Impact of Interest Rates on Agricultural Commodity Price Dynamics

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Abstract

Over the past decade, the U.S. Federal Reserve has undertaken unusually aggressive interest rates interventions to stabilize and stimulate the economy in response to recessionary pressures, high inflation, international supply chain disruptions, global oil market disturbances, and other macroeconomic shocks. The changes in interest rates have had a profound impact on agricultural commodity prices, causing them to become increasingly volatile. In this paper, I explore how U.S. corn and soybean wheat prices respond, both in the short-run and the long-run, to Federal Reserve monetary policy interventions. More specifically, we utilize a nonlinear autoregressive distributed lag model to capture three key features of agricultural commodity price responses to changes in interest rates. First, commodity prices initially overreact to changes in the interest rate, "*overshooting*" their long-run equilibrium and slowly regressing to it with the passage of time. Next, the response of commodity prices is *asymmetric in the short run,* with the magnitude of the initial price change being greater for an interest rate increase than for an interest rate decrease of equal magnitude. Similarly, the response of commodity prices is as*ymmetric in the long run*. The findings show that corn and soybean prices both have indeed exhibited overshooting, short- and long-run asymmetry in response to the interest rate change in the recent 30 years.

JEL Codes: Q02, Q14, E40

Keywords: agricultural commodity prices, interest rates, nonlinear autoregressive distributed lag models, structural changes, futures basis

Subject Codes: Agricultural Finance & Farm Management

1. Introduction

Due to major changes in commodity programs in the 1990s, U.S. agriculture has become increasingly market oriented, exposing it to the vagaries of macroeconomic shocks from which it heretofore had been relatively insulated (Burfisher & Hopkins, 2004; Nigatu et al., 2020). As a result, U.S. agricultural commodity prices since 2000 have experienced periods of extreme volatility (USDA National Agricultural Statistical Service, see figure 1).

Among the macroeconomic shocks that affect commodity prices, interest rates are particularly important. High interest rates raise the cost of borrowing to farmers, causing investment in farm production activities to fall. High interest rates also raise the opportunity cost of carrying commodities in storage over the marketing season. Commodities are also physical assets that can serve as a store of value and thus compete with other assets, such as bonds, in decisions made by investors and speculators (Scrimgeour, 2015). Higher interest rates cause the price of bonds to fall, making them a more attractive investment than commodities, thus causing the demand for commodities to fall. Agricultural commodities, moreover, have flexible prices while manufactured goods do not. In the short run, the prices of manufactured goods will change slowly in response to the interest rates changes, causing market shocks to be absorbed by commodity prices. As such, commodity prices can initially overreact to macroeconomic shocks, adjusting to long-run equilibrium slowly, as the prices manufactured goods catch up.

Recent dramatic changes in monetary policy have led to a renewed interest in how interest rates affect agricultural commodity prices. Over the past decade, the U.S. Federal Reserve (Fed) has undertaken unusually aggressive interest rates interventions to stabilize and stimulate the economy in response to recessionary pressures, high inflation, international supply chain disruptions, global oil market disturbances, and other macroeconomic shocks (Amatov & Dorfman, 2017). Between 2008 and 2015, the Fed targeted a zero interest-rate to help the economy recover from the Great Recession of 2007-2009 (see figure 1). Between 2015 and 2020, the Fed allowed the interest to rise. Between 2020 and the end of 2021, in the wake of the Covid-19 pandemic, the Fed returned to a zero-interest rate policy due to fears that a recession would emerge. However, due to the adverse supply chain impacts of Covid-19 and the Russian-Ukrainian war, inflation began to increase rapidly, reaching 7.5% in January 2022. To combat inflation, the Fed reversed course, raising the interest rates by 25 basis points in March 2022, by another 50 basis points in May 2022, and by an additional 75 basis points in each of June, July and September 2022.

[Figure 1 insert here]

In this research, we examine how agricultural commodity prices respond to changes in the interest rate, both in the short- and long-run. To this end, we estimate a nonlinear autoregressive distributed lag (NARDL) model (Shin et al., 2014), to uncover the short-run and long-run impact of interest rates on corn and soybean prices. To allow for studying asymmetric short-and long-term impact of real interest rates on agricultural commodity prices, first differences on interest rates and lags are decomposed into positive and negative partial sums in the nonlinear ARDL model. We apply an Augmented Dickey-Fuller Unit Root test (Dickey & Fuller, 1979) to estimate the order of integration and perform Bai & Perron (1998, 2003) sequential tests for structural breaks between commodity prices and interest rates. We also apply a bound test suggested by Shin et al. (2014), which procedures follow Banerjee et al. (1998) and Pesaran et al. (2001), to test the existence of a stable long-run relationship between cointegrated variables in the case of corn and soybean. Wald tests are applied to test the symmetry of short- and long-run impacts of interest rate changes on commodity prices. We calculate and plot the cumulative dynamic multiplier to graph the impact of negative and positive interest rate change on the corn and soybean prices.

This research identifies 6 break points in the relationship of corn and soybean prices and interest rates. After controlling for those structural changes in the NARDL model, we find evidence that interest rate changes are negatively associated with corn and soybean prices, both in short and long run. Results from the Wald test and cumulative dynamic multipliers implicate that corn and soybean prices have indeed exhibited overshooting, short- and long-run asymmetry, in response to the interest rates change in recent 30 years. Specifically, corn and soybean prices are more sensitive in response to positive interest rate changes.

The research contributes to a well-established but now dated empirical literature on the impact of interest rates on commodity prices by employing updated data that spans the recent period of highly volatile Fed monetary policy, utilizing NARDL that can capture nonlinear, short- and long-run relationship of commodity prices and interest rates, and taking structural changes, cost of carrying and storage cost into account to improve the statistical results. This research will help farmers to better understand how interest rates affect agricultural commodity prices, allowing them to make better informed production and risk management decisions. It will also help inform agricultural processors, commodity traders and brokers, and agricultural policymakers account for the impacts of monetary policy in their decision-making.

