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Assessing the Recent Shift in the Price Relationship Between India's and Global Grain Markets

Kayode Ajewole, Yacob Abrehe Zereyesus, Lila Cardell, Ethan Sabala, Inder Majumdar

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Abstract

In response to the Coronavirus (COVID-19) pandemic that began in 2020 and a year of unprecedented food inflation, India's Government doubled the amount of wheat and rice provided to food insecure households through its food distribution programs. In the 2020–2024 period following India's food distribution program expansion, India's Government also implemented trade restrictions. An exception to these trade restrictions, however, is the recent allowance of genetically engineered soybean product imports, which were historically banned. Although some food distribution program details and trade restrictions have changed, these policies remained in effect through April 2024. This report empirically investigates the underlying price relationship between international grain and oilseed prices and domestic market prices in India before and after implementing a new policy framework. The report finds a substantial shift in the long-term price relationship between India's domestic and international grain markets except for soybeans. The report also finds that India's domestic rice, wheat, and corn prices are less dependent on international prices after the new policies were introduced. However, domestic soybean product prices in India have become more dependent on international soybean prices.

Keywords: India, autoregressive distributed lag model, exchange rate, commodity prices, COVID-19 pandemic

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About the Authors

Kayode Ajewole, Yacob Abrehe Zereyesus, Lila Cardell, and Ethan Sabala are research agricultural economists at USDA, Economic Research Service, and Inder Majumdar is a PhD student at the Department of Agricultural and Applied Economics, University of Wisconsin-Madison.

Contents

Summary iii

Introduction 1

India's Consumer Price Index by Food Category 3

India's Recent Grain and Oilseeds Trade Policy 3

International Price Transmission to India's Domestic Food Markets 6

Relationship Between India's Domestic Market and Global Market: Before and After Implementing New Food Policies 10

Conclusion 18

References 19

Appendix 22

Model Description and Estimation 22

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A report summary from the Economic Research Service *April 2025*

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What Is the Issue?

India's commodity prices have risen more rapidly in recent years compared to increases prior to the Coronavirus (COVID-19) pandemic. To mitigate the effect of unprecedented food price inflation, the Government of India implemented new policies after the occurrence of the COVID-19 pandemic (2020–2024) for rice, wheat, and soybeans to protect domestic markets from global food price inflation. These new policies included distributing rice and wheat to consumers at no cost or reduced cost, limiting wheat and rice exports, and increasing soybean product imports. This study investigated whether the prices of staple cereals and oilseeds in India's domestic market have become more or less influenced by global grain market prices before and after the implementation of India's food policies. By analyzing how international grain price fluctuations influence domestic grain prices in India, we aimed to understand the potential changes to the relationship of India's domestic grain prices and global grain prices associated with India's trade policy changes implemented during and after the COVID-19 pandemic. This analysis is particularly relevant as India's Government adjusts its trade policies in response to domestic market price movements. For example, the Government of India relaxed its rules for importing soybean meal sourced from genetically engineered soybeans in 2021 when India was experiencing a lower domestic supply of animal feed in the poultry industry and increased feed prices.

India plays an important role in the global food market, and its staple food commodity policies may cause market distortions and shifts in global prices. India's position as a major grain producer and consumer is critical to the global supply and price stability of major food grains. Moreover, India accounted for roughly 40 percent of global rice exports in 2022. Since the COVID-19 pandemic and the subsequent food inflation crisis, India has implemented several trade restrictions, most notably export bans and taxes on rice and wheat. India's rice trade policies have had a significant effect on the global rice market, as demonstrated by the nonbasmati white rice export bans that started in July 2023 and the 20-percent export tax on parboiled rice exports that started in August 2023. Similarly, the ban on wheat exports that began in May 2022 was implemented to address concerns about food security and domestic price stability.

What Did the Study Find?

This report's analysis revealed a substantial change in the long-term relationship between domestic grain prices in India and international grain prices. This study's findings include:

- India's domestic prices for rice, wheat, corn, and soybeans exhibited a significant long-term dependence on international prices before the introduction of new food policies.
- After the implementation of the new food policies, this long-term dependence became insignificant for all grains, but not for soybeans.
- India's retail soybean prices continued to show significant dependence on international soybean prices after the new food policies were implemented. This suggests that the price relationship remained unchanged from the prepolicy period (2011–2019). Moreover, the connection between domestic soybean prices and international soybean prices strengthened during periods of increased soybean product imports.
- The Indian-U.S. exchange rate (Indian rupees per U.S. dollar) primarily affected heavily traded commodities. It significantly affected rice prices before and after the policy changes. However, the exchange rate's effect on soybean prices was more pronounced after the trade policy changes, which coincided with India's record soybean meal imports.

How Was the Study Conducted?

This study analyzed trends in domestic and international grain prices (rice, wheat, corn, and soybeans) in India. We employed an autoregressive distributed lag (ARDL) model to empirically investigate the price relationship between India's and global markets before and after the implementation of India's new food policies. Monthly domestic grain prices in India's retail markets were obtained from the Unified Portal for Agricultural Statistics (UPAg) of the Government of India's Directorate of Economics and Statistics, Ministry of Agriculture. Monthly international prices, including Thailand's 25-percent broken rice, U.S. hard red winter wheat, U.S. No. 2 yellow corn free on board (FOB) U.S. Gulf ports, U.S. Gulf Yellow Soybean No. 2, and crude oil prices, were collected from the May 2024 World Bank Commodity Price Data (The Pink Sheet). Monthly average real exchange rate values were sourced from the USDA, Economic Research Service Macroeconomics dataset.

Assessing the Recent Shift in the Price Relationship Between India's and Global Grain Markets

Introduction

India and its influence are important to the global food market. India's policies targeting staple food commodities may lead to distortions in the global market and a shift in global price discovery.[1] For instance, India is the largest exporter of rice in the world, so significant fluctuations in India's domestic rice market can reverberate throughout global markets. Although corn and wheat price fluctuations might have limited effect due to India's lower trade volumes, rice fluctuations are more significant. Understanding food inflation in India is crucial as food expenditures are a major component of India's household expenditures (Anand et al., 2014). In addition, high volatility and the persistence of food price shocks among emerging economies cause food inflation to be a major concern, for example, spikes in food prices are easily transmitted into nonfood inflation (Walsh, 2011; Anand et al., 2014). Food inflation has trended upwards for several years, but the Consumer Price Index (CPI) grew more rapidly after the start of the Coronavirus (COVID-19) pandemic[2] (Anand et al., 2014; figures 1, A.1).

Recently, India's commodity prices have increased more rapidly compared to the prepandemic era. To mitigate the effect of unprecedented food inflation, India implemented new policies in 2022 and 2023 for rice, wheat, and soybeans to protect domestic markets from global food inflation. These new policies included distributing rice and wheat to consumers at no cost or reduced cost, limiting wheat and rice exports, and increasing soybean product imports. This study examined whether the prices of staple cereals (rice, wheat, corn) and oilseeds (soybeans) in India's domestic market prior to the implementation of India's new food policies (2011–19) have become insulated from fluctuations in global grain market prices after the implementation of India's new food policies (2020–2024). India's domestic food prices spiked in 2021 following increases in global food prices (figure 2). Analysis of price transmission can show to what extent India's domestic markets are, or are not, insulated from international price fluctuations. This is particularly relevant because the Government of India adjusts its trade policies in response to domestic market price movements.

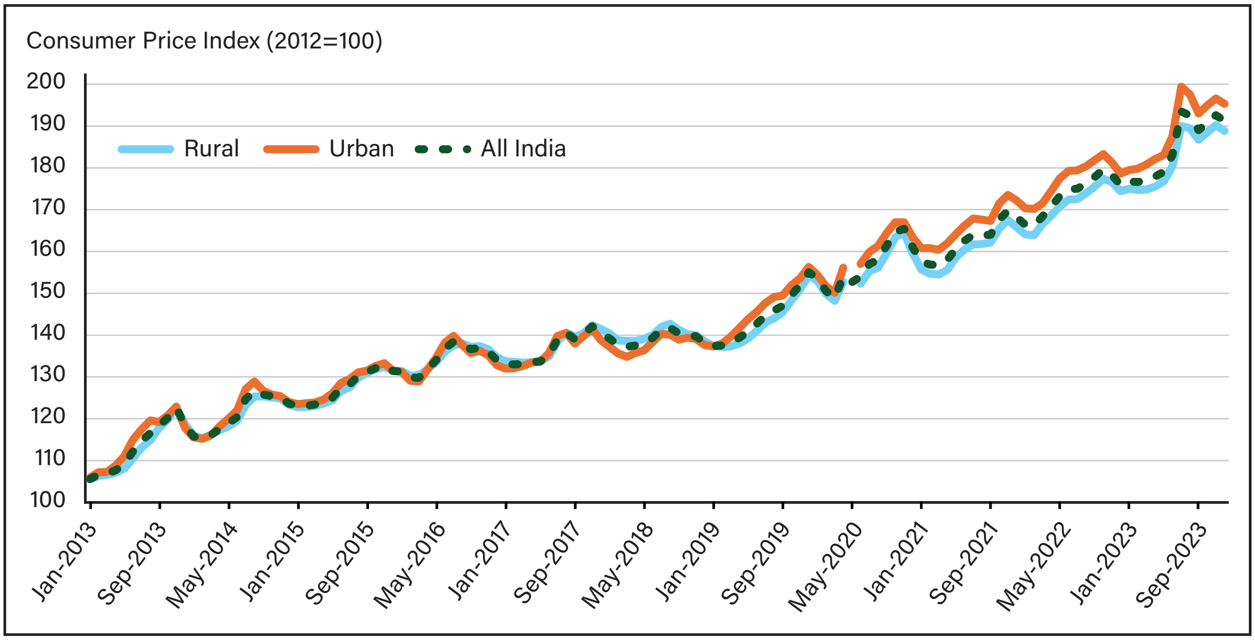
This study focused on rice, wheat, corn, and soybeans, four primary commodities that are crucial to India and the global food market. Rice, a staple food for more than half of the world population (Fukagawa & Ziska, 2019), is essential to global food security. Wheat, another major source of food calories, is consumed by an average person at a rate of 65 kilograms (143.3 pounds) annually (Erenstein et al, 2022). Corn is a versatile commodity used for both human consumption and animal feed. It plays a significant role in India's feed industry. The United States, as the world's largest producer and exporter of corn, represented about 36 percent of global exports in 2020 (World Economic Forum, 2021). Soybeans are a major crop in animal feed production around the world, and the United States, Brazil, and Argentina are the major global soybean producers and exporters (FAO, 2022). Continuous growth in demand for animal protein in India has also led to an increase in demand for soybean products in the feed industry, with more than 70 percent of soybeans being used for animal feed production. Although India produces and trades other cereals and oilseed

[1] There is a large amount of literature on how price insulation policies affect global prices, especially after the COVID-19 pandemic (see, Martin & Minot, 2022; Arita et al., 2022; Ahn & Steinbach, 2023).

[2] In this study, we define the post COVID-19 pandemic as the period after the major lockdown in India (March 25, 2020–May 31, 2020).

commodities (such as pearl millet, sorghum, sesame seeds, and peanuts), comprehensive and reliable price data on international and domestic prices for these products are often limited or unavailable.

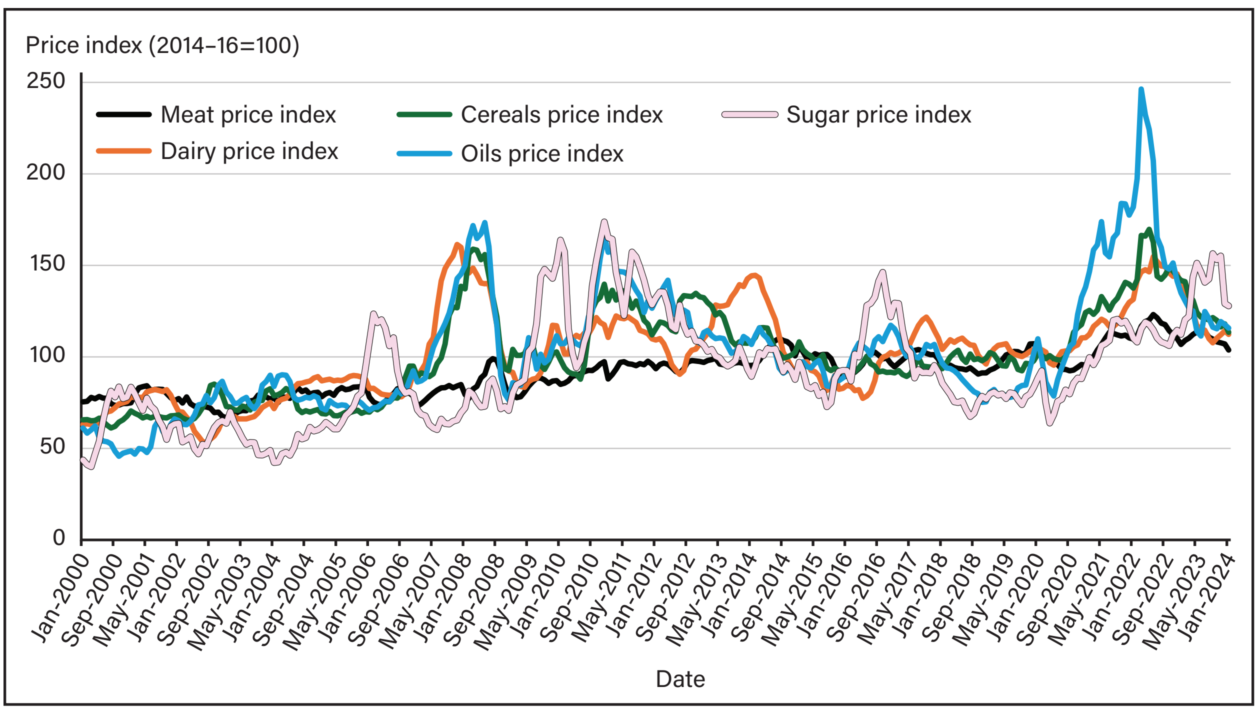
Figure 1
India's consumer price index for food and beverages (2012 = 100), 2013–23



Note: The gap between rural and urban Consumer Price Index (CPI) started around 2020 and remained high throughout the height of the Coronavirus (COVID-19) pandemic and supply chain disruption issues.

Source: USDA, Economic Research Service using Reserve Bank of India data.

Figure 2
Global real food price indices by commodity group (2014–16 = 100), 2000–23

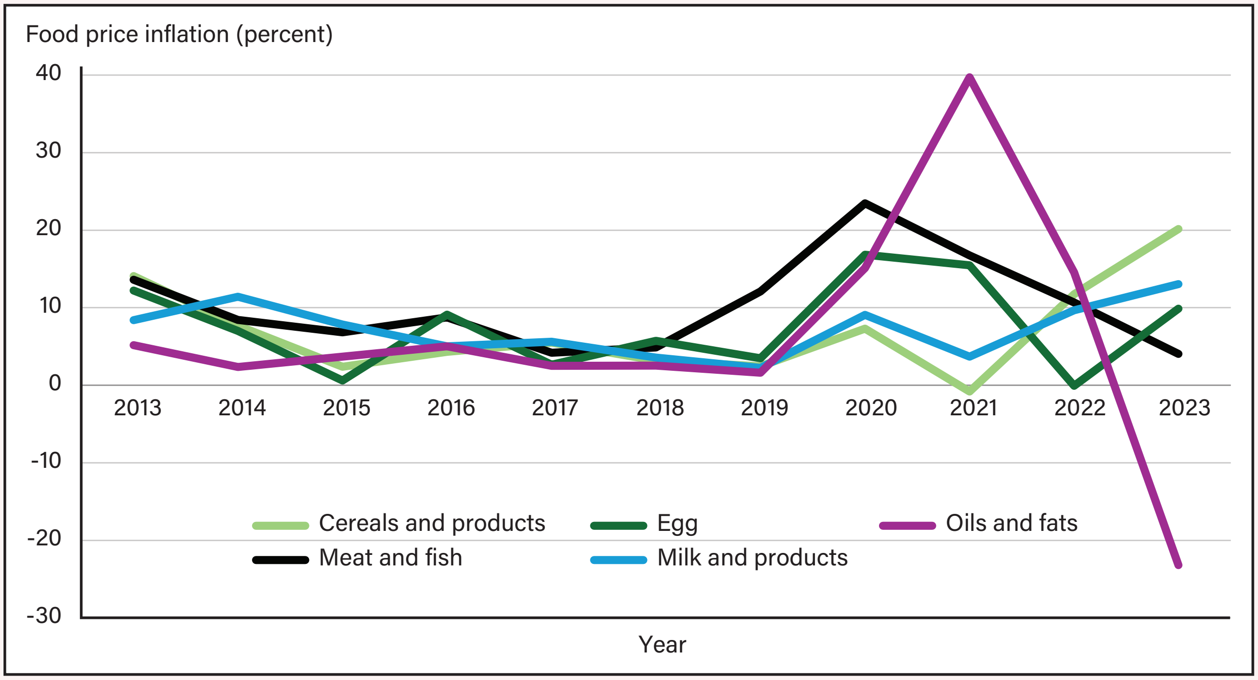


Source: USDA, Economic Research Service calculation using Food and Agriculture Organization of the United Nations data.

India's Consumer Price Index by Food Category

India's food prices increased more rapidly in 2020 and beyond (compared to 2013–2020) with some distinct changes in individual food categories (box figure 1). Examining India's food prices since 2013, we find that prices have increased more rapidly since the start of the Coronavirus (COVID-19) pandemic with only the cereals and products category showing price reductions from 2020 to 2021, a 0.8-percentage-point decrease (box figure 1). However, this price drop was short lived as the cereals and products Consumer Price Index (CPI), a measure of food inflation, increased considerably in 2022 and 2023. During the COVID-19 pandemic, the Government of India distributed an extra 5 kilograms (11 pounds) of rice or wheat per person to vulnerable consumers in 2021 (Ajewole & Childs, 2020; Government of India, 2021) to help protect the domestic market from price surges which contributed to the CPI decline in cereals and products in 2021. Following a significant surge in prices during 2021 and 2022, oil and fat prices experienced a sharp decline in 2023 dropping by 23 percent from 2022 (box figure 1).

