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Grain Futures Market Response to the Black Sea Grain Initiative

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Abstract: This paper assesses the impact of the Black Sea Grain Initiative on the grain futures market. We rely on counterfactual evaluation techniques and detailed futures price series to estimate how corn and wheat futures prices and historical volatility responded to the Grain Deal enforcement, renewals, and termination. Our event study estimates reveal that market participants anticipated the impact of the Black Sea Grain Initiative. This anticipation is evident from the declining trend in grain futures prices aligned with the EU Solidarity Lanes, implying that commodity traders factored in the Grain Deal's effects on grain futures price dynamics. Our analysis also uncovers a limited market response to the subsequent renewals and termination of the Grain Deal. Commodity traders did not perceive the Russian threat of withdrawing from the Grain Deal as a primary market risk. These findings expand our understanding of commodity trader behavior and market sentiment under the Black Sea Grain Initiative.

Keywords: Black Sea Grain Initiative, Commodity Futures Market, Corn and Wheat, Event Studies

1 Introduction

The armed conflict between Russia and Ukraine, which commenced in February 2022, has had profound humanitarian and economic ramifications that persist and have intensified over time. Among the adverse outcomes of this war is the disruption of agricultural trade and price formation, particularly within the grain market (e.g., Ahn, Kim and Steinbach, 2023; Carter and Steinbach, 2023b; Steinbach, 2023). With the involvement of two major global grain suppliers in this conflict, grain futures markets witnessed an immediate and substantive response. During the initial period of the conflict, economic forecasts by the World Trade Organization indicated that wheat prices in certain regions could have surged by as much as 85 percent (World Trade Organization, 2022). According to research conducted by Carter and Steinbach (2023a), the prices of wheat and corn futures experienced more moderate increases of up to 35 percent and 16 percent beyond their counterfactual levels during the first two months of the war. To revitalize grain exports from Ukraine, which had been blockaded since the Russia-Ukraine war commenced, the European Union established the Solidarity Lanes in May 2022. Shortly after, Türkiye and the United Nations helped to broker the Black Sea Grain Initiative, which became effective in late July 2022 and revitalized grain shipments from Black Sea ports. According to the World Trade Organization (2023), these initiatives have played a crucial role in facilitating the resumption of grain shipments from blockaded ports critical for global food security and price stability. Yet, little empirical evidence exists of how the Black Sea Grain Initiative enforcement, renewals, and termination affected agricultural commodity prices.

A considerable literature studies the response of agricultural commodity futures prices to market shocks. Previous studies have examined internal drivers, such as market participants and traders (Williams and Wright, 1991; Gorton, Hayashi and Rouwenhorst, 2013; Fama and French, 2016), and external influences, which include economic and geopolitical factors (Bailey and Chan, 1993; Hess, Huang and Niessen, 2008). Additionally, studies have explored the relationship between commodity futures prices and investment portfolios (Erb and Harvey, 2006; Gorton and Rouwenhorst, 2006), USDA reports (Huang, Serra and Garcia, 2021; Massa, Karali and Irwin, 2023), market patterns (Decoster, Labys and Mitchell, 1992; Chinn and Coibion, 2014), and market efficiency (Kellard et al., 1999; Kristoufek and Vosvrda, 2014; Kuruppuarachchi, Lin and Premachandra, 2019). Some researchers have focused explicitly on grain futures prices, mainly studying the implications of market speculation and its determinants (e.g., Sanders, Irwin and Merrin, 2010; Karali and Thurman, 2010; Etienne, Irwin and Garcia, 2015). Recent studies concerned with the Russian invasion of Ukraine have examined the global food security implications (Behnassi and El Haiba, 2022; Lin et al., 2023), global trade effects (Ahn, Kim and Steinbach, 2023; Poursina et al., 2024; Steinbach, 2023), volatility in commodity markets (Legrand, 2022; Wang et al., 2022; Fang and Shao, 2022; Goyal and Steinbach, 2023), and the impact on stock markets (Sun and Zhang, 2022; Boungou and Yatié, 2022). However, there is limited empirical evidence regarding the impact of the Black Sea Grain Initiative implementation, renewals, and termination on grain futures prices. One notable exemption is Carter and Steinbach (2023a), who employed dynamics treatment models to investigate whether corn and wheat futures markets overreacted to the Russian invasion of Ukraine. They found no unusual speculative pressure for corn and wheat futures and concluded that the markets priced the wartime risk fairly. Branger, Hanke and Weissensteiner (2024) analyzed wheat derivatives to extract market forecasts of futures prices and volatility associated with the Russia-Ukraine war. Their findings indicated that the predictive power of wheat derivatives for anticipating the war's development diminished once the market foresaw the Black Sea Grain Initiative.