2. Impact of Interest Rate Changes on Commodity Price Dynamics

Our analysis aims to investigate how commodity prices respond to major changes in interest rates by examining three potential patterns. The first pattern we explore is the tendency of commodity prices initially overreact to changes in the interest rate, "*overshooting*" their long-run equilibrium and only slowly regressing to it with the passage of time. The second pattern is the *asymmetric* response of commodity prices *in the short run*, with the magnitude of the change in commodity prices is greater for an interest rate increase than for an interest rate decrease of equal magnitude. The third pattern is the *asymmetric* response of commodity prices *in the long run*.

Overshooting occurs when agricultural commodity prices initially overreact to changes in the interest rate, moving well past their new long-run equilibrium, before regressing towards it over time. Frankel (1984) adapts the overshooting model of Schuh (1974) and finds that agricultural commodity prices can initially overreact in response to unanticipated interest rate changes. Frankel (1984) argues that commodities behave like financial assets with flexible prices, while manufactured goods have sticky prices. In efficient markets, risk-adjusted net returns on financial and real assets should be equal across asset classes. In particular, the rate of return on treasury bills should not exceed the risk-adjusted expected appreciation in the commodity price less storage costs. However, since prices of manufactured goods are fixed in the short run, an increase in the interest rate requires spot prices of agricultural commodities to drop more than expected as the cost of carrying also increases. As interest rates increase, firm have incentives to shift to treasury bills from commodity assets, and the cost of borrowing increase as well. Consequently, commodity prices continue to drop until prices are considered "undervalued", at which time there is rational market anticipation that future capital gain, together with convenience yield can offset the high interest rate and high cost of carrying (Frankel, 1986, 2008). Commodity prices will subsequently converge back to the long-run equilibrium price over time.

A considerable amount of literature has studied overshooting. Numerous studies (Belongia, 1991; Castro Campos, 2020; Frankel, 1986, 2008; Lapp, 1990) applied the theoretical model suggested by Frankel (1984). The impulse response function, which can be derived from vector error correction model or vector autoregressive model, is a widely used tool to graph the overshooting of commodity price adjustment from short-term to long-term equilibrium (Akram, 2009; Amatov & Dorfman, 2017; Castro Campos, 2020; Kirchgässner & Kübler, 1992; Saghaian et al., 2002). In this paper, we instead utilize cumulative dynamic multiplier derived from NARDL model, which captures the full dynamic impact of negative and positive interest rate shock over time on the corn and soybean prices, providing a more comprehensive understanding of the cumulative effect of the interest shock.

Empirical evidence on the relationship between real interest rates and commodity prices is not unanimous. Some studies have found that increasing interest rates negatively affect the commodity prices (Amatov & Dorfman, 2017; Frankel, 1984, 2008, 2014; Scrimgeour, 2015). Frankel (1986, 2014) finds that a decline in the money supply raises the real interest rate and depresses the commodity price. Scrimgeour (2015) similarly finds that a 1% increase in the interest rate reduced the commodity price by 5%. Frankel (2008) finds that a 1% increase in the interest rate decreases the Commodity Research Bureau (CRB) commodity price index by 6% during 1970s. However, the same study fails to identify significant relationships using data since the 1980s. The downturn in the farm economy in the 1980s may have led to inconsistency. Also, other studies have found that positive monetary policy shocks do not have a significant or economically important impact on agricultural commodity prices (Belongia, 1991; Lapp, 1990). More recently, Castro Campos (2020) applies the fixed-effect panel threshold model and finds that an additional 1% increase in real interest rate reduces (raises) the agricultural commodity price by 8% (3.4%) under (above) the threshold of 1.45 basis points. These inconsistent findings suggest that further research is needed to better understand the impact of interest rates on commodity prices.

The existing empirical evidence on the relationship between interest rates and commodity prices is inconclusive, and not much attention has been put on short- and long-run asymmetry in this relationship. To improve upon previous research, this research uses a new dataset spanning from 1990 to 2022, applies a new methodology, and provides more perspectives in the relationship between interest rates and corn and soybean prices. We investigate the existence of overshooting, short- and long-run asymmetry, and incorporate proxy and indicator variables in a NARDL model to capture the effect of storage, cost of carrying, and structural changes. We aim to demonstrate that the magnitude of the change in commodity prices is different for an interest rate decrease compared to an interest rate increase of equal magnitude in both the short and long run. We also examine the overshooting process of commodity prices in response to positive and negative interest rate changes, separately. By doing so, we hope to provide a more comprehensive understanding of the relationship between interest rates and commodity prices.

3. Methodology

3.1. Empirical Estimation Model

3.1.1. Nonlinear Autoregressive Distributed Lag Model

To study the asymmetric short- and long-run impacts of interest rates on agricultural commodity prices, we employ the nonlinear autoregressive distributed lag (NARDL) model in the error correction form developed by Shin et al. (2014). The NARDL model is a time series model suitable for fitting a non-stationary time series or mixed order of integration time series with driving variables—interest rates, change of commodity prices, change of interest and other control variables that exhibit zero- or first-order stationarity, but not second-order stationarity. A salient feature of this model is that interest rate changes and their lags are decomposed into positive and negative parts:

$$\Delta p_t = \alpha p_{t-1} + \beta^+ \sum_{i=1}^{t-1} \Delta r_i^+ + \beta^- \sum_{i=1}^{t-1} \Delta r_i^- + \sum_{h=1}^{H} \tau_h \Delta p_{t-h} + \sum_{m=0}^{M} \gamma_m^+ \Delta r_{t-m}^+ + \sum_{n=0}^{N} \gamma_n^- \Delta r_{t-n}^- + \sum_{i=0}^{I} \mu_i X_{i,t} + \tilde{\epsilon}_t \quad (1)$$