Box figure 1
India's food price inflation by food category, 2013–23



Note: Food price inflation is based on each food category's specific price index (2012=100).

Source: USDA, Economic Research Service using Reserve Bank of India data.

India's Recent Grain and Oilseeds Trade Policy

India is the largest global exporter of rice. Also, India's wheat exports have increased in recent years. Although India is involved in the international trade of several agricultural commodities, there are trade protections implemented by India's Government for major food commodities including rice and wheat that influence global prices and trade. To protect domestic markets from global price shocks or prevent excess domestic supply, India has used trade measures such as export taxes, export subsidies, export bans, and import restrictions to control the domestic supply and food commodity prices. India applies one of the highest Most-Favored-Nation tariff rates for agricultural products imports among World Trade Organization (WTO) members with an average tariff rate of 36.5 percent in the 2020/21 market year (WTO, 2020). There have been several WTO cases brought against India for its price supports and trade restrictions. In 2018, the United States filed its first counter notification to the WTO Committee on Agriculture on India's market price supports for wheat and rice. The United States notified the

WTO that India was underreporting its market price support for rice and wheat (USDA, 2018). The price support system has been reported to create market distortion by increasing domestic supply beyond market equilibrium levels and lowering demand for imported rice and wheat (Narayanan & Tomar, 2023).

Since the start of the COVID-19 pandemic and the resulting price inflation, India put in place several trade restrictions, most notably the introduction of export bans and taxes on rice and wheat exports. Citing food security risks from the sudden spike in global wheat prices and the importance of ensuring staple food prices for consumers, India's Government implemented a ban on wheat exports on May 13, 2022 (USDA, 2022a; Swaminathan & Johnson, 2022). India also introduced several export restrictions on rice as the domestic rice price was rising. India implemented an export restriction on rice during the 2007/08 food crisis (Childs & Kiawu, 2009).

India has a significant influence on the global rice market since India accounted for about 40 percent of total rice exports in 2022. India is a major supplier of rice to Asian and Sub-Saharan African countries, accounting for more than 80 percent of the market share in several countries in 2022, for example, Central Africa Republic (88 percent), Togo (89 percent), Liberia (96 percent), Guinea (94 percent), and Madagascar (90 percent) (see, Glauber & Mamun, 2023). The nonbasmati white rice export ban implemented by India's Government in July 2023 had an immediate effect on global markets through a sharp increase in the international price of rice (USDA, 2023). In addition to the nonbasmati white rice export ban, an export tax on parboiled rice was also introduced in August 2023 (USDA, 2023). Before the 2023 ban and tax, India limited exports of broken rice[3] in 2022 as well. The introduction of export restrictions by India led major rice importers to shift to other exporters such as Thailand and Vietnam.

While India introduced restrictive measures against the trade of rice and wheat, India's Government also reduced import restriction measures for soybean products. In 2021, the Government of India officially permitted 1.2 million metric tons of soybean meal and soy cake imports from genetically engineered soybeans (USDA, 2021). India has a very protective policy against food and feed crops from genetically engineered sources. India's Environment (Protection) Act, 1986 has regulated the use, import, export, or storage of genetically engineered crops (Government of India, 2019). India introduced the soybean trade policy change during a period of inadequate domestic supply of animal feed in the poultry industry that resulted in continuous local feed price increases. Due to the unfilled import quota from the 2021 allotment, India's Government reapproved the importation of genetically engineered soybean meal in May 2022 (USDA, 2022b). The changes in trade policies are likely to affect the level of India's domestic food commodity markets integration to the global market.

Recent Domestic Price Support Policies in India

Although India's Government has prioritized making food affordable for people living in India, India also has one of the highest numbers of food insecure people in the world. In 2024, 181.5 million people (13.3 percent of India's population) in India were classified as food insecure (Cardell et al., 2024). To ensure food security for Indian households during the COVID-19 pandemic, the government implemented a program that provided an additional 5 kilograms (11 pounds) of rice or wheat per person per month at no cost. India's food distribution program provides foodgrains at a subsidized rate to food insecure citizens, especially those in urban food-scarce areas (Government of India, 2024a; George & McKay, 2019). The first distribution batch took place in March 2020 following the outbreak of the COVID-19 pandemic (Government of India, 2021). The Pradhan Mantri Garib Kalyan Anna Yojana (PMGKAY) food distribution program was in place until the end of 2022 when it was replaced with a new subsidized food program to Antyodaya Anna Yojana (AAY)[4] households and Priority Households (PHH) beneficiaries (Government of India, 2024b). While some

[3] Broken rice is a category of rice grains that break during the milling process and are separated from whole grains. Broken rice is used for food, animal feed, brewing, and other industries.

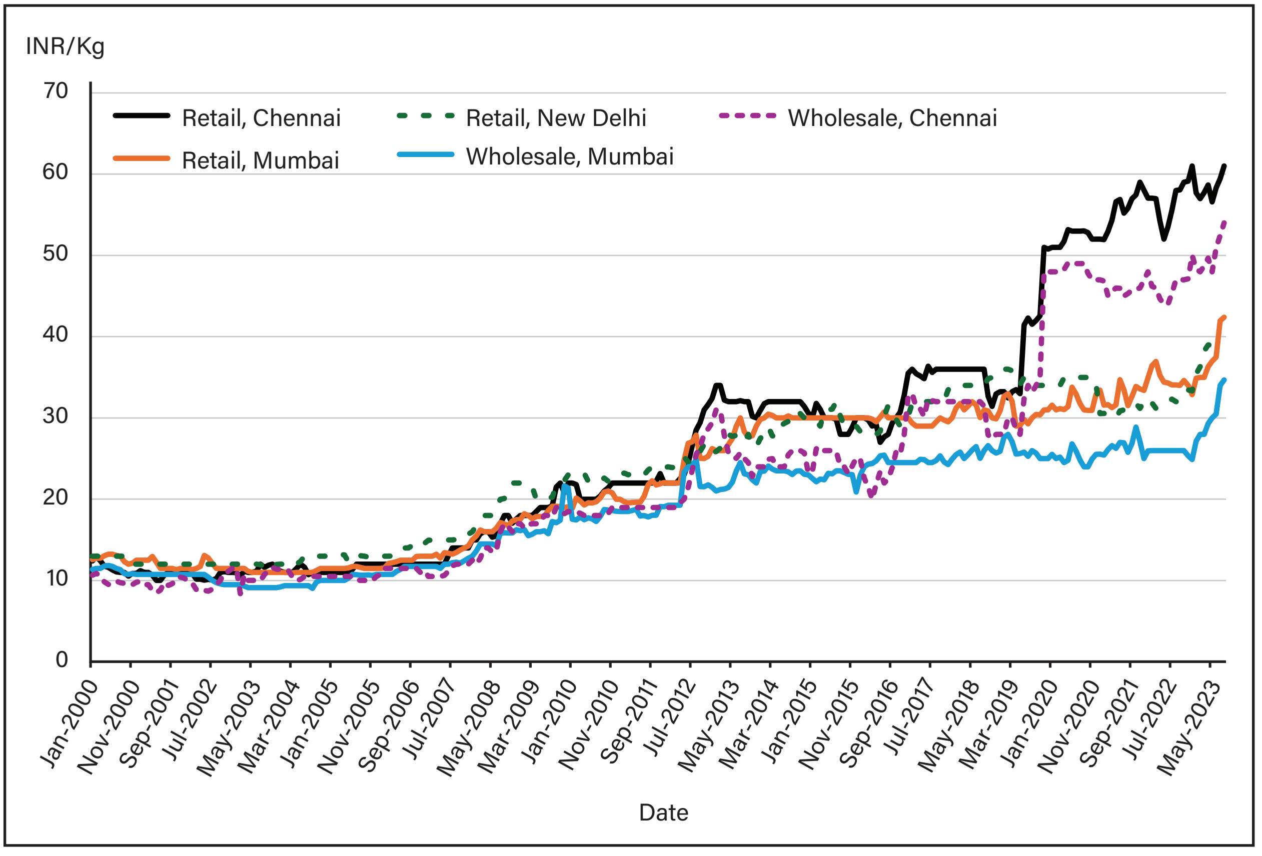
[4] Antyodaya Anna Yojana (AAY) is a scheme of Government of India to fight against malnutrition and poverty in India. The program provides subsidized food to millions of India's poorest families.

markets have price stability, a sharp increase in the wholesale and retail price of rice in Chennai occurred in early 2020 (figure 3). This spike in the price of rice in Chennai directly preceded India's initial distribution of rice and wheat to vulnerable consumers. Additionally, wholesale and retail wheat prices in Chennai increased at the start of 2020 (figure 4). Although prices fell slightly in the second half of 2021, wheat retail and wholesale prices spiked up again in mid-to-late 2022 for all regions.

India's Government regularly supports domestic food markets through its Price Support Scheme whereby it implements price supports to farmers through State governments to increase agricultural production and productivity through the yearly minimum support price to farmers. The State and central governments purchase selected crops through procurement agencies from farmers at the government-set minimum support price with the objective of stabilizing market prices at or above the minimum support price and protecting farmers from losses (Government of India, 2024c). The minimum support price is meant to create a stable price environment and profitable prices for India's farmers (Government of India, 2024c). The purchased commodities are later distributed to the domestic market to ease the purchase price for consumers.

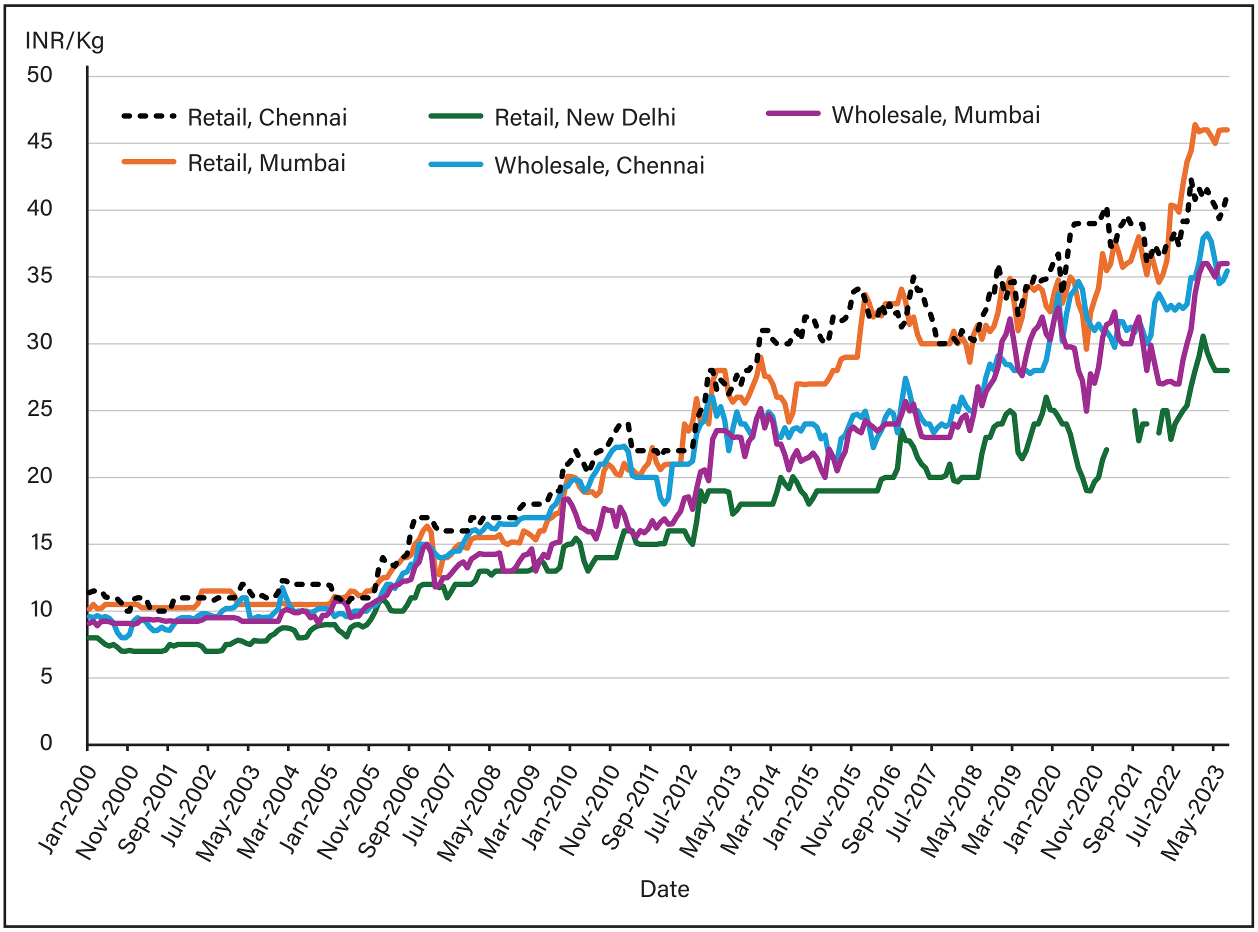
Besides price supports to farmers and food distribution to consumers, India's Government supports farmers with agricultural input subsidies for fertilizers, irrigation, and electricity (Zafar et al., 2023). Despite the Price Support Scheme's goal to provide an assurance of profitability and to encourage farmers to produce crops crucial to food security (Majumdar & Janzen, 2022), India's direct subsidies to producers have the potential to create market distortions and reduce global competition. In some cases, the recommended support prices have been much higher than the actual cost of production, thereby creating distorted parity between crop prices (Dev & Rao, 2010).

Figure 3
Wholesale and retail rice prices across selected markets in India, 2000–23



Source: USDA, Economic Research Service calculation using Food and Agriculture Organization of the United Nations data.

Figure 4
Wholesale and retail wheat prices across selected markets in India, 2000–23

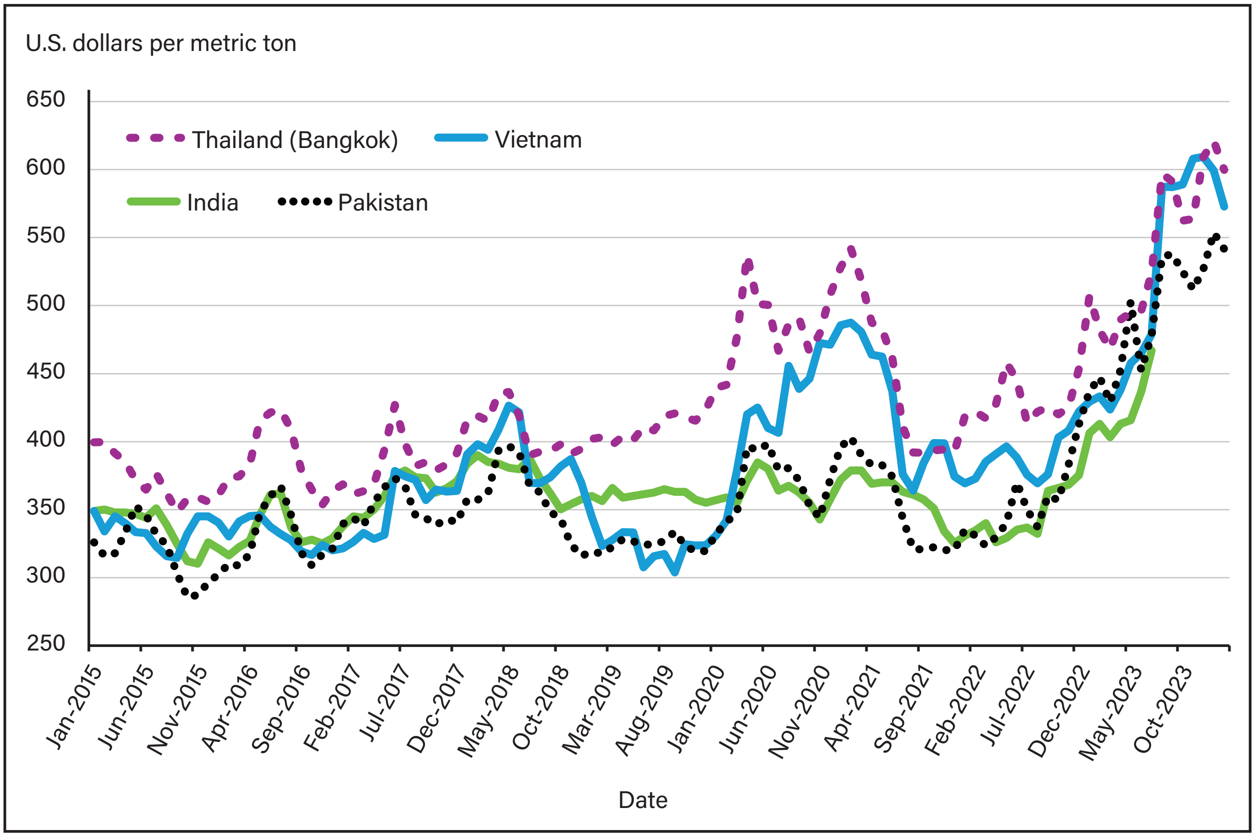


Source: USDA, Economic Research Service calculation using Food and Agriculture Organization of the United Nations data.

International Price Transmission to India's Domestic Food Markets

Although primarily produced in certain regions of the world (including India), rice, wheat, corn, and soybeans are essential food and animal feed staples that are in high demand worldwide and are heavily traded commodities globally. Therefore, it is expected that a shock to the international price of any of these commodities would be reflected in the domestic market in India. Moreover, India is the world's largest exporter of rice, so fluctuations in India's domestic rice market are likely to reverberate throughout global markets. For instance, export bans were introduced to counter the surge in India's domestic rice price while international prices were increasing since 2021 (figure 5). Rice and wheat are major food staples in India, while corn and soybeans are important to the animal feed industry.

Figure 5
International rice export prices, 2015–23



Note: India's rice price data stopped at July 2023 due to the introduction of the export ban on nonbasmati rice. The prices represent international export prices for 25 percent broken rice.

Source: USDA, Economic Research Service calculation using International Grain Council data.