This paper investigates how grain futures prices responded to the Grain Deal enforcement, renewals, and termination. We used detailed futures price data, counterfactual statistical techniques, and event study methods. Our empirical approach, which relies on a comparison group exhibiting similar pre-treatment trends while remaining unaffected by the Grain Deal's market uncertainty, enhances the reliability of the estimated treatment effects. By employing grain futures outcomes from previous years, we leverage the inherent seasonal patterns for a robust comparison, mitigating potential biases and aligning with the parallel trends assumption, thus offering a more accurate analysis of the initiative's impact on market dynamics. Our findings indicate that in the first six weeks after the Black Sea Grain Initiative was enforced, the corn futures price increased by 7.8 percent, while the wheat futures price decreased by 4.2 percent. Grain traders anticipated the successful enforcement of the Black Sea Grain Initiative as corn and wheat futures prices started to retreat after the establishment of the EU Solidarity Lanes in May 2022. Notably, we found no evidence suggesting that commodity traders considered Russia's threat of canceling the Grain Deal credible, as there was no significant increase in grain futures prices before the Grain Deal was renewed. We also found no evidence of contagion effects for agricultural commodities not directly affected by the Russian invasion of Ukraine. The futures prices for soybeans and rice barely increased during the conflict and remained unchanged after the Black Sea Grain Initiative was implemented. These findings imply that market participants acted rationally by anticipating that the disruptions in global grain markets would be temporary and localized. Our findings challenge the narrative that the Black Sea Grain Initiative was instrumental in reducing prices for agricultural commodities. Following the termination of the Black Sea Grain Initiative, the corn futures price increased by 5.6 percent, while the wheat futures price decreased to 1.9 percent below the counterfactual level. The dynamic estimates reveal the short-lasting impact of the increased market uncertainty following the Grain Deal termination, reflected by the surge of wheat volatility of 25.4 percent in the post-event event.

Our paper makes two distinct contributions to the growing literature on the commodity market implications of the Black Sea Grain Initiative. First, our paper expands on earlier work investigating the response of agricultural commodity markets to the Russian invasion of Ukraine. Carter and Steinbach (2023*a*) found that the more robust response in the wheat futures market is likely due to an expected complete shutdown of grain shipments via Black Sea ports in the initial weeks after the war started. We expand on those findings by revealing how agricultural commodity traders reacted to changes in market uncertainty caused by the enforcement, renewals, and termination of the Black Sea Grain Initiative. To do so, we apply a robust approach to constructing counterfactual futures prices and historical volatility series based on previous years, selecting control groups that mirror the treatment group's pre-event trends without being influenced by the initiative's market uncertainty. Our event studies show that grain futures prices started to decrease after the EU Solidarity Lanes were established in May 2022, implying that commodity traders anticipated the successful enforcement of the Black Sea Grain Initiative, which lowered market uncertainty considerably. This finding aligns with the work of Goyal and Steinbach (2023). In addition, favorable growing conditions in other grain production regions and relatively high global stocks made up for any shortfalls in grain exports from Ukraine, helping to lower market uncertainty caused by the event Carter and Steinbach (2023*b*). Second, our paper expands on the earlier work by showing how agricultural commodity markets reacted to the Russian threat of ending the Grain Deal prematurely. Our event studies show that traders considered Russia's threat of canceling the Grain Deal not credible, as there was no significant increase in grain futures prices and volatility before the renewals of the Black Sea Grain Initiative. These empirical insights are essential in light of the ongoing debate regarding the implications of the Russia-Ukraine war for agricultural trade and commodity prices.

2 Background

Ukraine and Russia are highly influential players in agricultural markets, particularly in the production and export of arable crops such as cereals and oilseeds. As a result, they have emerged as major contributors to the world's food supply chain. During the past five years, Russia accounted for an average of 10 percent of global wheat production, while Ukraine contributed around 3 percent. These figures solidify Russia and Ukraine as the leading and fifth-largest wheat exporters worldwide, responsible for approximately 20 percent and 10 percent of global wheat exports, respectively (United Nations, 2023). This crucial role extends to regions such as the Middle East and North Africa, where wheat is a staple food. Although Ukraine has the larger share, Russia and Ukraine contribute less than 5 percent of global corn production. With limited domestic consumption, most corn production is channeled toward international markets, making Ukraine the third-largest corn exporter. Both countries are also substantial producers and exporters of other cereals, with a particular focus on barley. Together, they account for 20 percent of global barley production, with Russia ranking third and Ukraine fourth in global exports. The barley these nations produce predominantly serves as feed for domestic animal husbandry.