In our model, p_t is the spot price of the commodity in month t; r_t is the interest rate in month t; $\Delta p_t \equiv p_t - p_{t-1}$ is the change in price in month t over the preceding month; $\Delta r_t \equiv r_t - r_{t-1}$ is the change in the interest rate in month t over the preceding month; $X_{i,t}$ is control variable i in month t; $\Delta r_t^+ \equiv \max(r_t - r_{t-1}, 0)$ is the magnitude of the increase in the interest rate, if any; $\Delta r_t^- \equiv \max(r_{t-1} - r_t, 0)$ is the magnitude of the decrease in the interest rate, if any; and the $\tilde{\epsilon}_t$ are i.i.d. normally distributed exogenous shocks with zero mean and variance σ^2.

The parameters to be estimated are: α, which measures impact of lagged price on the change in the current price; β^+ and β^-, which measure the impacts of cumulative increases and decreases in the interest rate, respectively; τ_h, which measures the impacts of past commodity price changes; γ_m^+ and γ_m^-, which measure the impacts of past interest rate increases and decreases, respectively; μ_i, which measure the influence of current and lagged values of the control variables; and σ^2, the variance of the error term. The optimal lag length is determined by minimizing the Akaike Information Criterion $AIC = 2K - 2ln(L)$, were K is number of independent linear terms in equation (1) and L is the log likelihood of the estimated model.

We use the Wald test to evaluate the following two null hypothesis. First, the commodity price exhibits short-run symmetry if $\sum_{m=0}^{M} \gamma_m^+ = \sum_{n=0}^{N} \gamma_n^-$. Second, the commodity price presents long-run symmetry if $\frac{\beta^+}{\alpha} = \frac{\beta^-}{\alpha}$.

3.1.2. Cumulative Dynamic Multipliers

After testing for the short- and long- run symmetry, we estimate the existence of overshooting by plotting the cumulative effect of negative and positive interest rate on the corn and soybean prices over time. We first extract cumulative dynamic multiplier effects of $\sum_{i=1}^{t-1} \Delta r_i^+$ and $\sum_{i=1}^{t-1} \Delta r_i^-$ on p_t following procedures in Shin et al. (2014). The cumulative dynamic multipliers are calculated as follows:

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial p_{t+j}}{\partial r_t^+}, h = 0,1 \quad (2)$$

$$m_h^- = \sum_{j=0}^{h} \frac{\partial p_{t+j}}{\partial r_t^-}, h = 0,1 \quad (3)$$

$r_t^+ = \sum_{i=1}^{t} \Delta r_i^+$ and $r_t^- = \sum_{i=1}^{t} \Delta r_i^-$. If $h \to \infty$, then $m_h^+ \to \frac{-\beta^+}{\rho}$, and $m_h^- \to \frac{-\beta^-}{\rho}$. $\frac{-\beta^+}{\rho}$ and $\frac{-\beta^-}{\rho}$ are asymmetric long-run coefficients according to equation 1. When there exists overshooting, we can observe adjustments in the cumulative multipliers over time.

3.1.3. Augmented Dickey-Fuller Unit Root Test

Before we apply the NARDL model (equation (1)) above, it is necessary for us to check its validity. Specifically, corn and soybean prices must be I (1), meaning that their first difference must be stationary. In addition, interest rates, change of interest rates and change of commodity prices, and control variables should have an order of integration that does not exceed I (1). To test for validity, we have employed the augmented Dickey-Fuller unit root test (Dickey & Fuller, 1979). The null hypothesis of the test is the presence of a unit root, while the alternative hypothesis is generally stationary or trend stationary. To meet the requirement for applying equation (1), we expect to reject all the null hypothesis.

3.1.4. Tests of Structural Breaks

The past 30 years has been marked by significant policy shifts and economic events such as the U.S. biofuel expansion, the great recession, U.S.- China trade dispute, and the Covid-19 pandemic. These events have led to changes in supply chain and consumer behaviors, suggesting that there may have been multiple structural changes in link between interest rate and corn and soybean prices. This is supported by previous literature in the case of exchange rate, such as Hatzenbuehler et al. (2016), who identified structural changes in the relationship between exchange rates and commodity prices.

In order to identify the number of structural breaks and their timing, we implement a series of sequential tests proposed by Bai & Perron (1998, 2003), Ditzen et al. (2021) and Karavias et al. (2022) for corn and soybean separately. These tests enable us to test the existence of structural changes and estimate the break points. As we have no prior knowledge of the number of breaks and their exact timing, we first employ the sequential F-test (Ditzen et al., 2021). After obtaining the estimated break points and number of breaks, we validate our results by testing the null hypothesis of no breaks against the estimated number of breaks. To account for the possibility of incorrect estimated break points, we assume we lack knowledge of break dates. In this case, we apply supremum F statistics, as proposed by Bai & Perron (1998). We expect to obtain the same estimated break points from this double-checking process.

3.1.5. Bound Test

In order to obtain reliable and accurate estimates from the NARDL model, it is essential to test for the presence of a stable long-run relationship between commodity price change and a set of regressors, which include changes in interest rates, lagged commodity prices, exchange rates and other relevant variables, as specified in equation (1). To conduct this test, we apply the NARDL cointegration approach, which is commonly known as the bound test (Banerjee et al., 1998;

Pesaran et al., 2001; Shin et al., 2014). Our testing procedures involve two methods. The first method is the joint F-test on all the lagged commodity prices p_{t-1}, and sum of positive and negative change in interest rates $\sum_{i=1}^{t} \Delta r_i^+$, $\sum_{i=1}^{t} \Delta r_i^-$ in equation (1) (Pesaran et al., 2001). The second method is the t-test on the lagged commodity prices p_{t-1} (Banerjee et al., 1998). If we reject both the null hypothesis under joint F-test $\alpha = \beta^+ = \beta^- = 0$, and the null hypothesis under the t test $\alpha = 0$, we can conclude that there is a stable long run relationship among commodity prices, interest rates change and other control variables.