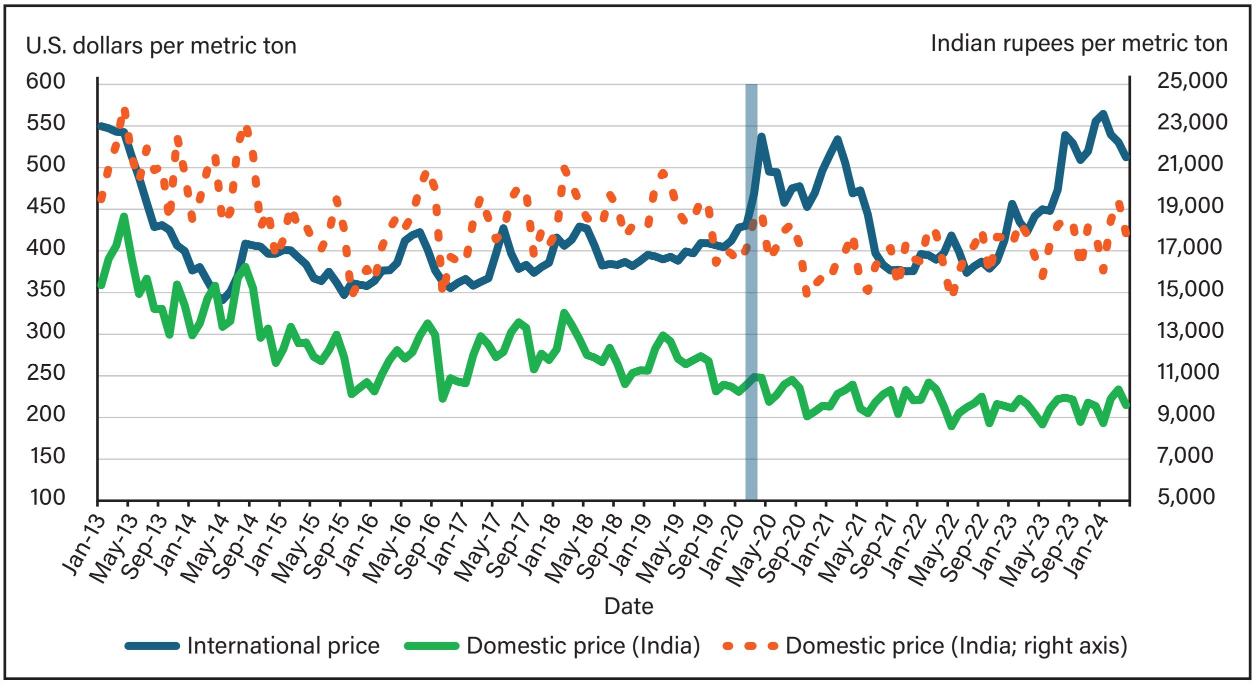
India's major staples market protection policies indicate the importance of government regulation on domestic market prices and protection of the domestic market from the global market's influence. If price shocks are indeed transmitted from international to domestic markets, analyzing how domestic markets react becomes critical for major stakeholders in domestic and global grain markets.

We analyzed the relationship between India's domestic and international prices for rice, wheat, corn, and soybeans.[5] Using an autoregressive distributed lag (ARDL) model, we examined how international price fluctuations have affected domestic prices in India. Additionally, we used Pesaran et al.'s (2001) bound cointegration tests to evaluate if there are long-term cointegrated relationships between global commodity markets and domestic commodity markets for the crops under study. Our study compared domestic real prices and international real prices of the four food grains (figures 6–9). India's domestic rice price and international rice price show similar patterns before the COVID-19 pandemic (figure 6). Although the domestic real price of rice stabilized between \$350 and \$450 per metric ton after the COVID-19 pandemic, the international real price experienced increased price volatility with the global real price reaching \$500 per metric ton multiple times after the pandemic. From 2015 to 2020, the international wheat price had largely been below the domestic wheat price in India (figure 7). There was more pronounced divergence between India's domestic real price of wheat and the international real price of wheat in the post-COVID-19 pandemic lockdown period (June 2020–April 2024) (figure 7). During the postpandemic period, India implemented trade measures including export taxes,

[5] The domestic price of soybean is derived from the combined price of soybean meal and soybean oil. Soybean meal and soybean oil are the byproducts of oilseed crushing (Persaud, 2019). Therefore, India's domestic soybean price is a good indicator of the price for soybean products used for both food and feed production in India.

export subsidies, export bans, and import restrictions as a means of controlling the supply and prices of food commodities in domestic markets. Similar to wheat, the international price of corn had mostly trended below India's domestic corn price until the COVID-19 pandemic (figure 8). Although India's domestic rice, wheat, and corn prices diverged from international price patterns in the years following the pandemic (2021–2024), the domestic soybean price in India continued to follow international prices (figure 9). Introducing exchange rates affects global and domestic price movements (i.e., domestic commodity prices in U.S. dollars sometimes shows different movement patterns compared with prices that are quoted in the domestic currency such as Indian rupees). We used U.S. dollar, real prices for both India's domestic prices and global prices in our model estimations (see figure A.2 for exchange rates between Indian rupees and U.S. dollars).

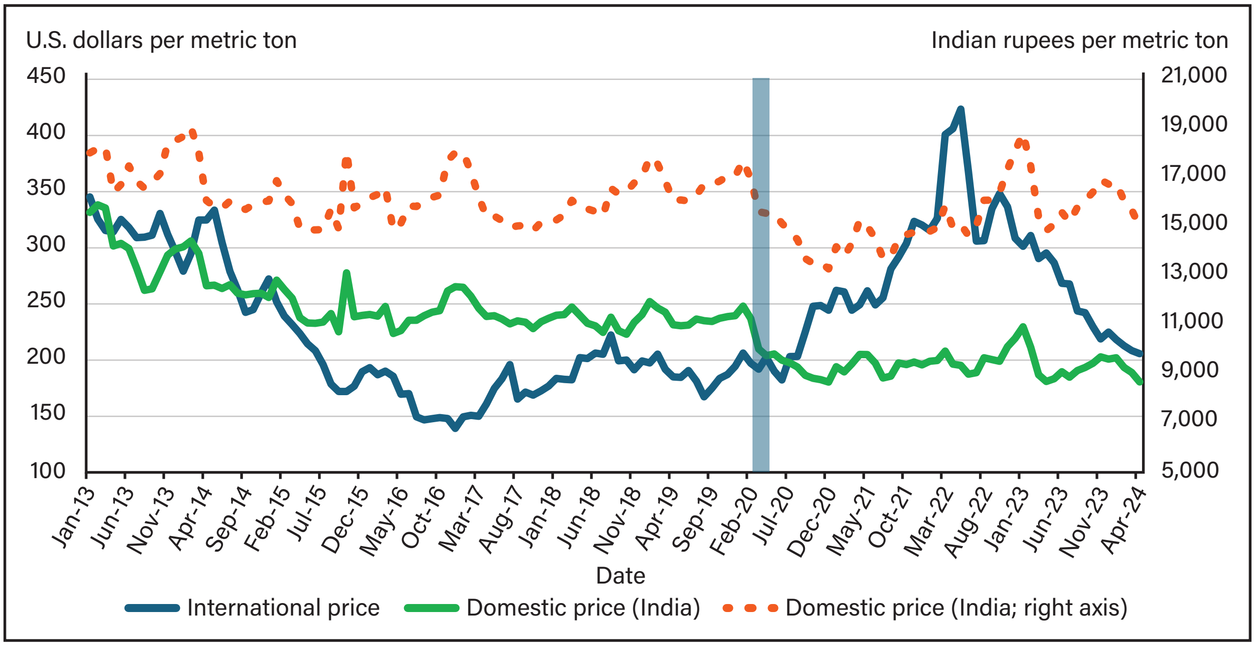
Figure 6
Global and India's domestic rice prices, 2013–24



Note: The vertical blue bar indicates the period of Coronavirus (COVID-19) pandemic lockdown in India (March 25, 2020–May 31, 2020). All prices in left axis are in real dollars.

Source: USDA, Economic Research Service using data from Food and Agriculture Organization of the United Nations, Food Price Monitoring Analysis Tool data; and Government of India's Directorate of Economics and Statistics, Ministry of Agriculture, Unified Portal for Agricultural Statistics.

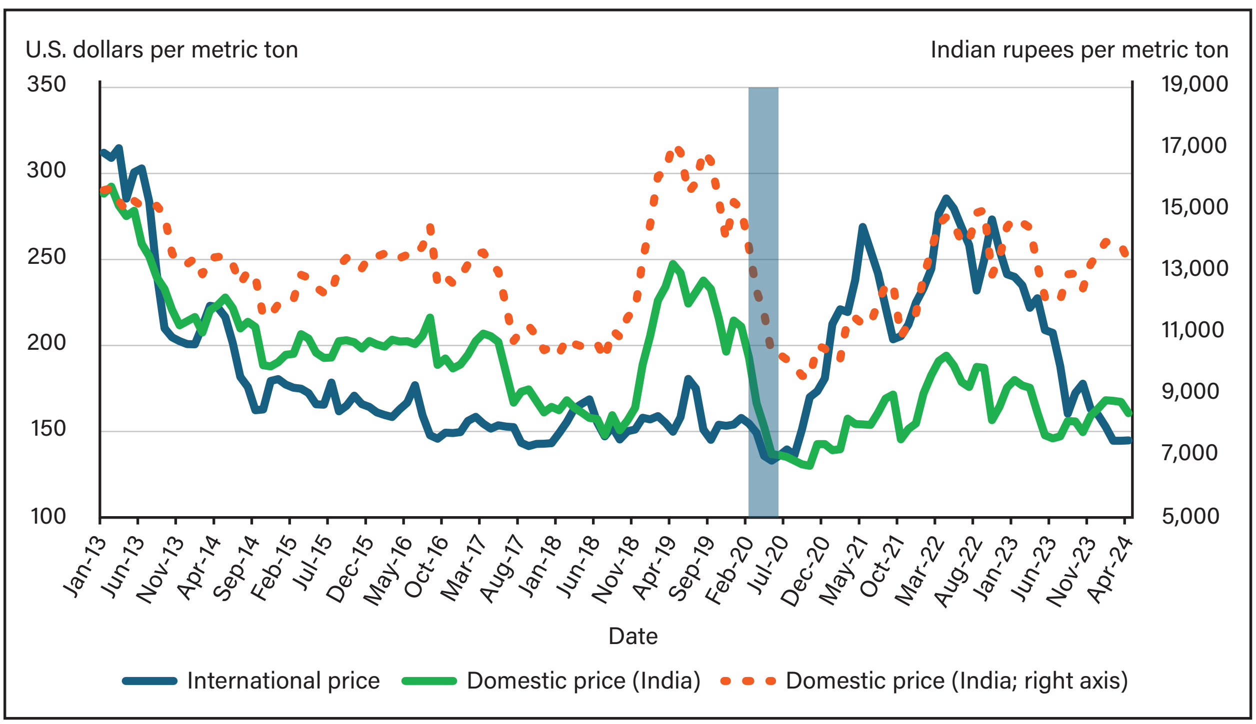
Figure 7
Global and India's domestic wheat prices, 2013–24



Note: The vertical blue bar indicates the period of Coronavirus (COVID-19) pandemic lockdown in India (March 25, 2020–May 31, 2020). All prices in left axis are in real dollars.

Source: USDA, Economic Research Service using data from Food and Agriculture Organization of the United Nations, Food Price Monitoring Analysis Tool data; and Government of India's Directorate of Economics and Statistics, Ministry of Agriculture, Unified Portal for Agricultural Statistics.

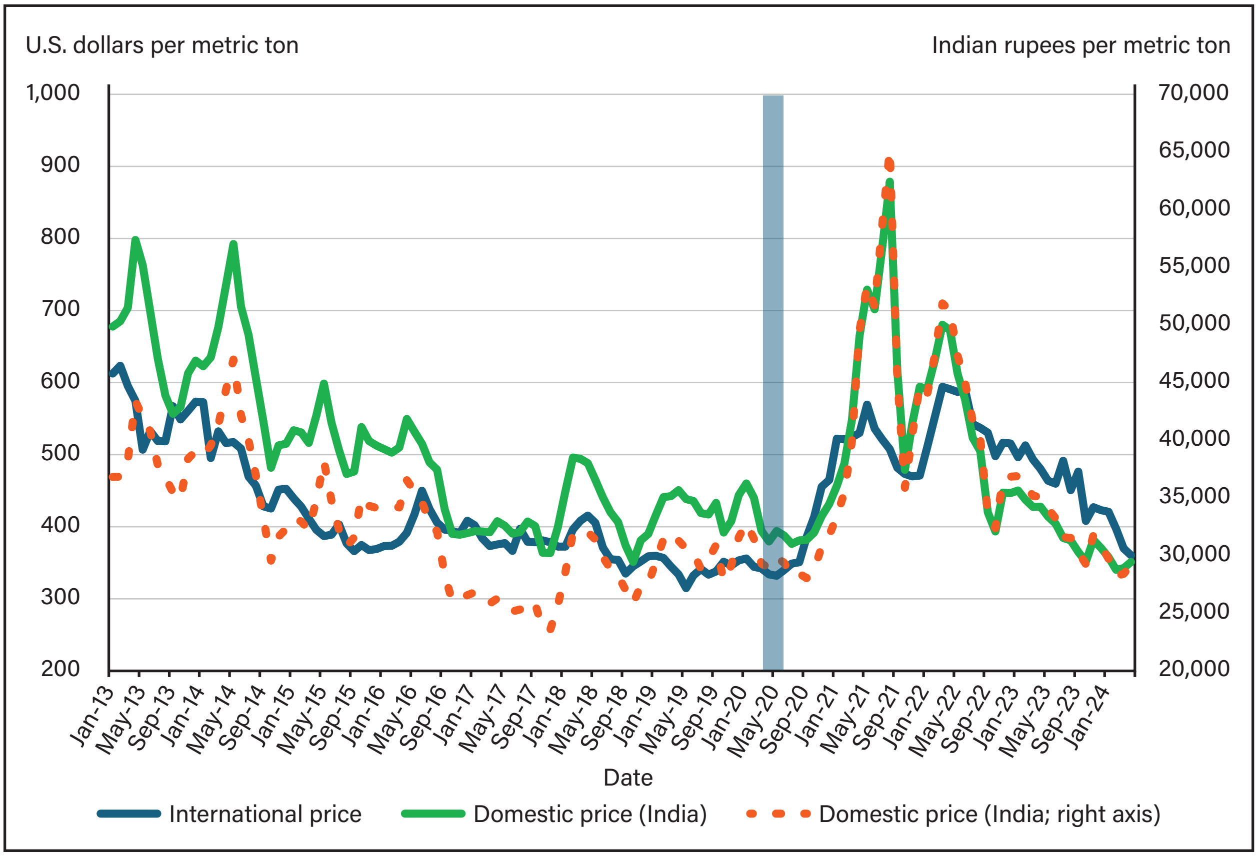
Figure 8
Global and India's domestic corn prices, 2013–24



Note: The vertical blue bar indicates the period of Coronavirus (COVID-19) pandemic lockdown in India (March 25, 2020–May 31, 2020). All prices in left axis are in real dollars.

Source: USDA, Economic Research Service using data from Food and Agriculture Organization of the United Nations, Food Price Monitoring Analysis Tool data; and Government of India's Directorate of Economics and Statistics, Ministry of Agriculture, Unified Portal for Agricultural Statistics.

Figure 9
Global and India's domestic soybean prices, 2013–24



Note: The vertical blue bar indicates the period of Coronavirus (COVID-19) pandemic in India (March 25, 2020–May 31, 2020). All prices on left axis are in real dollars.

Source: USDA, Economic Research Service using data from Food and Agriculture Organization of the United Nations, Food Price Monitoring Analysis Tool data; and Government of India's Directorate of Economics and Statistics, Ministry of Agriculture, Unified Portal for Agricultural Statistics.

For this study, we collected India's monthly domestic prices of rice, wheat, corn, and soybeans from the Government of India's Directorate of Economics and Statistics, Ministry of Agriculture's Unified Portal for Agricultural Statistics (UPAg). In addition, we collected monthly international prices, including Thailand's 25 percent broken rice prices, U.S. hard red winter wheat, U.S. No. 2 yellow free on board (FOB) U.S. Gulf soybean ports prices, and crude oil prices from the May 2024 World Bank Commodity Price Data (The Pink Sheet). We collected the monthly average real exchange rate values from the USDA, Economic Research Service Macroeconomics dataset. Summary statistics of the data used in our estimation are presented in table A.1.

Relationship Between India's Domestic Market and Global Market: Before and After Implementing New Food Policies

Our methodology follows the Law of One Price, which suggests that a homogenous commodity should have the same price across different markets, accounting for transportation and transaction costs (Baquedano & Leifert, 2014). However, government policies can distort this law. India's use of subsidies and export bans is expected to affect the relationship between international and domestic prices for major commodities like rice. Although export restrictions may aim to insulate domestic prices from international fluctuations, we expect the price transmission estimation to capture not just policy effects but also market efficiency.

Our initial step in this examination was to determine if the price series were stationary.[6] One of the major problems confronted in the time series model is nonstationary data series, which can lead to biased estimates (Kalkulh, 2016). We used both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests[7] to examine the stationarity of each price series. We presented the results of the ADF and PP unit root tests in tables A2 and A3, respectively. The ADF and PP results showed that most of the price series had the presence of a unit root at level, in other words, they had not exhibited constant mean and variance over the periods of the datasets. We examined two distinct time periods to identify any shifts in the relationship between prices before and after the implementation of new food policies in India following the COVID-19 pandemic.

To avoid the problem of spurious regression, we applied an autoregressive distributed lag (ARDL) time series model. The choice of the ARDL model enabled us to check for a short-term and long-term relationship between domestic and international commodity prices, even in the presence of a nonstationary time series (Kripfganz & Schneider, 2023). Model details are presented in the appendix.[8]

Continuous changes in policies across countries during the pandemic created possibilities for structural breaks in the price series relationship timeline. A structural break is when a time series' underlying pattern suddenly changes at a point in time. To test for a structural break, we applied the Wald test at specified dates (the test is also called the Chow test) to confirm if the two periods' covered estimates were significantly different from each other (StataCorp, 2023).

