvests is the primary driver of this volatility increase. Farmers in the U.S. who sell their crops to food companies can effectively hedge their price risk by taking short positions in U.S. dollar-based commodity futures contracts. Farmers outside the U.S. can do the same, and simultaneously hedge their currency risk. At the national level, policymakers shouldn't seek a one-size solution for farmers and food consumers exposed to price pressures, but instead should examine the price impacts in the local currency for each commodity.

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