3.2. Data

3.2.1. Prices, Interest Rates and Analysis Period

Our analysis period spans over three decades, starting from 1990 to 2022. During this period, the U.S. agriculture becomes market-oriented, and several significant events and policy changes occurred that could potentially impact the relationship between corn and soybean prices and interest rates.

To examine the relationship over this period, we use the monthly spot price data for U.S. corn and soybeans spanning from 1990 to 2022. While the data is originally available in daily frequency from Macrotrends[1] as daily data, we aggregate it to monthly frequency to minimize the noise in the data and account for other data limitation. We compute the weighted average of the daily prices for each month to create the monthly series. To capture the effect of monetary policy on market choices and commodity prices, we incorporate the monthly "1-year real interest rates" series published by the Federal Reserve Bank of St. Louis. This series represents the true cost of

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[1] https://www.macrotrends.net/

borrowing and return on investment and captures the impact of interest rate changes on participants' behavior and decisions. The estimates used are derived from a model that incorporates treasury yields, inflation, inflation swaps and measures of inflation expectations[2]. This series help us to better understand the impact of interest rate changes on commodity prices. We believe that by using this series, we can more accurately examine the impact of interest rate changes on market behavior and the resulting impact on commodity prices.

3.2.2. Storage and Cost of Carrying

Understanding the storage and cost of carrying is crucial for us when analyzing the relationship between interest rates and commodity prices. These factors reveal the behavior of market participants and their expectations regarding future prices, as well as production choice across different periods. Incorporating these factors into our analysis can help to mitigate concerns about the impact of interest rates on future production, supply, and storage, which can, in turn, affect commodity prices.

To capture the effect of storage and cost of carrying, we use two proxy variables—futures contract traded volumes and futures basis for corn and soybeans. We collect monthly futures contract traded volumes from multiple sources, including investing.com[3], Yahoo Finance[4], Nasdaq[5] and tradingcharts.com[6], to address the issue of missing values. Futures basis, which is the difference between futures price and spot price, where futures price is obtained from investing.com and spot price is obtained from Macrotrends. The magnitude and direction of the futures basis can

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[2] https://fred.stlouisfed.org/series/REAINTRATREARAT1YE
[3] https://www.investing.com/
[4] https://finance.yahoo.com/
[5] https://www.nasdaq.com/
[6] https://tradingcharts.com/

provide valuable insights into the supply and demand dynamics of the commodity market. A positive futures basis suggests that the cost of carrying underlying assts is higher than the cost of carrying the futures contract, indicating market participants' expectation of commodity shortage and willingness to pay a premium for future delivery. Conversely, a negative futures basis suggests market participants expect future prices to be lower than the current spot price, indicating an oversupply of the commodity. Market participants hence are willing to sell at a lower future price to avoid storage costs. The two proxy variables provide us with a more comprehensive understanding of the underlying mechanisms in the market and improve the accuracy of our analysis by controlling them.

3.2.3. Structural changes

The corn and soybean markets have experienced significant changes from 1990 to 2022 due to several notable trends. The technology evolution in the late 1990s, commodity price booms in the early 2000s, the 2008 financial crisis, trade policies and tariffs, and the COVID-19 pandemic have affected the corn and soybean markets. These significant changes indicate the potential existence of structural breaks in the commodity market. To verify this suspicion, we conduct sequential tests to identify structural breaks in the case of corn and soybean markets over the past 30 years and find a total of five break points for each commodity. By examining the historical context surrounding these breaks, we are able to link them to policy changes and weather conditions.

Specifically, for corn, the first structural change occurred in August 1996, during a severe drought in the US. The second change occurred in December 2002, when the US government implemented Farm Security & Rural Investment Act. The third one took place in November 2007, when the U.S. government implemented RFS Renewable Fuel Standards. The fourth change occurred in December 2012, during the worst drought over the past 50 years. Finally, the fifth change took place in January 2019, during a trade dispute between the US and China.

Similarly, for soybean, the first structural change occurred in May 1996, when the US announced the commercialization of genetically modified soybeans. The second change occurred in August 2002, when the US government implemented Farm Security & Rural Investment Act. The third change took place in February 2008, when Argentina experienced drought and Brazil experienced floods, affecting two major soybean exporters in the global market. The fourth change occurred in February 2013, during the worst drought in the US. Lastly, the fifth change was in January 2018, because of the trade dispute.

Due to the impact of Covid-19 pandemic on the global commodity market and supply chains, we hypothesized that there may have been sixth structural change. To test this, we conduct an F test (Bai & Perron, 1998) comparing the null hypothesis of five structural breaks against six breaks. We manage to reject the null hypothesis and identify a sixth structural change for both corn and soybean in January 2020, coinciding with the onset of the pandemic.

Because of the ongoing conflict in Ukraine, there may be additional structural changes in the year 2022 that could affect the commodity market. However, considering the short time series of 30 years and the potential instability of adding an indicator variable in 2022, we have decided to stick to existing 6 structural changes for both corn and soybean. While we acknowledge the potential impact of the Ukraine conflict on the commodity market, we believe that our model with 6 structural breaks is sufficient for our analysis.

[Table 1 and Table 2]

Table 1 and table 2 are the summary of how we conduct indicator variables for corn and soybean.