Relationship Between Global Rice and India's Domestic Rice Prices

Given that India is the world's largest rice exporter, we hypothesized that there is a long-term relationship between its domestic rice price and the global rice price, both before and after India implemented new food policies following the pandemic. Our results showed that India's rice price exhibited no long-term relationship with global rice prices after the implementation of new food policies, which is a shift from the prepandemic period when global and domestic rice prices demonstrated a long-term relationship (figure 10). For instance, a 10-percent change in the global rice price led to about a 2.6-percent change in India's rice price; however, the global rice price did not show a statistically significant effect on domestic retail rice prices in India after the implementation of new food policies (figure 10). To confirm if our estimates from the period before the pandemic lockdown and the period after the lockdown were different from each other, we conducted a structural break test on the ARDL model that is comprised of the whole period (January 2011–April 2024) before and after the implementation of new food policies using March 2020 (or the start of COVID-19 lockdown in India and expansion of food distribution programs) as the break date. The structural break test confirmed a structural break, which indicates that the relationship between India's domestic rice price and the global rice price changed after the outbreak of the COVID-19 pandemic.

Our results consistently showed that both India's domestic and global prices were trending towards long run equilibrium in both time periods. We reject the null hypothesis of no cointegration at the 5-percent significance level for both periods (table A9). Pesaran et al. (2001) bounds test for cointegration determined if two or more variables are integrated at the same order (i.e., moving towards equilibrium). The long-run relationship coefficient captured dependence between two variables, in other words, it captured a one-on-one relationship between the dependent variable and the independent variable. Two variables may be cointegrated without having a dependent relationship. In our case, we found that the shocks to global rice prices

[6] A stationary time series means that the series has constant mean and variance over time. A nonstationary time series means that the mean and variance is changing over time. We use unit root tests to test how much stationarity a time series model is over time.

[7] Augmented Dickey-Fuller and Phillips-Peron unit root tests check if data points in a time series change overtime in a predictable way, i.e. the tests check if the mean and variance of the data points are the same over time.

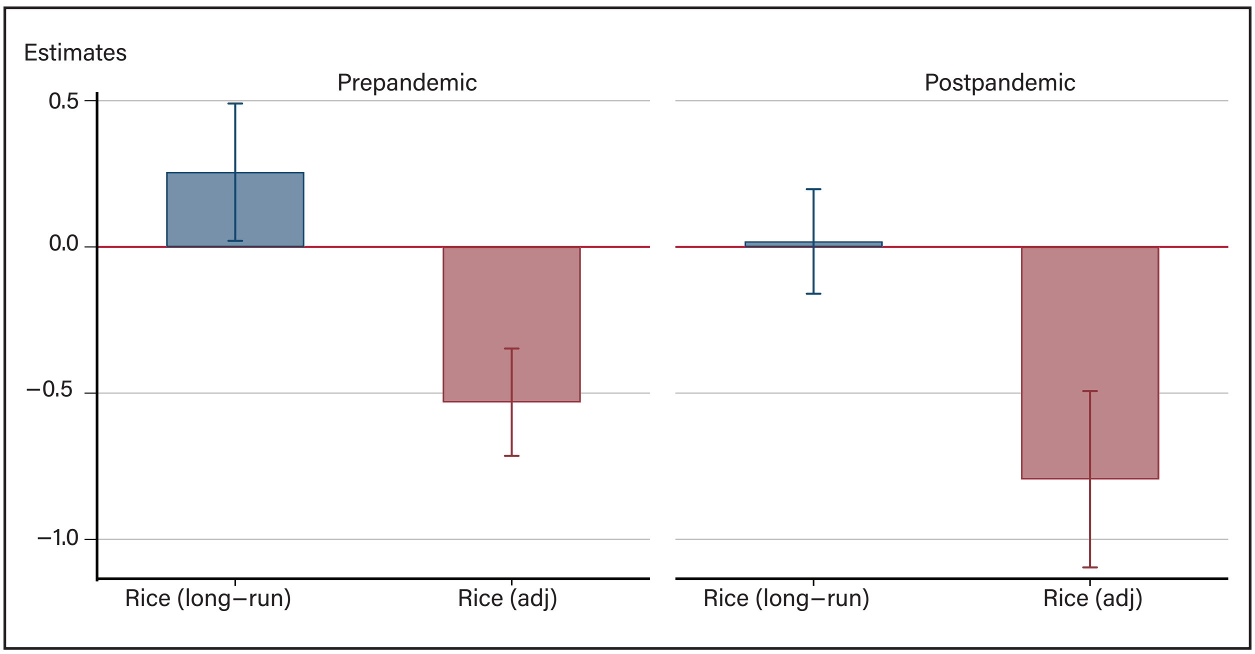
[8] In addition to testing for unit root, we tested for the existence of a long-run cointegration relationship between domestic and international prices of each commodity and tested for stability in our models (tables A.4–A.8).

were transmitted to India's domestic rice prices before the pandemic while we could not confirm shocks were transmitted after the implementation of new food policies in India following the COVID-19 pandemic. The speed of adjustment (ADJ)[9] coefficient towards the long-run equilibrium was significant at 1 percent for the prepandemic and postpandemic periods with negative ADJ coefficients of 0.53 and 0.79, respectively. Before India implemented new food policies following the COVID-19 pandemic, about 50 percent of domestic price deviation from the long-run equilibrium with global market price is corrected within a month, whereas after the COVID-19 pandemic about 80 percent is corrected within a month (figure 10). The changes to the long-run relationship in the post-COVID-19 period may be associated with the result of India's policies to shield the domestic market from global grain market price hikes. Since we could not capture all the government policies in our model, changes to the price transmission from global grain markets to the domestic grain market in India indicate changes to market efficiency.

Our results also indicated that the real exchange rate has had a significant effect on India's domestic price of rice, thereby influencing the dependency of the domestic price of rice in India on the international market price. While crude oil prices affected India's domestic rice prices before the COVID-19 pandemic (2013–19), our results showed that the crude oil price had no significant relationship with the domestic price of rice in India after the implementation of new food policies in India following the COVID-19 pandemic (table A.9). Postestimation diagnostics of our rice models showed that our models were stable and that they satisfied the necessary requirements for a time series model (tables A.13 and A.14; figures A.3 and A.4).

Figure 10

Price relationship model estimates between India's retail rice prices and global rice prices, prepandemic versus postpandemic



Adj = Speed-of-adjustment coefficient. Long-run = long-run coefficients. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Note: The long-run coefficient indicates the equilibrium effects of the international prices on domestic price in India. The speed-of-adjustment coefficient measures the speed of convergence towards long-run equilibrium, i.e. how strongly the domestic price in India corrects a deviation from long-run relationship with the international price within a single period.

Source: USDA, Economic Research Service estimate.

[9] The ADJ coefficient measures the strength of reaction of the dependent variable to a deviation from the long-run equilibrium with the independent variable.

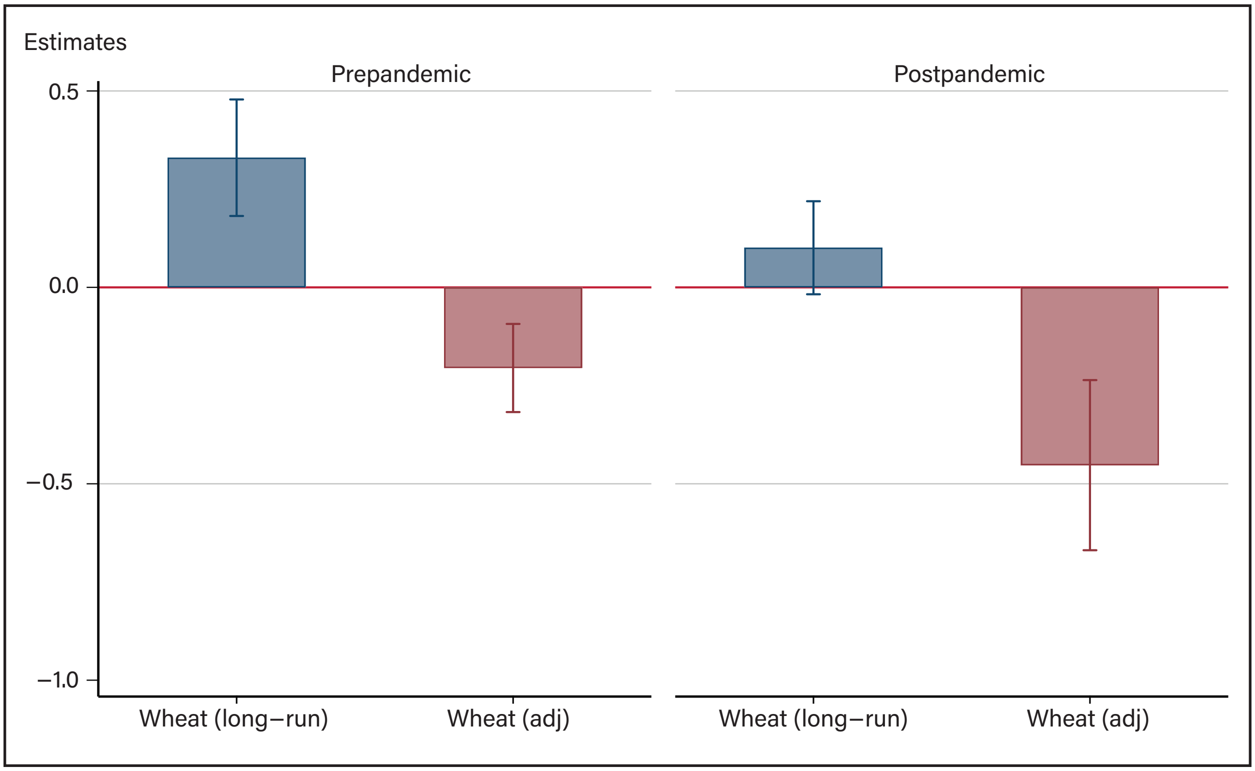
Relationship Between Global Wheat and India's Domestic Wheat Prices

Compared with the prepandemic period (January 2011–February 2020), there is a strong link between domestic wheat prices and international wheat prices after India implemented new food policies following the COVID-19 pandemic (figure 11). In other words, India's local wheat prices responded more to shocks in global wheat prices before the COVID-19 outbreak. We expected that domestic wheat prices in India would be less likely to be affected by global price changes because of India's small wheat trade volume in the global market. Using the 5-percent significance level, the long-run relationship between the domestic wheat price and international wheat price is only significant before the COVID-19 pandemic (figure 11). Before the pandemic, for instance, a 10-percent increase in global wheat and rice prices led to a 3.3-percent increase in domestic price of wheat in India. The level of transmission from global prices to India's domestic market prices was reduced after the COVID-19 outbreak. For instance, a 10-percent increase in global wheat price led to only a 1-percent increase in the domestic price of wheat in India at a 10-percent significance level.

The speed of adjustment coefficients increased during the implementation of new food policies in India following the COVID-19 pandemic period, which indicated that domestic wheat prices adjusted back to equilibrium more quickly (figure 11). In the post-COVID-19 period, about 45 percent of the short-term deviation from equilibrium was corrected during the first month, while only about 21 percent of deviation from equilibrium was corrected during first month in the pre-COVID-19 era. While India is currently the second-largest producer of wheat in the world with more than 110 million metric tons of wheat expected to be produced in the 2023–24 season (USDA, 2024a), India trades only a small amount of wheat so it is less integrated into the global wheat market than the global rice market. Our structural break test also indicated a statistically significant difference between estimates from the pre-COVID-19 period to estimates from the period after the implementation of new food policies in India following the COVID-19 pandemic.

Our results indicated that India's domestic wheat prices were partially protected from global wheat price shocks after the COVID-19 pandemic because India has not been very active in the global market, as it has produced enough to cover most of its domestic consumption. During the COVID-19 pandemic, India's government aimed to protect domestic retail wheat prices from a surge in global prices by subsidizing the consumption of wheat to its vulnerable citizens. The Government of India also introduced a wheat export ban in 2022 to protect the domestic price from a surge in global prices (USDA, 2022a). Exchange rates and crude oil prices were not statistically significant in our analysis of wheat prices (table A.10). Postestimation diagnostics of our wheat models satisfied the stability and necessary requirements for a time series model (tables A.15 and A.16; figures A.5 and A.6).

Figure 11
Price relationship model estimates between India's retail wheat prices and global wheat prices, prepandemic versus postpandemic



Adj = Speed-of-adjustment coefficient. Long-run = long-run coefficients. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Note: The long-run coefficient indicates the equilibrium effects of the international prices on domestic price in India. The speed-of-adjustment coefficient measures the speed of convergence towards long-run equilibrium, i.e. how strongly the domestic price in India corrects a deviation from long-run relationship with the international price within a single period.

Source: USDA, Economic Research Service estimate.

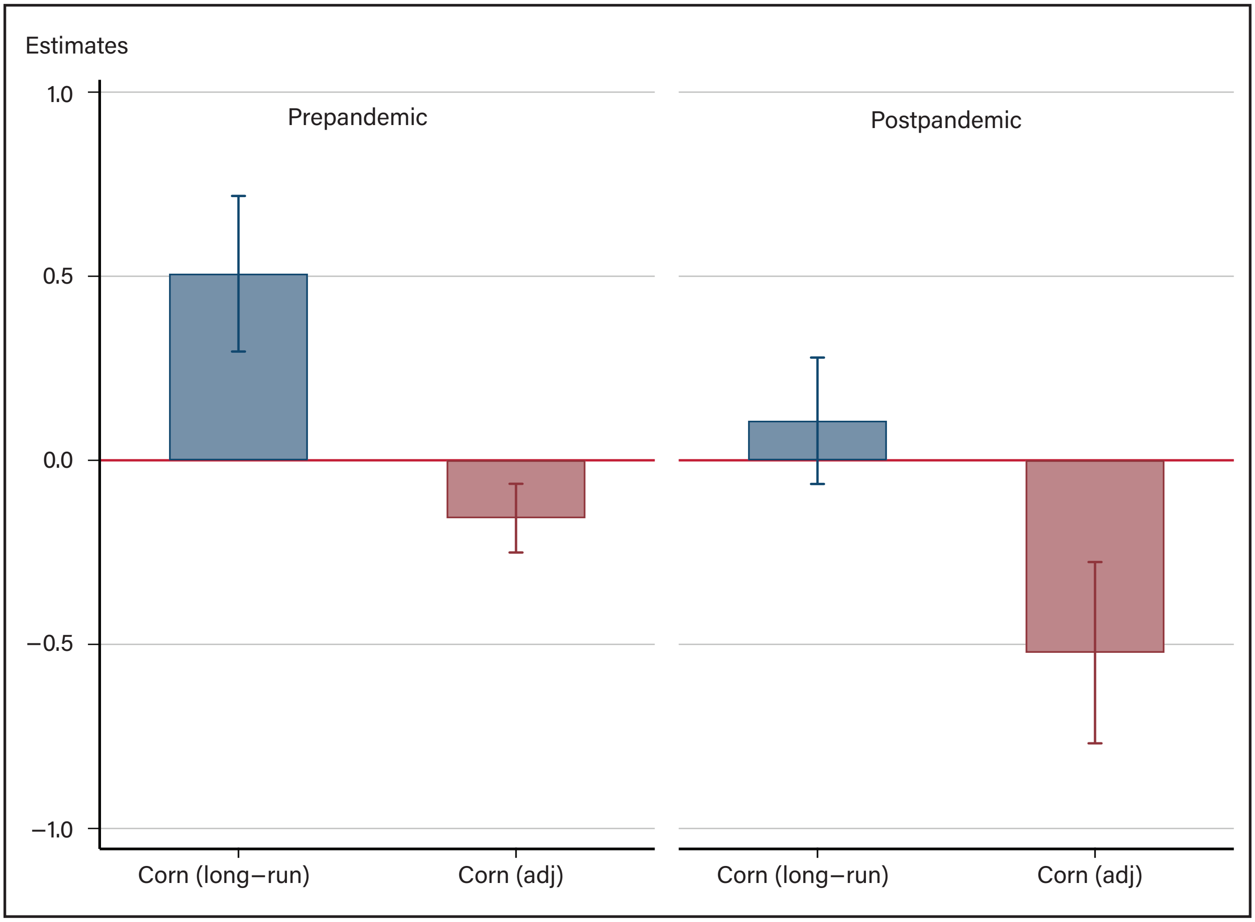
Relationship Between Global Corn and India's Domestic Corn Prices

We found a significant shift in the long-run relationship between international and India's domestic corn prices from the pre-COVID-19 pandemic period (2013–2019) to India's implementation of new food policies following the COVID-19 pandemic period (2020–2024). Since only a very small percentage of India's corn production is traded internationally (USDA, 2024b), we hypothesized that the country's domestic corn market is resistant to shocks to global corn prices. There is no significant price transmission from international corn prices to India's retail corn prices after the pandemic, a change from the prepandemic period where about 50 percent of a shock in global corn prices was transmitted to domestic corn prices in India (figure 12). That is, a 10-percent increase in the global corn price led to about a 5-percent increase in the domestic price of corn in India in the prepandemic era (table A.11). A structural break test further confirmed the change in the price relationship between global corn market prices and India's domestic corn markets starting from the COVID-19 lockdown period.

India's corn production has been steadily increasing in the last 5 years. By 2020, India ranked as the world's seventh-largest corn producer (Indian Institute of Corn Research (ICAR), 2020). Corn is a source of food for both humans and animals. More than half of the corn produced in India goes towards feeding poultry and cattle. In the last few years, India has produced more corn than is consumed domestically so it has become a net exporter of corn. Several factors could influence the relationship between global corn prices and India's domestic corn prices. For instance, since corn has often been used in combination with other ingredients, its price could be affected by the complementary or substitution effects of other feed or food items. Although the exchange rate showed no association with the domestic price of corn, our initial analysis showed that crude oil prices have significantly affected the price of corn in India, but only during India's implementation of new food policies following the COVID-19 pandemic period (table A.11). During the postpandemic period, a larger proportion of the deviation from equilibrium was corrected in the first month compared to the prepandemic period, which was similar to our rice and wheat findings. Postestimation diagnostics satisfied stability and the necessary requirements for a time series model (tables A.17 and A.18; figures A.7 and A.8).

Figure 12

Price relationship model estimates between India's retail corn prices and global corn prices, prepandemic versus postpandemic



Adj = Speed-of-adjustment coefficient. Long-run = long-run coefficients. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Note: The long-run coefficient indicates the equilibrium effects of the international prices on domestic price in India. The speed-of-adjustment coefficient measures the speed of convergence towards long-run equilibrium, i.e. how strongly the domestic price in India corrects a deviation from long-run relationship with the international price within a single period.