Following the Russian invasion of Ukraine on February 24, 2022, Russian armed forces attacked Ukraine's port infrastructure, while major sea routes were mined to prevent a Russian naval invasion of Odesa and other Black Sea ports, and the Russian Navy blockaded major sea lanes connecting Ukrainian grain exporters to foreign markets. Figure 1 shows the evolution of Ukraine's corn and wheat exports from January 2019 to November 2023 and compares export volumes by transport mode. The initial impact on Ukraine's grain trade had been severe, with about 20 million tons of grains being trapped in Black Sea ports in Spring 2022. Before the Russia-Ukraine war, nearly 80 percent of Ukraine's grain exports flowed through its southwestern ports of Odesa, Pivdennyi, Mykolayiv, and Chornomorsk into the Black Sea. As a result of the market uncertainty caused by the war, global food prices surged to an all-time high, with food supplies being particularly threatened in Middle Eastern and African countries, which rely heavily on Ukrainian grain exports (Ahn, Kim and Steinbach, 2023). The United

Nations estimated that prices of staple foods rose across these regions by an average of 30 percent. Rising food prices are also reflected in the grain futures market. Figure 2 shows that corn and wheat futures prices rose sharply after the Russian invasion of Ukraine. In response to the sea blockade, the European Commission and the Member States of the European Union established, together with Ukraine and the Republic of Moldova, the EU-Ukraine Solidarity Lanes in May 2022. Since the start of the war, the EU Solidarity Lanes have enabled the export of around 35 million tons of Ukrainian agricultural products, generating over $45 billion in revenue for Ukrainian farmers and businesses (European Council 2023).

In April 2022, the United Nations initiated talks with the conflict parties and Türkiye to address the Black Sea grain shipment disruptions and mitigate concerns about global food price hikes. The objective was to find a solution and resume grain shipments through Black Sea ports. These negotiations led to the Black Sea Grain Initiative signed in Istanbul on July 22, 2022. This initiative allowed Ukraine to resume vital food and fertilizer exports from Black Sea ports. A joint coordination and inspection center was established in Türkiye, with the United Nations acting as the secretariat. The Black Sea Grain Initiative permitted commercial food and fertilizer exports, including ammonia, from the crucial Ukrainian ports of Odesa, Chornomorsk, and Pivdennyi. Initially, the agreement was set to expire on November 19, 2022. However, Russia temporarily suspended its participation in the Joint Coordination and Inspection Center due to a drone attack on the Russian Navy. Following mediation efforts, Russia eventually rejoined the initiative. In late November, the United Nations and Ukraine announced a 120-day extension of the agreement. After the expiration of the first renewal of the Grain Deal in March 2023, Türkiye and the United Nations announced a second extension for at least 60 days. The Black Sea Grain Initiative was extended for a third time in mid-May and ultimately expired on July 18, 2023. Russia continued to claim that Western sanctions block Russian agricultural exports despite Russian grain exports being at a record high in the 2022/23 crop year. Following its termination, Russia escalated its military actions against

Ukraine, targeting Ukrainian grain storage and loading facilities with missiles and drone strikes. Additionally, Russia issued warnings that any vessels entering Ukrainian waters might be regarded as legitimate targets in the ongoing conflict. As of July 2023, the initiative had proven successful, with over 1,000 voyages departing from Ukrainian ports, transporting almost 33 million tons of grain and other food products to over 45 countries. These shipments were primarily destined for Asia-Pacific and Western European countries. Efforts are ongoing to revive the Black Sea Grain Initiative, which is widely recognized as having contributed to stabilizing grain shipments and alleviating concerns about global food prices (World Trade Organization, 2023).