3.2.4. Other Control Variables

To gain a deeper insight into the relationship between interest rates and corn and soybean prices, we include a couple of control variables. These variables include inflation rates, exchange rates, real GDP change, producer price index (Saghaian et al., 2002), industry production index, and unemployment rate. Except that unemployment rate is obtained from Bureau of Economic Analysis[7] and exchange rates are obtained from International Monetary Fund (IMF), while all other variables are obtained from the Federal Reserve Bank of St. Louis. Specifically, we have used the Brave-Butters-Kelley Real Gross Domestic Product" series to analyze real GDP change, and the "Trimmed mean PCE Inflation Rate" series to analyze inflation rates. By including these control variables, we aim to reduce omitted variable bias and obtain more accurate estimates of the relationship between the interest rates and corn and soybean markets. Table 3 displays descriptive statistics from 1990 to 2020 for all variables that we use. Corn spot price has the mean of $3.57 while the soybean spot price has a much higher mean of $8.61. The mean of interest rate is 0.64. The mean futures basis for corn and soybean are 0.03 and 0.00, respectively.

[Table 3 insert here]

4. Results

4.1. Stationary of Series (Augmented Dickey-Fuller Unit Root Test)

Before we implement NARDL model in our analysis, we need to ensure the stationary of the variable series. Specifically, we need to determine whether the variable series are stationary in in levels (I(0)) or first differences (I(1)). To achieve this, we conduct the Augmented Dickey-Fuller

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[7] https://www.bea.gov/

Unit Root Test (Dickey & Fuller, 1979). We present the detailed results of this test in Table 4. The results indicate that corn and soybean spot price series are stationary in levels at 10% significance level and stationery in first difference at 1% significance level. What's more, industry production index, producer price index and inflation rates are stationary in first differences (I(1)). The interest rates, exchange rates, futures traded volumes for corn and soybeans, corn and soybean futures basis, unemployment, real GDP change are integrated of order 0 (I (0)). The results provide evidence that the NARDL model is appropriate to use in our analysis.

[Table 4 insert here]

4.2. NARDL Model

4.2.1. Cointegration Test

To reliability and accuracy of the NARDL model in our analysis, we employ the bound test to verify the existence of a stable long-run relationship between commodity price change and relevant regressors such as interest rates change, lagged commodity prices changes, and others, which is necessary for the application of the NARDL. Table 5 shows t-statistics and F statistics obtained from the two procedures in the bound test. The results indicate that all statistics are significant at 1% significance level, allowing us to reject the null hypothesis for both t test and F test for corn and soybean. Therefore, we can conclude that there is a stable long-run relationship between commodity price and related regressors. This finding provides support for the appropriate use of the NARDL model in our analysis.

[Table 5 insert here]

4.2.2. The Effect of Interest Rate on Corn and Soybean Prices

After verifying the appropriate use of NARDL, we aim to estimate the impact of interest rates on corn and soybean prices. We employ NARDL models (equation (1)) with indicator variables to find out the relationship. The results of the analysis are presented in Table 6, with coefficient estimates for indicator variables in Table 7 and 8.

Table 6 provides us evidence that the short and long-run coefficients corresponding to positive and negative interest rate changes are all negative, indicating an inverse relationship between commodity prices and interest rates both in short- and long run. This result is consistent with previous literature, such as Amatov & Dorfman (2017), Saghaian et al. (2002), and Scrimgeour (2015). Moreover, we observe that coefficients corresponding to positive interest rate changes are more significant than those corresponding to negative interest rate changes. This finding implies that commodity prices are more sensitive facing positive interest rate changes. These findings provide further empirical evidence on the study of relationship between interest rates and commodity prices. The results also provide important implications for policymakers and investors in the agricultural sector. The inverse relationship between commodity prices and interest rates indicates that changes in interest rates can affect the profitability of farmers and agribusinesses, as well as the consumers' affordability. Moreover, the fact that commodity prices are more sensitive to positive interest rate changes underscores the need for careful consideration of interest rate policies and their potential impact on commodity markets.

[Table 6,7,8 insert here]

Table 7 and 8 report coefficients of indicator for corn and soybean respectively. In the case of corn, the 2012 drought and 2007 RFS have a significant and positive impact on corn price. The positive impact of droughts on corn price is not surprising, as lower yield and lower supply. The significant impact of 2007 RFS can be explained by the increasing demand on biofuels and the subsequent rise in corn prices due to the policy mandate to use a certain amount of ethanol in gasoline. Turning to soybean prices, we observe that the 1996 commercialization of genetically modified soybeans, the 2008 drought in Argentina and flood in Brazil, and the Covid-19 pandemic all significantly increase the soybean price. The 1996 commercialization of genetically modified soybeans reflect the increased productivity and reduced cost of growing soybeans. The 2008 droughts and flood disrupted soybean production in the two major exporting countries, leading to higher prices in the global market due to decreasing supply. The Covid-19 pandemic caused disruptions in supply chains, which affected the distribution and transportation of soybeans, leading to increased prices. The significant impact of various events on corn and soybean prices highlights the importance of weather and government policies in shaping agricultural markets. The result also emphasizes the role of technological advancements, global trade, and unexpected events in affecting commodity prices.

4.2.3. Asymmetry and Overshooting

We next investigate short- and long-term asymmetric impact of interest rates on the corn and soybean prices and show the existence of overshooting. We apply the Wald test on both short ($\sum_{m=0}^{M} \gamma_m^+ = \sum_{n=0}^{N} \gamma_n^-$) and long run coefficients ($\frac{\beta^+}{\alpha} = \frac{\beta^-}{\alpha}$) in equation 1, where the estimated coefficients are reported in Table 6. The results of the Wald tests are in Table 9.