Source: USDA, Economic Research Service estimates.

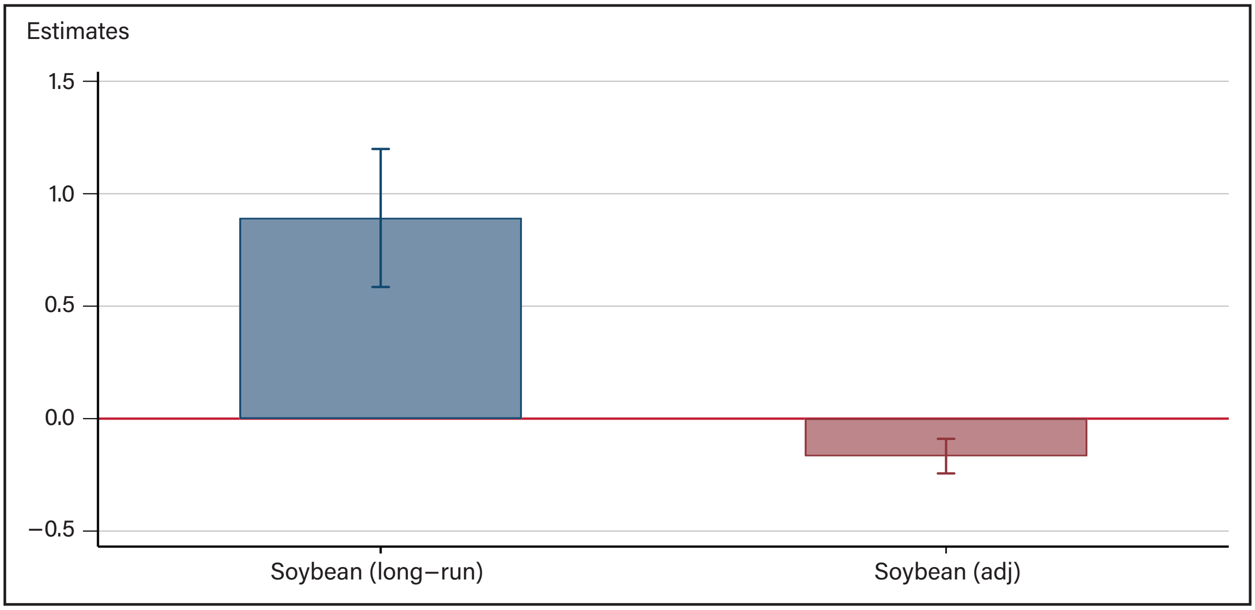
Relationship Between Global Soybean and India's Domestic Soybean Prices

Soybeans were the only commodity among the four in our study that demonstrated a more pronounced transmission of price fluctuations from the international soybean price to the domestic soybean price after the COVID-19 pandemic (figure 13).

A structural break test showed that there is no significant difference between estimates before versus estimates after implementation of India's new food policies following the COVID-19 pandemic period (table A.8). Furthermore, we also estimated the two periods of before and after COVID-19 to show similarities in the price transmission coefficients (figure 14). With no statistically significant difference between the two periods' results, our discussion has been focused on price transmission estimates across the whole period. The results confirmed our hypothesis that there was no change in the relationship between Indian domestic soybean prices and global soybean prices before and after India introduced new food policies. The long-run coefficient shows that during the whole period, about 90 percent of shocks from global soybean prices was transmitted to the domestic price of soybeans in India (figure 13). The long-run coefficients also show that a 10-percent increase in the international soybean price led to about a 9-percent increase in India's domestic soybean price. We present the estimate from prepandemic and postpandemic periods to show the similarities for the estimates between the two periods (figure 14). We did not find any statistically significant difference between the two periods' estimates for soybeans.

The exchange rate also indicated a significant effect on the domestic soybean price during the whole period (2013–24) (table A.12). The significance of the exchange rate illustrates the importance of trade in price discovery because an increased rupee-to-dollar exchange rate makes India's soybean market cheaper compared with international prices. While restrictive trade policies were introduced after the COVID-19 pandemic, the surge of domestic livestock feed prices in India can encourage imports expansion for soybean products. For instance, between 2020 and 2022, India's Government introduced a policy that allowed the importation of soybean meal produced using genetically engineered soybeans, which were previously banned. This deepened India's presence in the global market for soybean products which likely contributed to India's domestic price of soybeans becoming more susceptible to global price fluctuations. Although chicken demand has been growing in India as average income has grown, an inadequate supply of domestic feed ingredients and trade restrictions could limit supply and create an obstacle to animal protein consumption in India. Our postestimation diagnostics satisfied stability and the necessary requirements for a time series model (tables A.19–A.21, figures A.9–A.11).

Figure 13
Price relationship model estimates between India's retail soybean prices and global soybean prices, 2013–2024

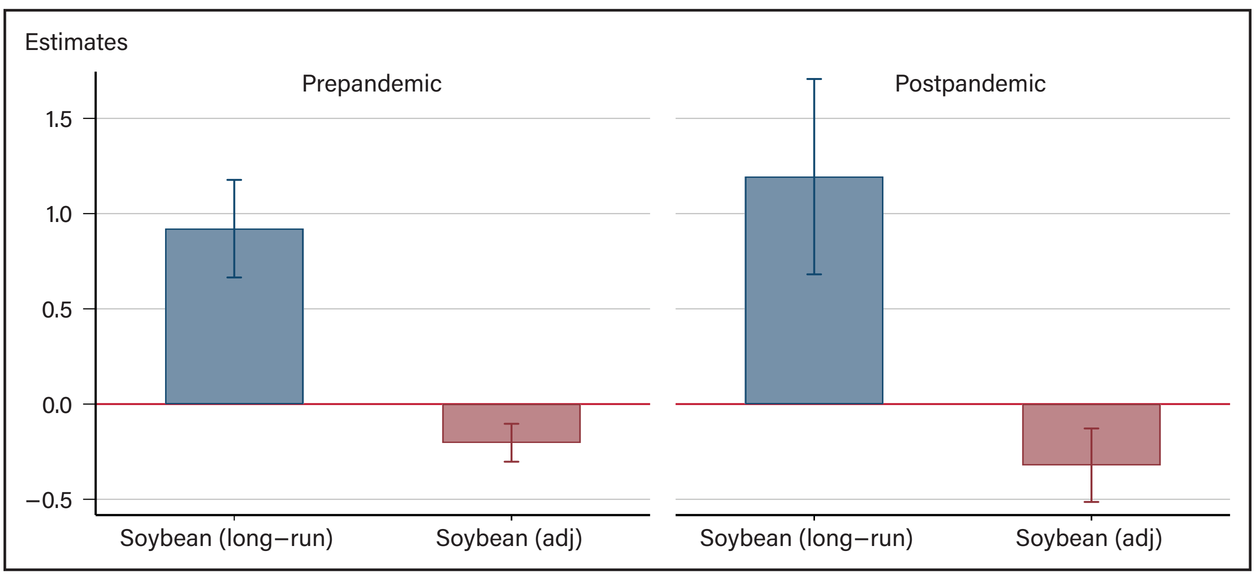


Adj = Speed-of-adjustment coefficient. Long-run = long-run coefficients.

Note: The long-run coefficient indicates the equilibrium effects of the international prices on domestic price in India. The speed-of-adjustment coefficient measures the speed of convergence towards long-run equilibrium, i.e. how strongly the domestic price in India corrects a deviation from long-run relationship with the international price within a single period.

Source: USDA, Economic Research Service estimates.

Figure 14
Price relationship model estimates between India's retail soybean prices and global soybean prices, prepandemic, January 2011–February 2020, versus postpandemic, May 2020–April 2024



Adj = Speed-of-adjustment coefficient. Long-run = long-run coefficients. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Note: The long-run coefficient indicates the equilibrium effects of the international prices on domestic price in India. The speed-of-adjustment coefficient measures the speed of convergence towards long-run equilibrium, i.e. how strongly the domestic price in India corrects a deviation from long-run relationship with the international price within a single period.

Source: USDA, Economic Research Service estimates.

Conclusion

India's Government has several domestic and international trade policies in place to reduce the effect of shocks from global commodity markets on India's domestic markets. India's restrictive trade policies were aimed at shielding India's population from global price hikes, but they have also restricted agricultural trade from one of the world's largest food providers which can exacerbate global food inflation and food insecurity. In this study, we examined whether the prices of staple cereals and oilseeds in the Indian market have become somewhat interconnected with global grain market prices before and after India implemented new food policies following the Coronavirus (COVID-19) pandemic.

The study found that domestic prices of rice, wheat, corn, and soybeans mostly moved towards long-run equilibrium with global prices. Our results showed that rice, wheat, corn, and soybean prices in India indicated significant long-run dependency on global prices before the COVID-19 pandemic. However, except for soybeans, the long-run dependency became statistically insignificant after India implemented new food policies after the COVID-19 pandemic. After India implemented new food policies, India's soybean retail prices continued showing a strong dependency on global prices (U.S. No. 2 soybean prices were used in this study). The integration of domestic and global soybean markets has been associated with the record-high soybean prices in India's domestic market, which was the same period (2021) global prices surged to the highest price in almost a decade. Market and trade policies put in place by the Government of India during the pandemic period (2020–2024) affected the dependency of domestic rice, wheat, and corn markets on the global market for price discovery in India. These policies aimed to insulate India's retail market for rice, wheat, and corn from global price shocks. With expanded trade policies on soybean products after the COVID-19 lockdown period, domestic shocks from global soybean prices continued to be transmitted to India's domestic soybean prices.

India's commodities that are more traded (rice and soybeans) had a higher influence from exchange rates than those that are less traded (wheat and corn). For instance, exchange rates showed a statistically significant relationship with India's rice market before and after the pandemic, while exchange rates continued influencing the soybean market after India implemented new food policies following the COVID-19 pandemic (a period of record-high imports of soybean meal for India). India's position as a major rice exporter creates a link between global rice export prices and domestic prices in India. This link allows for the transmission of market shocks to and from the international market and domestic rice market in India. Additionally, rising global rice prices incentivized India to export more rice in the global market. A weaker rupee-to-U.S. dollar exchange rate further strengthened the demand for India's traded commodities in the global market. The domestic wheat prices in India were not significantly influenced by exchange rate fluctuations because India minimally participates in the global wheat market.

One limitation of our study is that we have limited data for the post-COVID-19 analysis. Little time has elapsed since the pandemic, and researchers may need to revisit these questions. The price relationship between the domestic markets in India and global markets has the potential to change as government policies change. For instance, future changes in the Government of India's policies on domestic price supports and trade may create market distortions, thereby creating changes in the long-run and short-run relationships between domestic and global markets.

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Appendix

Model Description and Estimation

Model Specification: We assumed that two prices of a commodity, *X* and *Y*, have an equilibrious relationship where the current value of price *Y* has an underlying relationship with the current value and/or lag value of price *X*, or vice versa. In addition, the past value of price *Y* may also have an underlying influence on the current value of price *Y*. The relationship between *X* and *Y* can be represented as:

$$Y_t = \beta X_{t-i} + \epsilon_t \qquad \epsilon_t \sim N(0, \Sigma) \tag{1}$$

Estimating the above equation through simple linear regression, such as ordinary least squares (OLS), can generate a spurious regression if the two time-series are correlated but have no causal relationship between them them (i.e., regression of x_t on y_t comes out significant even when one does not influence the other) (Kripfganz & Schneider, 2023). To reduce the chances of spurious regression, we applied an autoregressive distributed lag (ARDL) model. In addition, ARDL enabled us to disentangle the long-run equilibrium relationship (cointegration) from the short-run dynamics (Kripfganz & Schneider, 2023). Some of the advantages of the ARDL model include: (1) one does not need to know the underlying order of integrated variable; (2) the ARDL procedure assumes only a single reduced form relationship exists between two variables; (3) ARDL models can be extended into error correction models (ECM) to report both long-run and short-run relationships; and (4) ARDL solves the endogeneity problem common in the traditional Engel-Granger method (Kim et al., 2020; Kripfganz & Schneider, 2023; Nkoro & Uko, 2016; Wang et al., 2021). Representing domestic prices in India at time *t* as y_t and international prices as x_t, the basic ARDL (*p, q, . . ., q*) model representation of the bivariate relationship between domestic and international prices is described by the following equation:

$$y_t = c_0 + c_1 t + \sum_{i=1}^{p} \emptyset_i y_{t-i} + \sum_{i=0}^{q} \beta_i x_{t-i} + \gamma_1 ex_t + \gamma_2 cr_t + \mu_t \tag{2}$$

Where y_t and x_t are the vectors of domestic and international commodity prices, $t = \max(p,q)$, $p \geq 1$ *and* $q \geq 0$ are the optimal lag order, $c_1 t$ is the linear trend, ex_t represents real exchange rate, cr_t is the average monthly crude oil prices, and μ_t is the error term (Kripfganz & Schneider, 2023). Exchange rate and crude oil prices are exogenous variables in our model. These variables were only included when they are significant. To determine the existence of a long-run relationship between domestic prices in India and international prices, ARDL enabled us to extend equation (2) above to an error correction representation without full information about the cointegration relationship between nonstationary variables (Kim et al., 2020; Kripfganz & Schneider, 2023). We followed Kripfganz and Schneider (2023) to estimate equation (2), and the error correction representation as follow:

$$\Delta y_t = c_0 + c_1 t - \alpha(y_{t-1} - \theta x_{t-1}) + \sum_{i=1}^{p-1} \psi_{y_i} \Delta y_i + w' \Delta x_t + \sum_{i=1}^{q-1} \psi_{x_i} \Delta x_i + \gamma_1 ex_t + \gamma_2 cr_t + \mu_t \tag{3}$$

Where the speed-of-adjustment coefficient $\alpha = \left(1 - \sum_{i=1}^{p} \Phi_i\right)$, the long-run coefficient $\theta = \left(\frac{\Sigma_{j=0}^{q} \beta_j}{\alpha}\right)$, and the short-run coefficient $\psi_{x_i} = -\sum_{j=i+1}^{q} \beta_j$. The speed-of-adjustment coefficient indicates how fast domestic price y_t reverts to its long-run relationship when distorted from equilibrium (Kripfganz & Schneider, 2023). When $\theta \neq 0$ it is confirmed that there exists a long-run relationship between domestic price y_t and international price x_t. We estimated the models in STATA 17, using the "ARDL" procedure by Kripfganz and Schneider (2023). Optimal lags *p and q* are determined using the Akaike information criterion (AIC). For the sake of our analyses, we controlled for the possible effects of exchange rates and the price of crude oil on India's domestic markets, which were expected to affect prices' connectedness between the domestic market and international markets. Monthly domestic retail prices of the four commodities were converted from the local currency (rupees) to real prices in U.S. dollars using average month exchange rates and consumer price index. Similarly, we used monthly consumer prices index of the referenced country to convert the international prices to real prices in U.S. dollars.

Table A.1

Summary statistics of prices and rupee-U.S.-dollar exchange rate

Variable	Unit	Obs.	Mean	Std. dev.	Minimum	Maximum
Corn India	US$/mt	160	203.34	49.90	130.05	355.48
Rice India	US$/mt	160	282.04	63.77	189.44	454.39
Wheat India	US$/mt	160	246.61	49.49	180.49	409.98
Soybeans India	US$/mt	160	523.66	132.46	340.29	910.82
Corn international	US$/mt	160	205.81	60.83	133.03	344.56
Rice international	US$/mt	160	439.29	70.68	340.86	614.23
Wheat international	US$/mt	160	251.51	68.38	139.24	423.51
Soybeans international	US$/mt	160	460.46	93.82	314.50	703.73
Real exchange rate	Rupees/US$	160	65.23	3.31	57.34	73.01
Crude oil prices	US$/Barrel	160	70.96	25.57	19.45	122.50

US$/mt = U.S. dollars per metric ton. Obs. = Observations. Std. dev. = Standard deviation.

Note: All prices are in converted to real prices using consumer price index for each market.

Source: USDA, Economic Research Service.

Table A.2

Augmented Dickey-Fuller unit root test of price series

	Prepandemic		Postpandemic	
Variable	Level prices	1st differenced	Level prices	1st differenced
Rice India	-3.154*	-5.986***	-3.271*	-5.383***
Wheat India	-3.107	-5.315***	-3.282*	-3.031
Corn India	-2.609	-4.758***	-2.578	-3.385**
Soybean India	-3.399*	-5.548***	-1.855	-3.533**
International rice	-1.505	-4.721***	-1.838	-3.758**
International wheat	-1.576	-5.045***	-0.162	-3.664**
International corn	-1.538	-5.754***	-1.209	-3.789**
International soybean	-2.248	-5.559***	-1.327	-3.593**
Real exchange rate	-3.039	-5.288***	-3.148	-3.009
Oil price	-1.582	-4.791***	-1.842	-7.664***
Obs.	105	104	48	48

Obs. = Observations. * = 10 percent statistical level of significance. ** = 5 percent statistical level of significance. *** = 1 percent statistical level of significance. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Note: First differenced indicates difference between each data point and the previous one. Level is the original data points at each period.

Source: USDA, Economic Research Service.

Table A.3

Phillips–Perron unit root test of price series

	Prepandemic		Postpandemic	
Variable	Level prices	1st differenced	Level prices	1st differenced
Rice India	-4.391***	-10.92***	-5.608***	-11.154***
Wheat India	-3.475**	-11.263***	-2.821	-5.321***
Corn India	-2.276	-8.227***	-2.207	-5.993***
Soybean India	-3.206*	-7.107***	-1.847	-5.022***
International rice	-1.523	-7.110***	-1.809	-6.838***
International wheat	-1.617	-9.495***	-0.672	-5.818***
International corn	-1.845	-9.003***	-1.068	-5.696***
International soybean	-2.647	-9.502***	-1.224	-7.491***
Real exchange rate	-3.430*	-8.853***	-2.373	-7.174***
Oil price	-1.819	-7.350***	-3.693**	-8.894***
Observations	105	104	48	48

Obs. = Observations. * = 10 percent statistical level of significance. ** = 5 percent statistical level of significance. *** = 1 percent statistical level of significance. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Note: First differenced indicates difference between each data point and the previous one. Level is the original data points at each time period.