[Table 9 insert here]

Table 9 shows the F-statistics of Wald tests for testing asymmetric relationships. We observe that F statistics are significant at 1% significance level for corn and soybean in the long run and significant at 10% significance level in the in the short run. The results indicate that corn and soybean both have asymmetric short- and long run relationship between real interest rates and commodity prices.

Besides asymmetry, we also focus on the overshooting by plotting the cumulative dynamic effects, which captures the full dynamic impact of negative and positive interest rate shock over time on the corn and soybean prices, as shown in Figure 2, 3 and 4. Figure 2 and 3 are the cumulative effect of interest rate change on the corn prices, while Figure 4 refers to the case of soybean. From the three figures, first we can observe that both prices exhibit overshooting facing the negative and positive interest rate change. Our analysis shows that the overshooting phenomenon is more significant in response to positive interest rate changes. This observation is consistent with our previous finding that commodity prices tend to be more sensitive to positive interest rate changes. One potential explanation for this phenomenon is the use of momentum investment strategies by market participants. It is widely believed that commodity trading is dominated by professionals, including traders at firms and financial institutions. Futures contracts, options, and spot transactions are the most widely accepted methods of trading commodities. These professionals often employ momentum investment strategies to take advantage of price trends and reduce storage costs. As interest rate changes are often cyclical, with varying lengths and cycles, it is typically easier to predict increases in interest rates than decreases. This predictability can further amplify the momentum effect in a rising interest rate environment, where market participants may anticipate further increases in interest rates, therefore, continue to sell the underlying commodity assets to reduce their storage costs. On the other hand, decreasing interest rates are typically less predictable and may not have the same momentum effect. Therefore, we would not expect to observe overshooting behavior in response to a decrease in interest rates. Moreover, from figures and our calculation of cumulative dynamic multipliers, we observe that corn and soybean have similar length of adjustment periods. Specifically, the adjustment process for soybean takes approximately 18 months and 20 months for corn. This finding is partially consistent to the finding in Amatov & Dorfman (2017), which states that agricultural commodity index takes around 13 months to fully adjust to equilibrium. Also, we find that in Figure 2, the commodity price has some unexpected fluctuations initially facing negative interest rate changes, however when we shrink time horizon from 1990-2022 to 1990-2021, the fluctuation disappears. We suspect that this may be due to structural changes, such as the Ukraine war that occurred in 2022, introducing noise to the analysis.

[Figure 2, 3,4 insert here]

5. Discussion and Conclusion

This paper provides a comprehensive analysis of the relationship between interest rates and commodity prices in three aspects—overshooting, short-run asymmetry and long-run asymmetry. We employ a new monthly dataset spanning from 1990 to 2022, including corn and soybean spot price, 1-year real interest rates calculated from treasury yield. We also incorporate control variables including macroeconomic factors and proxy variables for storage and cost of carrying, and indicator variables that are identified by sequential tests. A NARDL model is utilized, with first differences on interest rates and decomposition of lags into positive and negative partial sums that allow for short- and long-run asymmetries in the relationship. ADF unit root test and the NARDL cointegration tests are applied to ensure the valid use and reliable estimates of NARDL.

Our findings suggest that there is an inverse relationship between interest rates and corn and soybean spot prices. Moreover, the relationship is asymmetric both in the short and long run. The commodity price exhibits overshooting in response to interest rate changes. Specifically, it takes around 20 months for corn spot price to fully adjust to equilibrium and 18 months for soybeans. Furthermore, the commodity price reacts more sensitively to positive interest rate changes than to negative interest rate changes. This observation can be explained by the momentum investment strategy taken by professionals in the commodity market.

Overall, our findings provide valuable insights for policymakers, investors and farmers in the agricultural sector, allowing them to make more informed decisions about managing risks and maximizing returns in commodity markets. The inverse and asymmetric relationship between interest rates and commodity prices underscores the need for careful consideration of interest rate policies and their potential impact on commodity markets. The existence of structural changes in the relationship also shed lights on the important role of government policies, global trade, technology advancements, weather and unexpected events like pandemic, in the agriculture market.

Tables and Figures

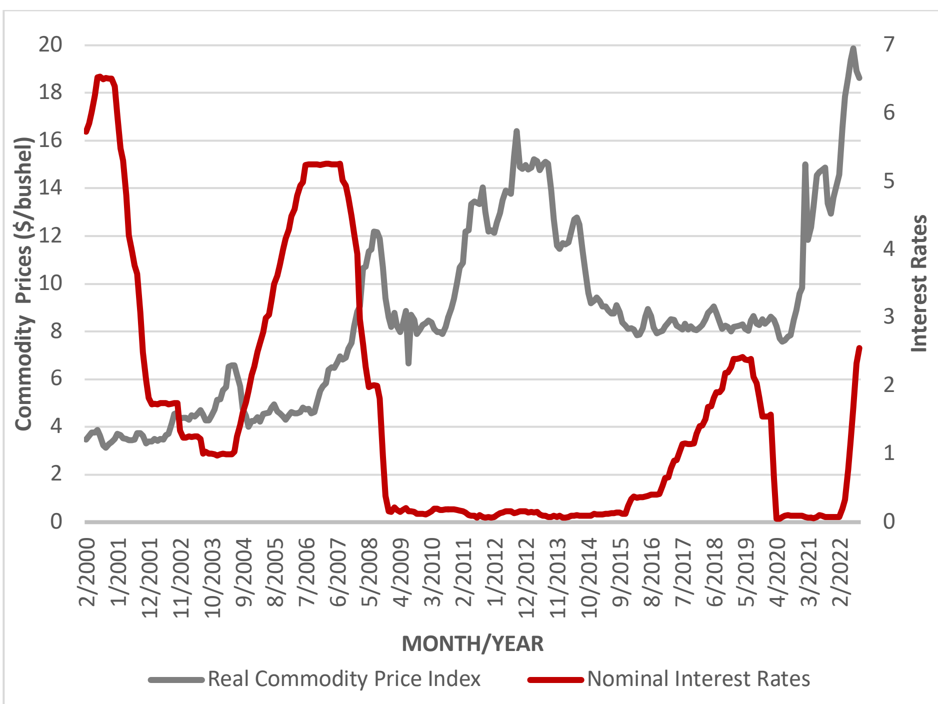

Figure 1: Nominal Interest Rates and Real Commodity Price Index, 2000.1 to 2022.9, by month.

Table 1: Indicator variables (Corn)

Indicator	=1	=0
1996 Drought	Aug 1996	Otherwise
2002 FSRIA	After Nov 2002	Otherwise
2007 RFS	After Oct 2007	Otherwise
2012 Drought	Between Oct 2012 & Jan 2013	Otherwise
2018 Dispute	After Dec 2017	Otherwise
Covid	After Jan 2020	Otherwise

Table 2: Indicator variables (Soybeans)

Indicator	=1	=0
1996 Comm	After April 1996	Otherwise
2002 FSRIA	After July 2002	Otherwise
2008	Between Feb 2008 & Feb	Otherwise
2013	Between Jan 2013 & Jan 2014	Otherwise
2018 Dispute	After Dec 2017	Otherwise
Covid	After Jan 2020	Otherwise

Table 3: Descriptive Statistics

Variables	Mean	SD	Min	Max	Obs
Spot Prices					
Corn	3.57	1.51	1.79	8.03	396
Soybean	8.61	3.26	4.31	16.88	396
Interest Rate	0.64	1.79	-3.97	5.70	396
Futures Basis					
Corn	0.03	0.64	-2.35	3.01	396
Soybean	0.00	1.48	-5.79	5.99	396
Futures Traded Volumes					
Corn	1,401,124	121.9	0	5,110,000	396
Soybean	780,107	74.8	40	3,327,825	396
Exchange Rates	109.61	8.90	92.44	133.85	396
Unemployment	5.83	1.73	3.50	14.70	396
Industry Production index	89.50	13.09	60.44	104.59	396
Producer Price index	159.72	34.71	112.20	262.42	396
Real GDP change	2.35	6.39	-75.68	46.64	396
Inflation	2.65	1.64	-2.1	9.1	396

Table 4: Dickey-Fuller Unit Root Test

Variables	I(0)	I(1)
Spot Prices		
Corn	-2.66^{*}	-17.91^{***}
Soybean	-2.61^{*}	-19.78^{***}
Interest Rate	-4.49^{***}	
Futures Basis		
Corn	-10.11^{***}	
Soybean	-8.82^{***}	
Futures Traded Volumes		
Corn	-10.19^{***}	
Soybean	-13.56^{***}	
Exchange Rates	-0.851	-13.18^{***}
Unemployment	-3.18^{**}	
Industry Production index	-1.91	-15.94^{***}
Producer Price index	1.763	-11.52^{***}
Real GDP change	-9.19^{***}	
Inflation	-2.15	-12.78^{***}

* p<0.1, **p<0.05, ***p<0.01

Table 5: Statistics for the Bound Test

	Corn	Sovbean
T-statistics	-12.07^{***}	-13.58^{***}
F-Statistics	48.68^{***}	61.59^{***}

* p<0.1, **p<0.05, ***p<0.01

Table 6: The Impact of Interest Rate on Commodity Prices, by Commodity

Coefficient	Variable	Corn	Soybean
α	p_{t-1}	-0.398***	-0.544***
		(0.034)	(0.040)
β^+	r^+_{t-1}	-0.036*	-0.170***
		(0.020)	(0.042)
β^-	r^-_{t-1}	-0.008	-0.128***
		(0.020)	(0.042)
τ_1	Δp_{t-1}	0.142***	0.143***
		(0.046)	(0.044)
γ^+_0	Δr^+_t	-0.089***	-0.218***
		(0.040)	(0.078)
γ^+_1	Δr^+_{t-1}	-0.067	-0.110
		(0.044)	(0.083)
γ^-_0	Δr^-_t	-0.006	-0.091
		(0.055)	(0.104)
γ^-_1	Δr^-_{t-1}	0.026	0.089
		(0.053)	(0.099)
μ_1	Inflation_t	-0.004	-0.134
		(0.020)	(0.039)
μ_2	$Exchange\ Rates_t$	-0.011***	-0.037***
		(0.004)	(0.007)
μ_3	$Producer\ Price\ Index_t$	0.029***	0.078***
		(0.004)	(0.009)
μ_4	$commodity\ volume_{t-1}$	9.96	1.41**
		(2.78)	(6.58)
μ_5	$commodity\ basis_t$	-0.268***	-0.308***
		(0.034)	(0.029)
μ_6	$Industry\ Production\ Index_t$		-0.041***
			(0.013)

Table 6 continued

μ_7	$unemployment_t$	0.042	
		(0.051)	
μ_8	$unemployment_{t-1}$		-0.236***
			(0.001)
μ_9	$Real\ GDP_t$	-0.003	-0.016**
		(0.005)	(0.007)

* p<0.1, **p<0.05, ***p<0.01

Table 7: Estimates of the Indicator Variables, Corn

Variable	Corn
1996 *Drought*	0.424
	(0.389)
2002 *FSRIA*	-0.103
	(0.087)
2007 *RFS*	0.319***
	(0.131)
2012 Drought	0.847***
	(0.205)
2018 *Dispute*	0.093
	(0.118)
Covid	0.367
	(0.120)

* p<0.1, **p<0.05, ***p<0.01

Table 8: Estimates of the Indicator Variables, Soybean

Variable	Soybean
1996 *Comm*	1.145***
	(0.249)
2002 *FSRIA*	-0.242
	(0.189)
2008 *Weather*	0.479**
	(0.233)
2013 Drought	0.344
	(0.235)
2018 *Dispute*	-0.142
	(0.228)
Covid	0.819***
	(0.236)