Source: USDA, Economic Research Service estimates.

Table A.4

Pesaran et al. (2001) bounds test for the existence of a long-run cointegration relationship between the international rice price and India's domestic price

Prepandemic		F-statistics = 16.597		T-statistics = -5.74		
	Critical values	Lower bound I(0)	Upper bound I(1)	Lower bound I(0)	Upper bound I(1)	H0=No long-run relationship
	1 percent	7.056	8.049	-3.467	-3.855	Rejected
	5 percent	4.979	5.827	-2.871	-3.238	Rejected
	10 percent	4.06	4.831	-2.565	-2.918	Rejected
Postpandemic		F-statistics = 14.546		T-statistics = -5.393		
	Critical values	Lower bound I(0)	Upper bound I (1)	Lower bound I(0)	Upper bound I (1)	H0=No long-run relationship
	1 percent	7.455	8.555	-3.551	-3.953	Rejected
	5 percent	5.130	6.036	-2.901	-3.279	Rejected
	10 percent	4.136	4.944	-2.575	-2.937	Rejected

Note: H0 = Null hypothesis of no long-run relationship. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024). See Pesaran et al. (2001) for more details about the bounds test and statistics.

Source: USDA, Economic Research Service estimates.

Table A.5

Pesaran et al. (2001) bounds test for the existence of a long-run cointegration relationship between the international wheat price and India's domestic price

Prepandemic		F-statistics = 6.851		T-statistics = -3.628		
	Critical values	Lower bound I (0)	Upper bound I (1)	Lower bound I (0)	Upper bound I (1)	H0=No long-run relationship
	1 percent	7.087	8.046	-3.474	-3.867	Rejected
	5 percent	5.010	5.837	-2.881	-3.254	Rejected
	10 percent	4.090	4.842	-2.577	-2.936	No rejection
Postpandemic		F-statistics = 9.560		T-statistics = -4.220		
	Critical values	Lower Bound I(0)	Upper Bound I(1)	Lower Bound I(0)	Upper Bound I(1)	H0=No long-run relationship
	1 percent	7.443	8.577	-3.549	-3.952	Rejected
	5 percent	5.113	6.038	-2.894	-3.272	Rejected
	10 percent	4.119	4.941	-2.567	-2.928	Rejected

Note: H0 = Null hypothesis of no long-run relationship. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024). See Pesaran et al. (2001) for more details about the bounds test and statistics.

Source: USDA, Economic Research Service estimates.

Table A.6

Pesaran et al. (2001) bounds test for the existence of a long-run cointegration relationship between the international corn price and India's domestic price

Prepandemic		F-statistics = 5.940		T-statistics = -3.341		
	Critical values	Lower bound I(0)	Upper bound I(1)	Lower bound I(0)	Upper bound I(1)	H0=No long-run relationship
	1 percent	7.046	8.050	-3.465	-3.851	No rejection
	5 percent	4.968	5.824	-2.867	-3.233	Rejected
	10 percent	4.051	4.827	-2.561	-2.912	Rejected
Postpandemic		F-statistics = 9.461		T-statistics = -4.286		
	Critical values	Lower bound I(0)	Upper bound I(1)	Lower bound I(0)	Upper bound I(1)	H0=No long-run relationship
	1 percent	7.443	8.577	-3.549	-3.952	Rejected
	5 percent	5.113	6.038	-2.894	-3.272	Rejected
	10 percent	4.119	4.941	-2.567	-2.928	Rejected

Note: H0 = Null hypothesis of no long-run relationship. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024). See Pesaran et al. (2001) for more details about the bounds test and statistics.

Source: USDA, Economic Research Service estimates.

Table A.7

Pesaran et al. (2001) bounds test for the existence of a long-run cointegration relationship between the international soybean price and India's domestic price

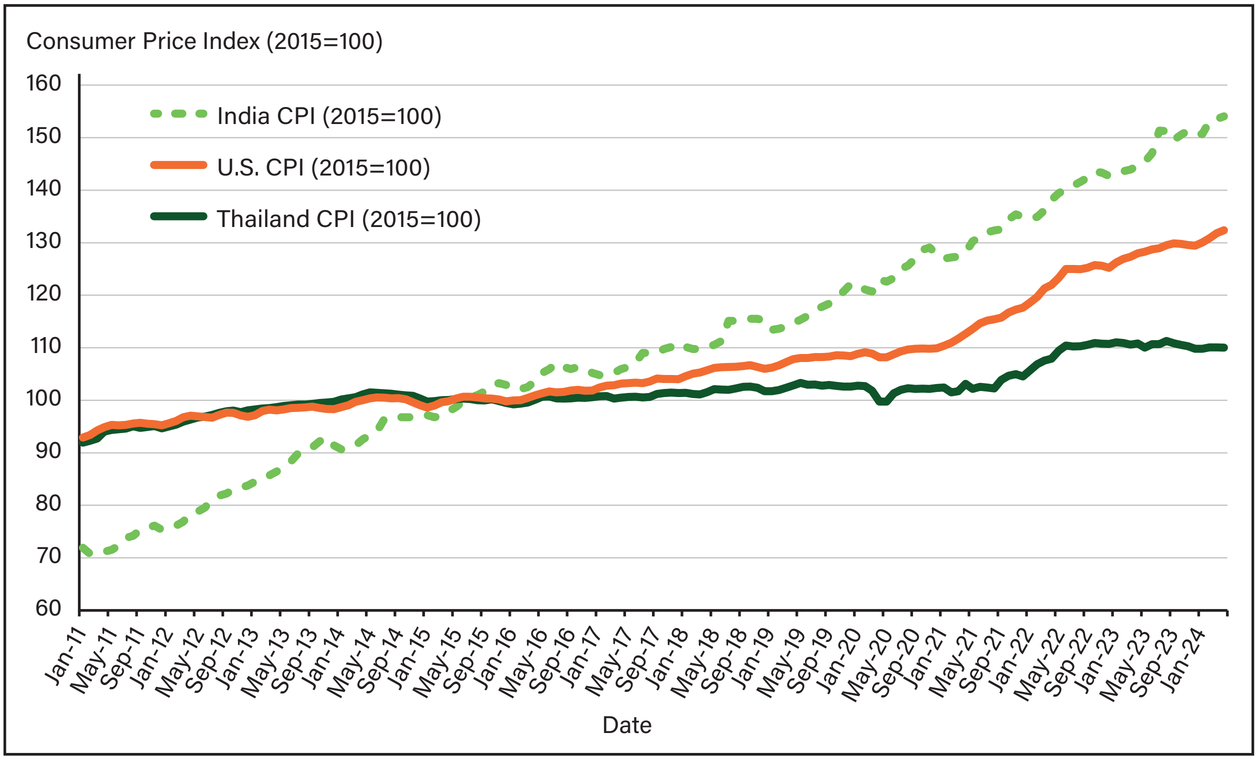
Prepandemic		F-statistics = 8.242		T-statistics = -4.047		
	Critical values	Lower bound I(0)	Upper bound I(1)	Lower bound I(0)	Upper bound I(1)	H0=No long-run relationship
	1 percent	7.067	8.048	-3.469	-3.859	Rejected
	5 percent	4.989	5.830	-2.874	-3.244	Rejected
	10 percent	4.070	4.834	-2.569	-2.924	Rejected
Postpandemic		**F-statistics = 5.686**		**T-statistics = -3.372**		
	Critical values	Lower bound I(0)	Upper bound I(1)	Lower bound I(0)	Upper bound I(1)	H0=No long-run relationship
	1 percent	7.397	8.665	-3.543	-3.948	No rejection
	5 percent	5.042	6.048	-2.868	-3.247	Inconclusive
	10 percent	4.047	4.929	-2.533	-2.894	Rejection

Note: H0 = Null hypothesis of no long-run relationship. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024). See Pesaran et al. (2001) for more details about the bounds test and statistics.

Source: USDA, Economic Research Service estimates.

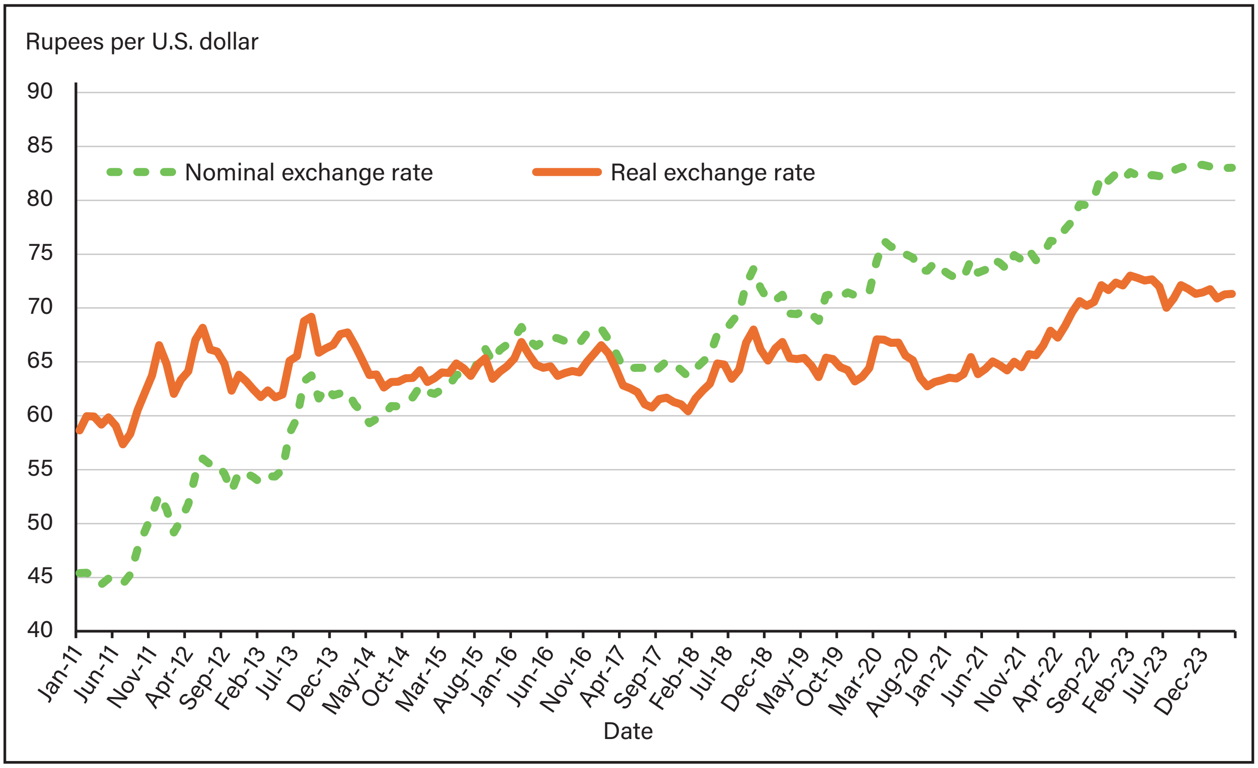
Figure A.1

Consumer Price Index (CPI) for India, Thailand, and the United States, 2011–23 (2015 = 100)



Source: USDA, Economic Research Service calculation using Food and Agriculture Organization of the United Nations data.

Figure A.2
Nominal and real exchange rates, India's rupees per U.S. dollar, 2011–23



Note: Nominal exchange rate is the rate at which a domestic currency (Indian rupees) exchanges for one unit of foreign currency (U.S. dollars). The real exchange rate is the relative price of goods and services between countries (India and U.S. in this chart).

Source: USDA, Economic Research Service (ERS) calculations using USDA, ERS, International Macroeconomic Data Set.

Table A.8
Wald test for structural break, known break date March 2020

	Chi2	Prob > Chi2
Rice	15.869	0.015
Wheat	23.793	0.000
Corn	29.432	0.000
Soybeans	10.118	0.182

Chi2 = Chi-Squared test statistics. Prob > Chi2 = p-value of Chi2.

Note: The Chi2 test the null hypothesis of no structural break. Prob > Chi2 determines the significant level of rejecting the null hypothesis. Null hypothesis is rejected at p-value less than or equal to 0.05.

Source: USDA, Economic Research Service estimates.

Table A.9

Autoregressive distributed lag error correction model for domestic and international rice prices

	Rice	
	Prepandemic	Postpandemic
Long-run adjustment coefficients		
Rice (first lag)	-0.531***	-0.794***
	(0.092)	(0.149)
Long-run coefficients		
International rice	0.255**	-0.019
	(0.118)	(0.089)
Short-run coefficients		
Rice (first lag difference)	0.221**	
	(0.097)	
Real exchange rate	-0.576**	-0.325*
	(0.252)	(0.186)
Crude oil	0.141***	
	(0.039)	
Constant	4.011***	5.557***
	(1.301)	(1.347)
R-Squared	0.252	0.396
Observations	106	47

Note: All prices are in natural log form. The dependent variable is the first difference of level price; ADJ is the long-run adjustment coefficient, LR represents long-run coeiffcients, and SR represents shortrun coeiffcients. Standard errors are communicated in parenthesis. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024). * = 10 percent statistical level of significance. ** = 5 percent statistical level of significance. *** = 1 percent statistical level of significance. Nonsignificant exogenous variables from initial estimates were dropped in the models to increase the degree of freedom.

Source: USDA, Economic Research Service estimates.

Table A.10

Autoregressive distributed lag error correction model for domestic and international wheat prices

	Wheat	
	Prepandemic	Postpandemic
Long-run adjustment coefficients		
Wheat (first lag)	-0.205***	-0.453***
	(0.057)	(0.107)
Long-run coefficients		
International wheat	0.330***	0.101*
	(0.075)	(0.059)
Short-run coefficients		
Wheat (first lag difference)		0.416***
		(0.135)
International wheat (first difference)		0.052
		(0.074)
International wheat (first lag difference)		-0.173**
		(0.075)
Constant	0.772**	2.131***
	(0.214)	(0.563)
R-Squared	0.117	0.388
Observations	106	47

Note: All prices are in natural log form. The dependent variable is the first difference of level price; ADJ is the long-run adjustment coefficient, LR represents long-run coeiffcients, and SR represents short-run coeiffcients. Standard errors are communicated in parenthesis. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024). * = 10 percent statistical level of significance. ** = 5 percent statistical level of significance. *** = 1 percent statistical level of significance. Nonsignificant exogenous variables from initial estimates were dropped in the models to increase the degree of freedom.

Source: USDA, Economic Research Service estimates.

Table A.11

Autoregressive distributed lag error correction model for domestic and international corn prices

	Corn	
	Prepandemic	Postpandemic
Long-run adjustment coefficients		
Corn (first lag)	-0.157***	-0.523***
	(0.047)	(0.122)
Long-run coefficients		
International corn	0.507***	0.107
	(0.107)	(0.085)
Short-run coefficients		
Corn (first lag difference)	0.175*	0.320**
	(0.093)	(0.131)
International corn (first difference)	0.134	-0.282**
	(0.095)	(0.113)
International corn (first lag difference)	0.008	
	(0.094)	
International corn (second lag difference)	0.241**	
	(0.092)	
Crude oil		0.126**
		(0.059)
Constant	0.424***	1.834***
	(0.136)	(0.452)
R-Squared	0.236	0.370
Observations	106	47

Note: All prices are in natural log form. The dependent variable is the first difference of level price; ADJ is the long-run adjustment coefficient, LR represents long-run coefficients, and SR represents short-run coefficients. Standard errors are communicated in parenthesis. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024). * = 10 percent statistical level of significance. ** = 5 percent statistical level of significance. *** = 1 percent statistical level of significance. Nonsignificant exogenous variables from initial estimates were dropped in the models to increase the degree of freedom.

Source: USDA, Economic Research Service estimates.

Table A.12

Autoregressive distributed lag (ARDL) error correction model for domestic and international soybean prices

	Soybeans		
	All period	Prepandemic	Postpandemic
Long-run adjustment coefficients			
Soybeans (first lag)	-0.167***	-0.203***	-0.321***
	(0.039)	(0.050)	(0.095)
Long-run coefficients			
International soybeans	0.892***	0.921***	1.194***
	(0.155)	(0.129)	(0.253)
Short-run coefficients			
Soybeans (first lag difference)	0.434***	0.368***	0.593***
	(0.075)	(0.087)	(0.159)
Soybeans (second lag difference)	-0.286***		-0.429**
	(0.077)		(0.162)
Soybeans (third lag difference)	0.209***		0.372**
	(0.074)		(0.153)
International soybeans (first difference)	0.291***	0.241*	-0.280
	(0.117)	(0.135)	(0.317)
Real exchange rate	-0.284**		-1.070***
	(0.119)		(0.390)
Constant	1.314	0.132	4.131**
	(0.525)	(0.161)	(1.574)
R-Squared	0.347	0.301	0.510
Observations	156	106	47

Note: All prices are in natural log form. The dependent variable is the first difference of level price; ADJ is the long-run adjustment coefficient, LR represents long-run coeiffcients, and SR represents short-run coeiffcients. Standard errors are communicated in parenthesis. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020). Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024). * = 10 percent statistical level of significance. ** = 5 percent statistical level of significance. *** = 1 percent statistical level of significance. Nonsignificant exogenous variables from initial estimates were dropped in the models to increase the degree of freedom.

Source: USDA, Economic Research Service estimates.