* p<0.1, **p<0.05, ***p<0.01

Table 9: Tests for Asymmetry

F-Statistic	Corn	Soybean
Short run	2.89*	2.78*
Long run	27.61***	19.09***

* p<0.1, **p<0.05, ***p<0.01

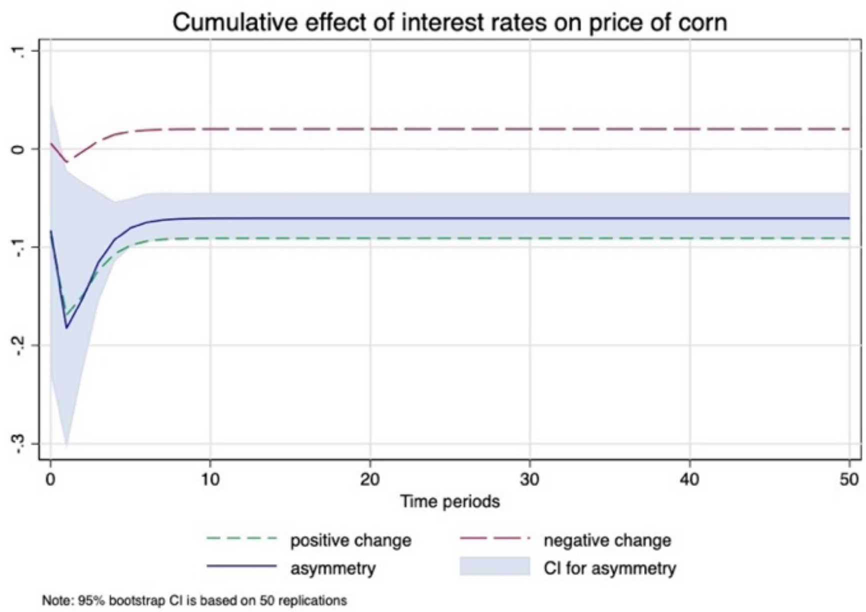

Figure 2

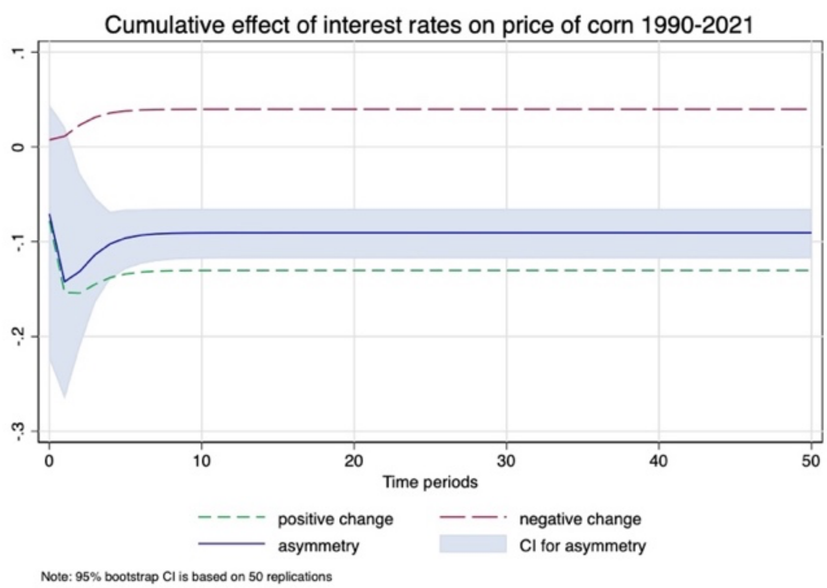

Figure 3

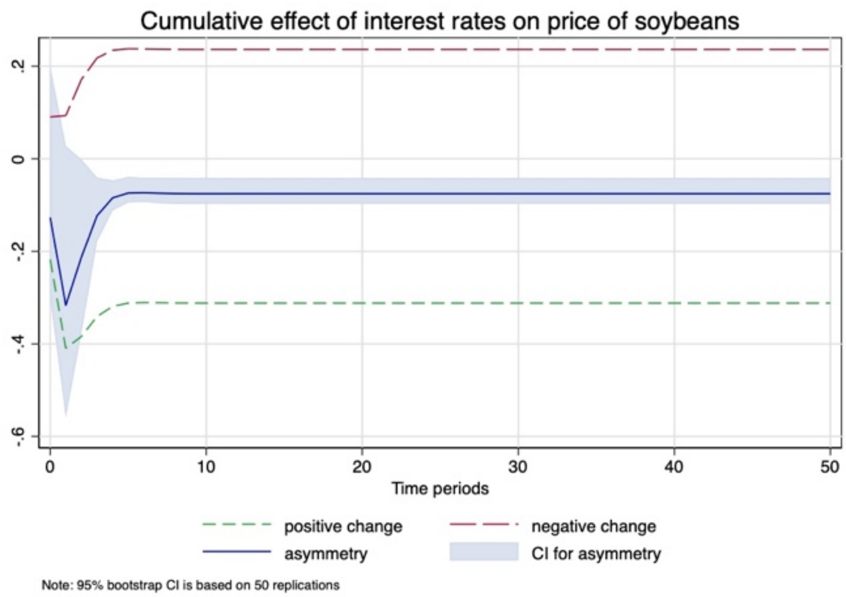
Cumulative effect of interest rates on price of soybeans
.2
0
-.2
-.4
-.6
0
10
20
30
40
50
Time periods
positive change
negative change
asymmetry
CI for asymmetry
Note: 95% bootstrap CI is based on 50 replications

Figure 4

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