Table A.13

Summary of postestimation diagnostic tests: Rice prepandemic

Test	Test type	Null hypothesis	Decision
Serial correlation	Breusch-Godfrey Lagrange Multiplier (LM) test for autocorrelation	H0: No serial correlation AR(1) chi2 test statistic= 0.163 Prob>Chi2 = 0.686	Failed to reject the null hypothesis
Heteroskedasticity	Breusch–Pagan/Cook–Weisberg test for heteroskedasticity	H0: Constant Variance chi2(1) = 0.870 Prob > chi2 = 0.352	Failed to reject the null hypothesis
Stability (Recursive)	Cumulative sum test for parameter stability	H0: No structural break Test statistic: 0.767	Failed to reject the null hypothesis
Stability (Ordinary Least Squares)	Cumulative sum test for parameter stability	H0: No structural break Test statistic: 1.288	Failed to reject the null hypothesis

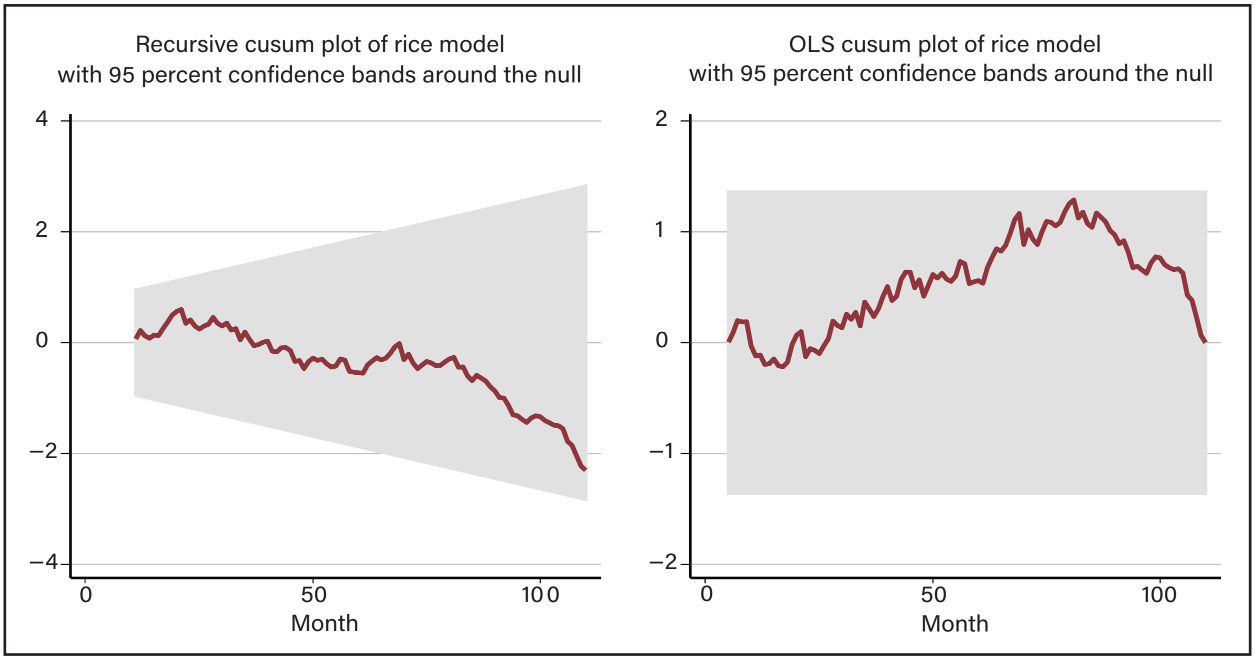
AR (1) = First-order autoregression. Chi2 = Chi-Squared. Prob >Chi2 = *p*-value. H0 = Null hypothesis.

Note: The null hypothesis for Breusch-Godfrey LM test is that there is no serial correlation. Presence of serial correlation may lead to biased standard error. Breusch–Pagan/Cook–Weisberg test whether the variance of errors in regression model is constant over time. Presence of heteroskedacity may lead to inconsistent estimated standard errors. Cumulative sum test check for structural break in estimates across observations. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020).

Source: USDA, Economic Research Service estimates.

Figure A.3

Postestimation plot for parameter stability: Rice prepandemic



OLS = Ordinary Least Squared. Cusum = Cumulative sum test. Null = Null hypothesis.

Note: The figure represents postestimation test for structural break, with null hypothesis of no structural break. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020).

Source: USDA, Economic Research Service estimates.

Table A.14
Summary of postestimation diagnostic tests: Rice postpandemic

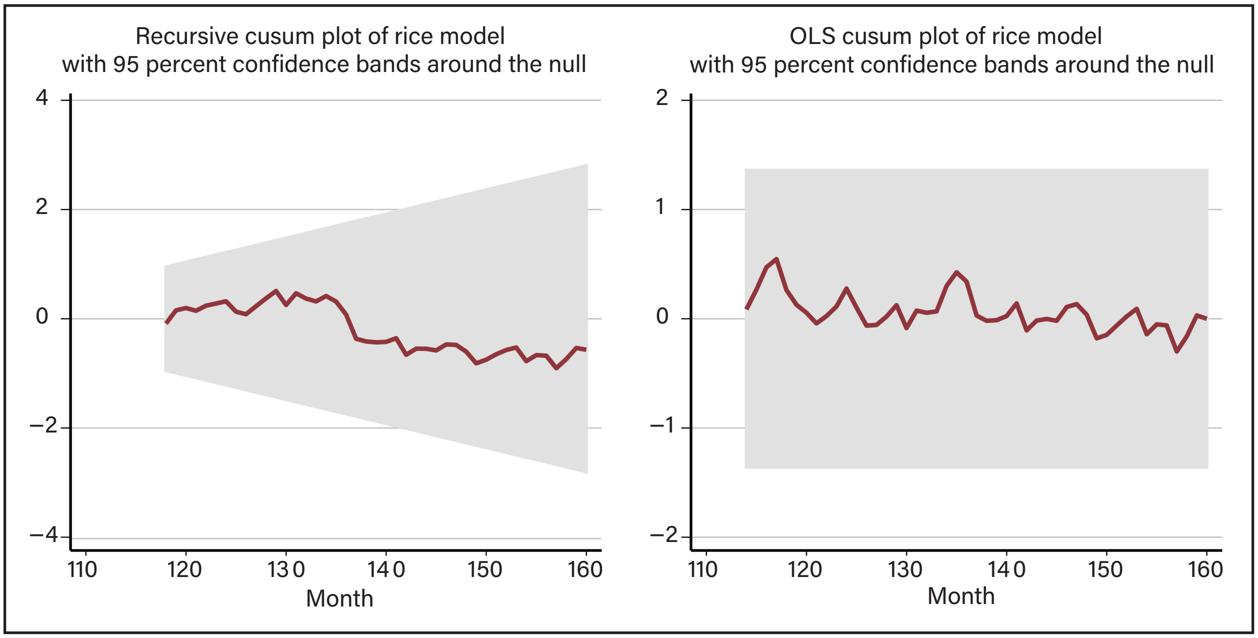
Test	Test type	Null hypothesis	Decision
Serial correlation	Breusch–Godfrey Lagrange multiplier(LM) test for autocorrelation	H0: No serial correlation AR(1) chi2 test stat= 0.038 Prob>Chi2 = 0.847	Failed to reject the null hypothesis
Heteroskedasticity	Breusch–Pagan/Cook–Weisberg test for heteroskedasticity	H0: Constant Variance chi2(1) = 1.47 Prob > chi2 = 0. 225	Failed to reject the null hypothesis
Stability (Recursive)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.719	Failed to reject the null hypothesis
Stability (Ordinary Least Squares)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.663	Failed to reject the null hypothesis

AR (1) = First-order autoregression. Chi2 = Chi-Squared. Prob >Chi2 = *p*-value. H0 = Null hypothesis.

Note: The null hypothesis for Breusch-Godfrey LM test is that there is no serial correlation. Presence of serial correlation may lead to biased standard error. Breusch–Pagan/Cook–Weisberg test whether the variance of errors in regression model is constant over time. Presence of heteroskedacity may lead to inconsistent estimated standard errors. Cumulative sum test check for structural break in estimates across observations. Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Source: USDA, Economic Research Service estimates.

Figure A.4
Postestimation plot for parameter stability: Rice postpandemic



OLS = Ordinary Least Squared. Cusum = Cumulative sum test. Null = Null hypothesis.

Note: The figure represents postestimation test for structural break, with null hypothesis of no structural break. Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Source: USDA, Economic Research Service estimates.

Table A.15

Summary of postestimation diagnostic tests: Wheat prepandemic

Test	Test type	Null hypothesis	Decision
Serial correlation	Breusch–Godfrey Lagrange multiplier(LM) test for autocorrelation	H0: No serial correlation AR(1) chi2 test stat= 0.023 Prob>Chi2 = 0.879	Failed to reject the null hypothesis
Heteroskedasticity	Breusch–Pagan/Cook–Weisberg test for heteroskedasticity	H0: Constant Variance chi2(1) = 0.450 Prob > chi2 = 0.504	Failed to reject the null hypothesis
Stability (Recursive)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.443	Failed to reject the null hypothesis
Stability (Ordinary Least Squares)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.836	Failed to reject the null hypothesis

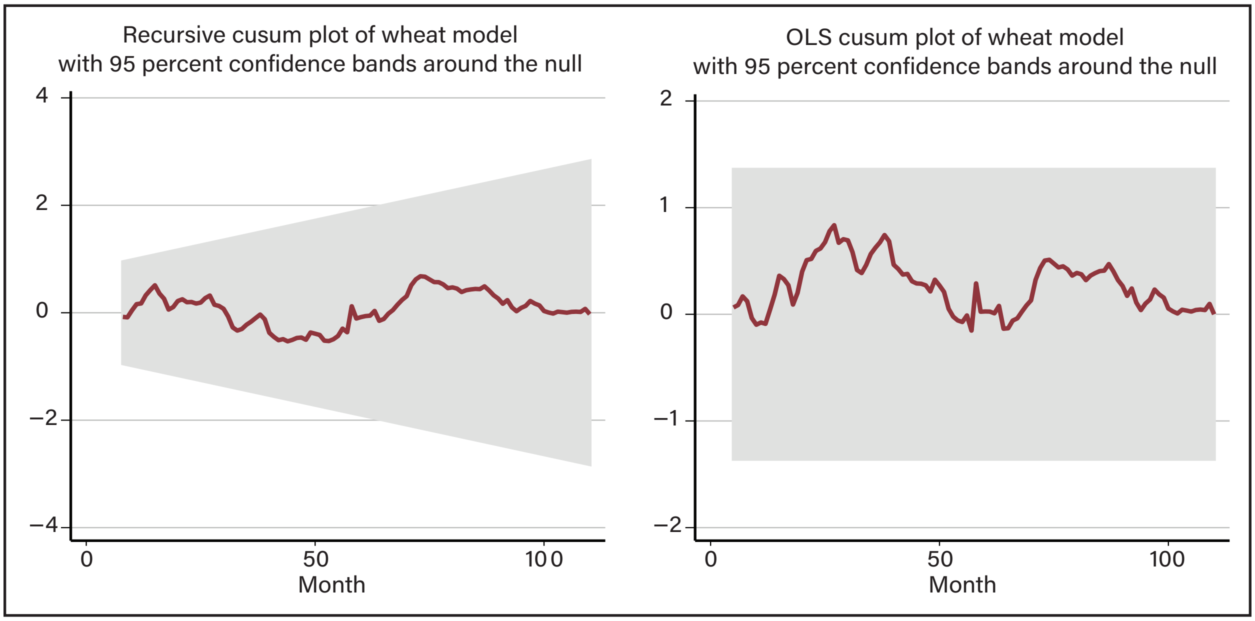
AR (1) = First-order autoregression. Chi2 = Chi-Squared. Prob >Chi2 = *p*-value. H0 = Null hypothesis.

Note: The null hypothesis for Breusch-Godfrey LM test is that there is no serial correlation. Presence of serial correlation may lead to biased standard error. Breusch–Pagan/Cook–Weisberg test whether the variance of errors in regression model is constant over time. Presence of heteroskedacity may lead to inconsistent estimated standard errors. Cumulative sum test check for structural break in estimates across observations. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020).

Source: USDA, Economic Research Service estimates.

Figure A.5

Postestimation plot for parameter stability: Wheat prepandemic



OLS = Ordinary Least Squared. Cusum = Cumulative sum test. Null = Null hypothesis.

Note: The figure represents postestimation test for structural break, with null hypothesis of no structural break. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020).

Source: USDA, Economic Research Service estimates.

Table A.16

Summary of postestimation diagnostic tests: Wheat Postpandemic

Test	Test type	Null hypothesis	Decision
Serial correlation	Breusch–Godfrey Lagrange multiplier(LM) test for autocorrelation	H0: No serial correlation AR(1) chi2 test stat= 1.507 Prob>Chi2 = 0.220	Failed to reject the null hypothesis
Heteroskedasticity	Breusch–Pagan/Cook–Weisberg test for heteroskedasticity	H0: Constant Variance chi2(1) = 0.15 Prob > chi2 = 0.701	Failed to reject the null hypothesis
Stability (Recursive)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.438	Failed to reject the null hypothesis
Stability (Ordinary Least Squares)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.630	Failed to reject the null hypothesis

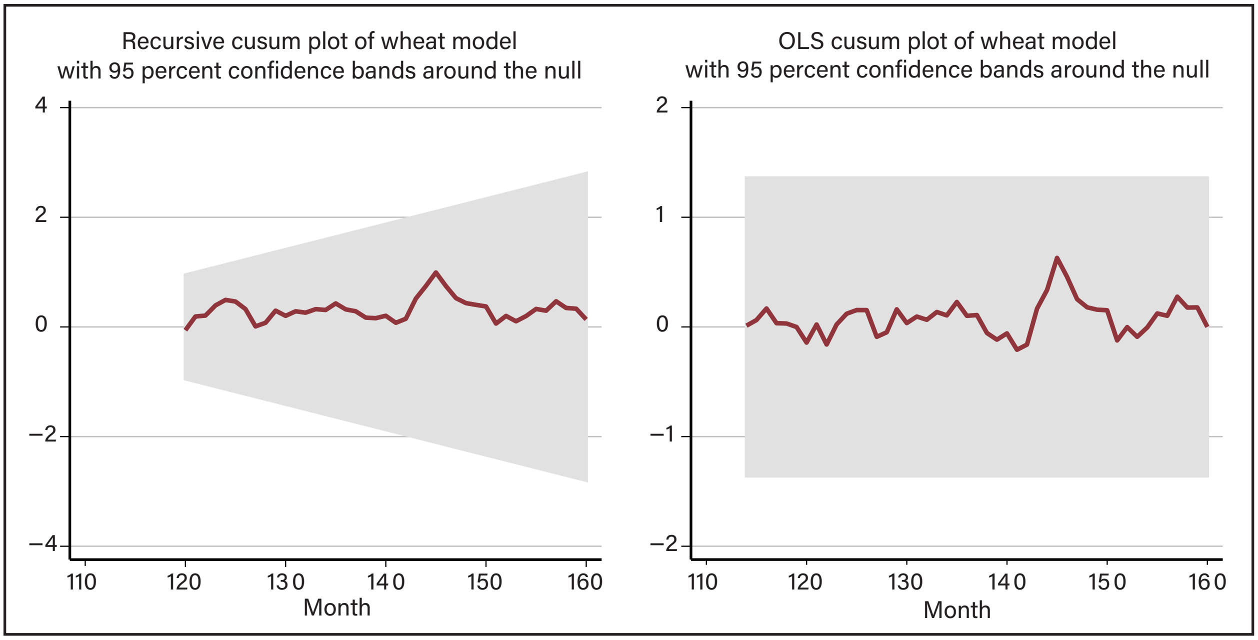
AR (1) = First-order autoregression. Chi2 = Chi-Squared. Prob >Chi2 = *p*-value. H0 = Null hypothesis.

Note: The null hypothesis for Breusch-Godfrey LM test is that there is no serial correlation. Presence of serial correlation may lead to biased standard error. Breusch–Pagan/Cook–Weisberg test whether the variance of errors in regression model is constant over time. Presence of heteroskedacity may lead to inconsistent estimated standard errors. Cumulative sum test check for structural break in estimates across observations. Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Source: USDA, Economic Research Service estimates.

Figure A.6

Postestimation plot for parameter stability: Wheat postpandemic



OLS = Ordinary Least Squared. Cusum = Cumulative sum test. Null = Null hypothesis.

Note: The figure represents postestimation test for structural break, with null hypothesis of no structural break. Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Source: USDA, Economic Research Service estimates.

Table A.17

Summary of postestimation diagnostic tests: Corn prepandemic

Test	Test type	Null hypothesis	Decision
Serial correlation	Breusch–Godfrey Lagrange multiplier test for autocorrelation	H0: No serial correlation AR(1) chi2 test stat= 0.056 Prob>Chi2 = 0.813	Failed to reject the null hypothesis
Heteroskedasticity	Breusch–Pagan/Cook–Weisberg test for heteroskedasticity	H0: Constant Variance chi2(1) = 0.050 Prob > chi2 = 0.823	Failed to reject the null hypothesis
Stability (Recursive)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.5727	Failed to reject the null hypothesis
Stability (Ordinary Least Squares)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.7535	Failed to reject the null hypothesis

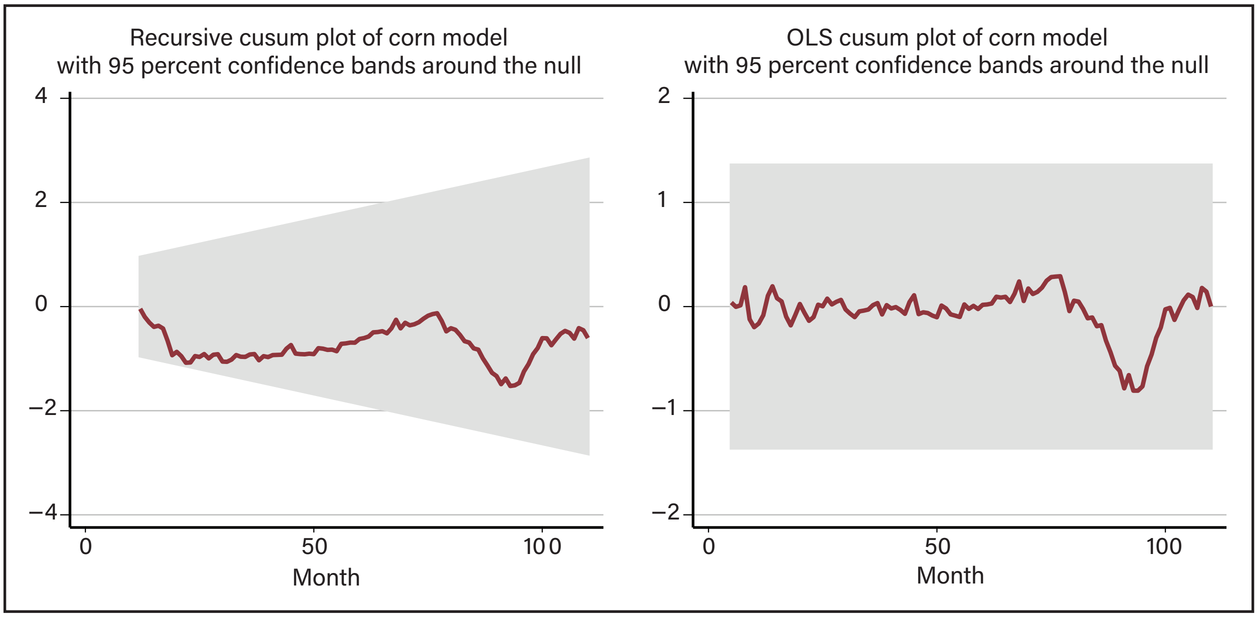
AR (1) = First-order autoregression. Chi2 = Chi-Squared. Prob >Chi2 = *p*-value. H0 = Null hypothesis.

Note: The null hypothesis for Breusch-Godfrey LM test is that there is no serial correlation. Presence of serial correlation may lead to biased standard error. Breusch–Pagan/Cook–Weisberg test whether the variance of errors in regression model is constant over time. Presence of heteroskedacity may lead to inconsistent estimated standard errors. Cumulative sum test check for structural break in estimates across observations. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020).

Source: USDA, Economic Research Service estimates.

Figure A.7

Postestimation plot for parameter stability: Corn prepandemic



OLS = Ordinary Least Squared. Cusum = Cumulative sum test. Null = Null hypothesis.

Note: The figure represents postestimation test for structural break, with null hypothesis of no structural break. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020).

Source: USDA, Economic Research Service estimates.

Table A.18

Summary of postestimation diagnostic tests: Corn postpandemic

Test	Test type	Null hypothesis	Decision
Serial correlation	Breusch–Godfrey Lagrange multiplier test for autocorrelation	H0: No serial correlation AR(1) chi2 test stat= 0.000 Prob>Chi2 = 0.985	Failed to reject the null hypothesis
Heteroskedasticity	Breusch–Pagan/Cook–Weisberg test for heteroskedasticity	H0: Constant Variance chi2(1) = 1.860 Prob > chi2 = 0.172	Failed to reject the null hypothesis
Stability (Recursive)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.756	Failed to reject the null hypothesis
Stability (Ordinary Least Squares)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.551	Failed to reject the null hypothesis

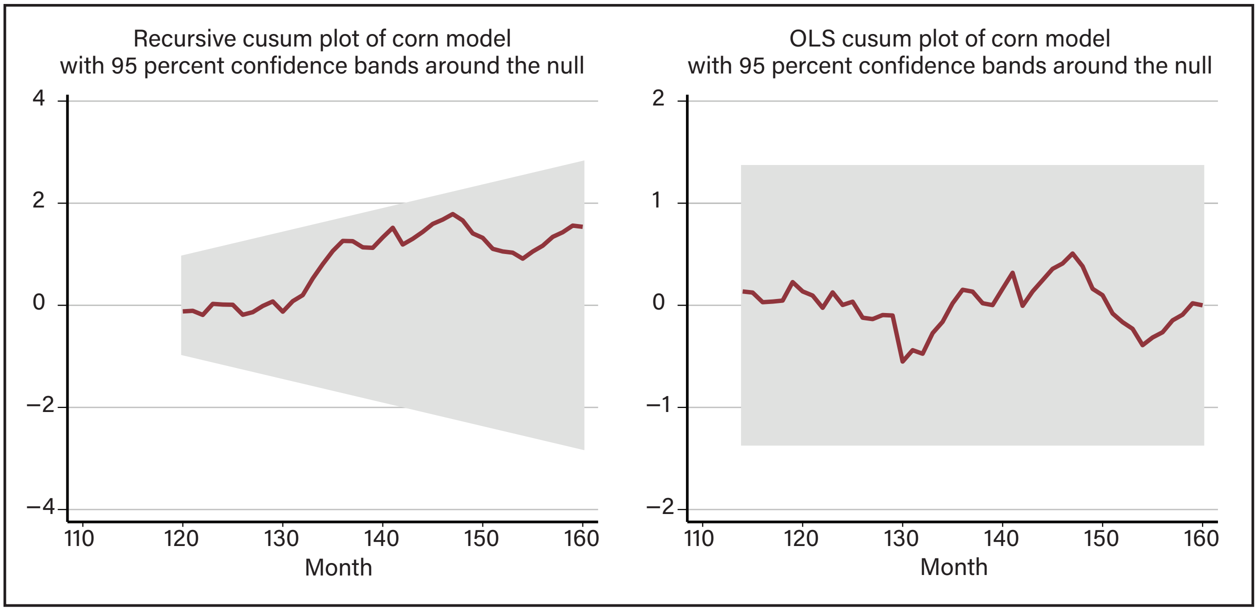
AR (1) = First-order autoregression. Chi2 = Chi-Squared. Prob >Chi2 = *p*-value. H0 = Null hypothesis.

Note: The null hypothesis for Breusch-Godfrey LM test is that there is no serial correlation. Presence of serial correlation may lead to biased standard error. Breusch–Pagan/Cook–Weisberg test whether the variance of errors in regression model is constant over time. Presence of heteroskedacity may lead to inconsistent estimated standard errors. Cumulative sum test check for structural break in estimates across observations. Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Source: USDA, Economic Research Service estimates.

Figure A.8

Postestimation plot for parameter stability: Corn postpandemic



OLS = Ordinary Least Squared. Cusum = Cumulative sum test. Null = Null hypothesis.

Note: The figure represents postestimation test for structural break, with null hypothesis of no structural break. Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Source: USDA, Economic Research Service estimates.

Table A.19

Summary of postestimation diagnostic tests: Soybeans all periods

Test	Test type	Null hypothesis	Decision
Serial correlation	Breusch–Godfrey Lagrange multiplier test for autocorrelation	H0: No serial correlation AR(1) chi2 test stat= 1.296 Prob>Chi2 = 0.255	Failed to reject the null hypothesis
Heteroskedasticity	Breusch–Pagan/Cook–Weisberg test for heteroskedasticity	H0: Constant Variance chi2(1) = 2.650 Prob > chi2 = 0.104	Failed to reject the null hypothesis
Stability (Recursive)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.744	Failed to reject the null hypothesis
Stability (Ordinary Least Squares)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.961	Failed to reject the null hypothesis

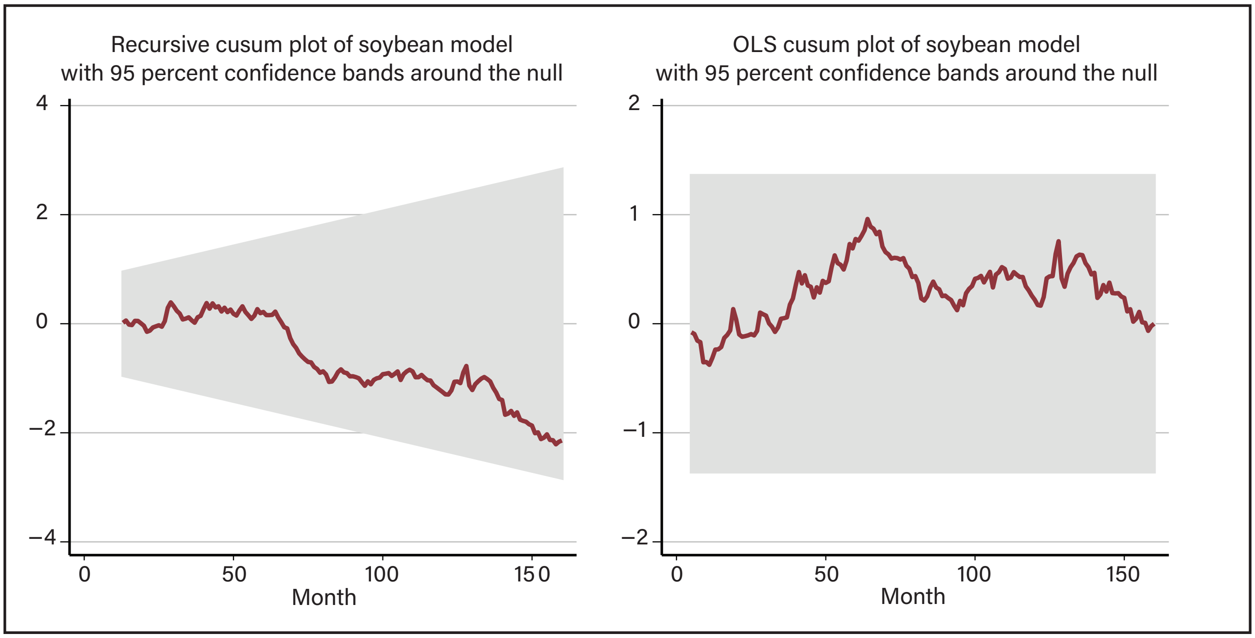
AR (1) = First-order autoregression. Chi2 = Chi-Squared. Prob >Chi2 = p-value. H0 = Null hypothesis.

Note: The null hypothesis for Breusch-Godfrey LM test is that there is no serial correlation. Presence of serial correlation may lead to biased standard error. Breusch–Pagan/Cook–Weisberg test whether the variance of errors in regression model is constant over time. Presence of heteroskedacity may lead to inconsistent estimated standard errors. Cumulative sum test check for structural break in estimates across observations. All periods = January 2011–April 2024.

Source: USDA, Economic Research Service estimates.

Figure A.9

Postestimation plot for parameter stability: Soybeans all periods



OLS = Ordinary Least Squared. Cusum = Cumulative sum test. Null = Null hypothesis.

Note: The figure represents postestimation test for structural break, with null hypothesis of no structural break. All periods = January 2011–April 2024).

Source: USDA, Economic Research Service estimates.

Table A.20
Summary of postestimation diagnostic tests: Soybeans prepandemic

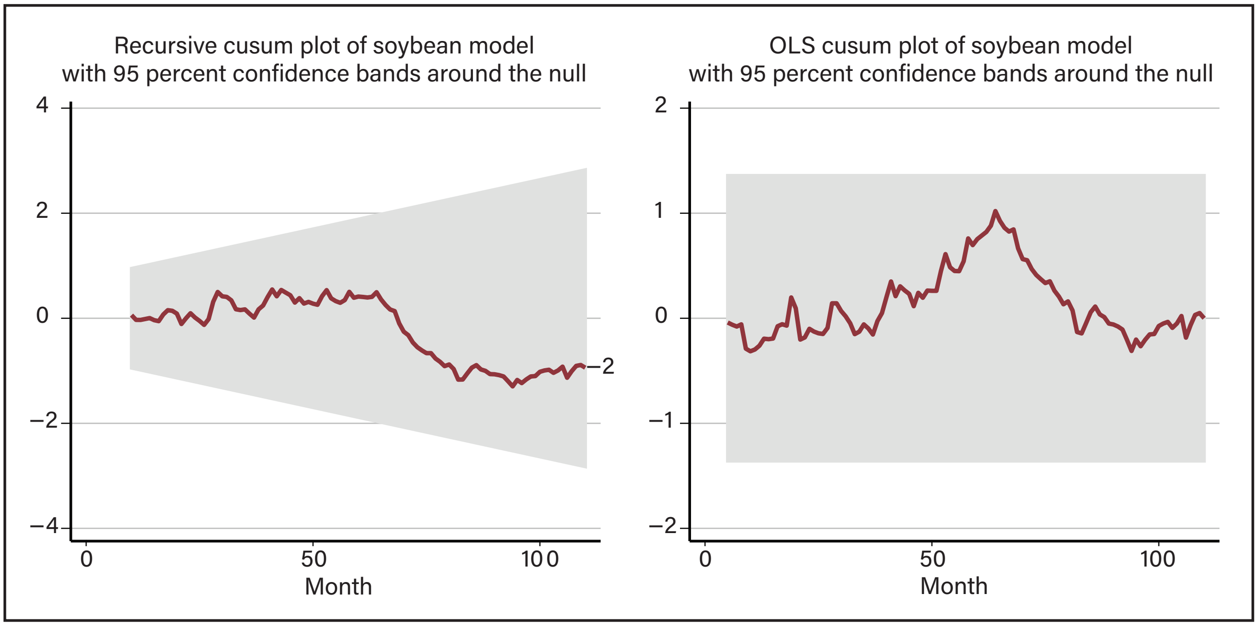
Test	Test type	Null hypothesis	Decision
Serial correlation	Breusch–Godfrey Lagrange multiplier test for autocorrelation	H0: No serial correlation AR(1) chi2 test stat= 2.408 Prob>Chi2 = 0.121	Failed to reject the null hypothesis
Heteroskedasticity	Breusch–Pagan/Cook–Weisberg test for heteroskedasticity	H0: Constant Variance chi2(1) = 0.010 Prob > chi2 = 0.918	Failed to reject the null hypothesis
Stability (Recursive)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.483	Failed to reject the null hypothesis
Stability (Ordinary Least Squares)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 1.021	Failed to reject the null hypothesis

AR (1) = First-order autoregression. Chi2 = Chi-Squared. Prob >Chi2 = *p*-value. H0 = Null hypothesis.

Note: The null hypothesis for Breusch-Godfrey LM test is that there is no serial correlation. Presence of serial correlation may lead to biased standard error. Breusch–Pagan/Cook–Weisberg test whether the variance of errors in regression model is constant over time. Presence of heteroskedacity may lead to inconsistent estimated standard errors. Cumulative sum test check for structural break in estimates across observations. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020).

Source: USDA, Economic Research Service estimates.

Figure A.10
Postestimation plot for parameter stability: Soybeans prepandemic



OLS = Ordinary Least Squared. Cusum = Cumulative sum test. Null = Null hypothesis.

Note: The figure represents postestimation test for structural break, with null hypothesis of no structural break. Prepandemic = period before the initial pandemic lockdown (January 2011–February 2020).

Source: USDA, Economic Research Service estimates.

Table A.21
Summary of postestimation diagnostic tests: Soybeans postpandemic

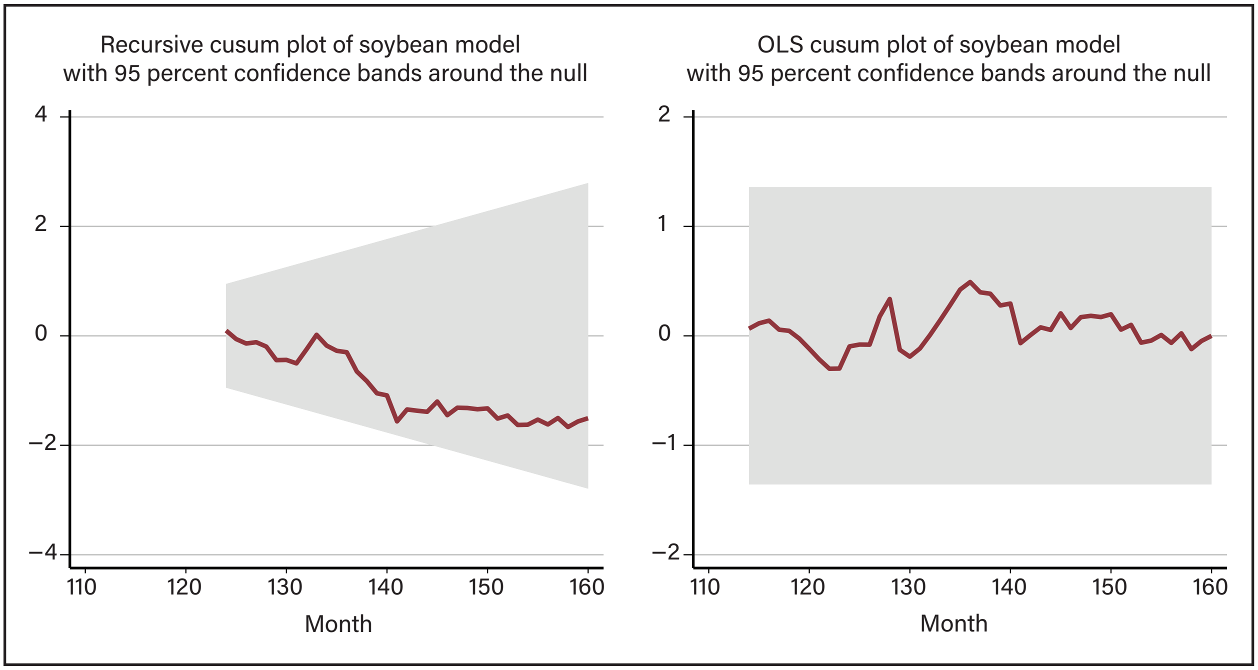
Test	Test type	Null hypothesis	Decision
Serial correlation	Breusch–Godfrey Lagrange multiplier test for autocorrelation	H0: No serial correlation AR(1) chi2 test stat= 0.783 Prob>Chi2 = 0.376	Failed to reject the null hypothesis
Heteroskedasticity	Breusch–Pagan/Cook–Weisberg test for heteroskedasticity	H0: Constant Variance chi2(1) = 3.200 Prob > chi2 = 0.074	Failed to reject the null hypothesis
Stability (Recursive)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.551	Failed to reject the null hypothesis
Stability (Ordinary Least Squares)	Cumulative sum test for parameter stability	H0: No structural break Test stat: 0.485	Failed to reject the null hypothesis

AR (1) = First-order autoregression. Chi2 = Chi-Squared. Prob >Chi2 = *p*-value. H0 = Null hypothesis.

Note: The null hypothesis for Breusch-Godfrey LM test is that there is no serial correlation. Presence of serial correlation may lead to biased standard error. Breusch–Pagan/Cook–Weisberg test whether the variance of errors in regression model is constant over time. Presence of heteroskedacity may lead to inconsistent estimated standard errors. Cumulative sum test check for structural break in estimates across observations. Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Source: USDA, Economic Research Service estimates.

Figure A.11
Postestimation plot for parameter stability: Soybeans postpandemic



OLS = Ordinary Least Squared. Cusum = Cumulative sum test. Null = Null hypothesis.

Note: The figure represents postestimation test for structural break, with null hypothesis of no structural break. Postpandemic = period after the initial pandemic lockdown (May 2020–April 2024).

Source: USDA, Economic Research Service estimates.