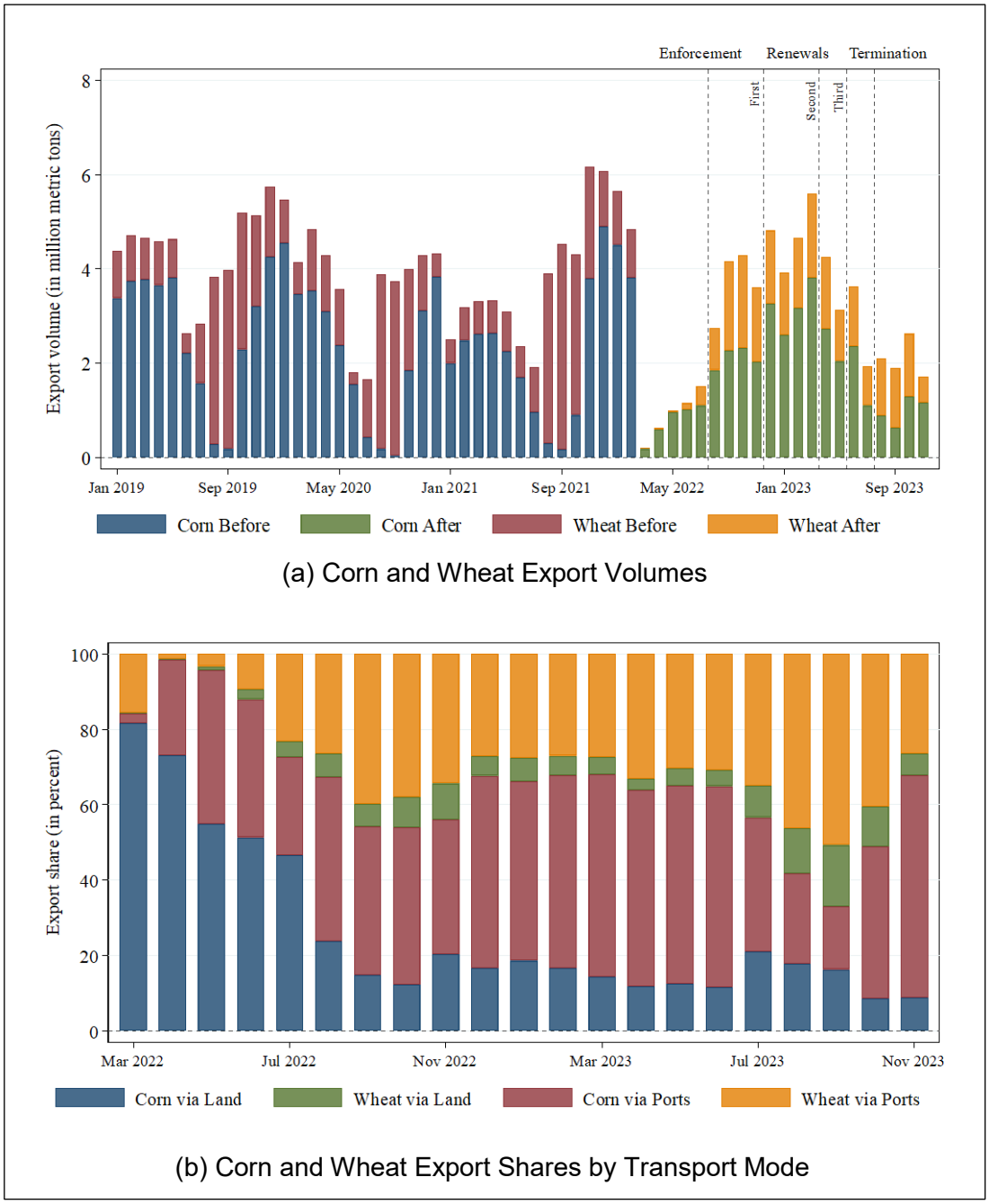

Figure 1. Corn and Wheat Exports from Ukraine

Note: The figure shows corn and wheat exports from Ukraine. Panel (a) shows the export volume between January 2019 and November 2023, and panel (b) the share of land and sea shipments after the Russian invasion commenced. Data on the export volume before March 2022 is from the Trade Data Monitor (2023) and after March 2022 from the Ministry of Agrarian Policy and Food of Ukraine (2023). The color coding indicates the break in the data sources in panel (a) and the different transport modes in panel (b). The five vertical lines indicate the key events during the Black Sea Grain Initiative. These events are the initial Grain Deal enforcement in July 2022, the three renewals in November 2022, March 2023, and May 2023, and the Grain Deal termination in July 2023.
Source: authors' own calculations

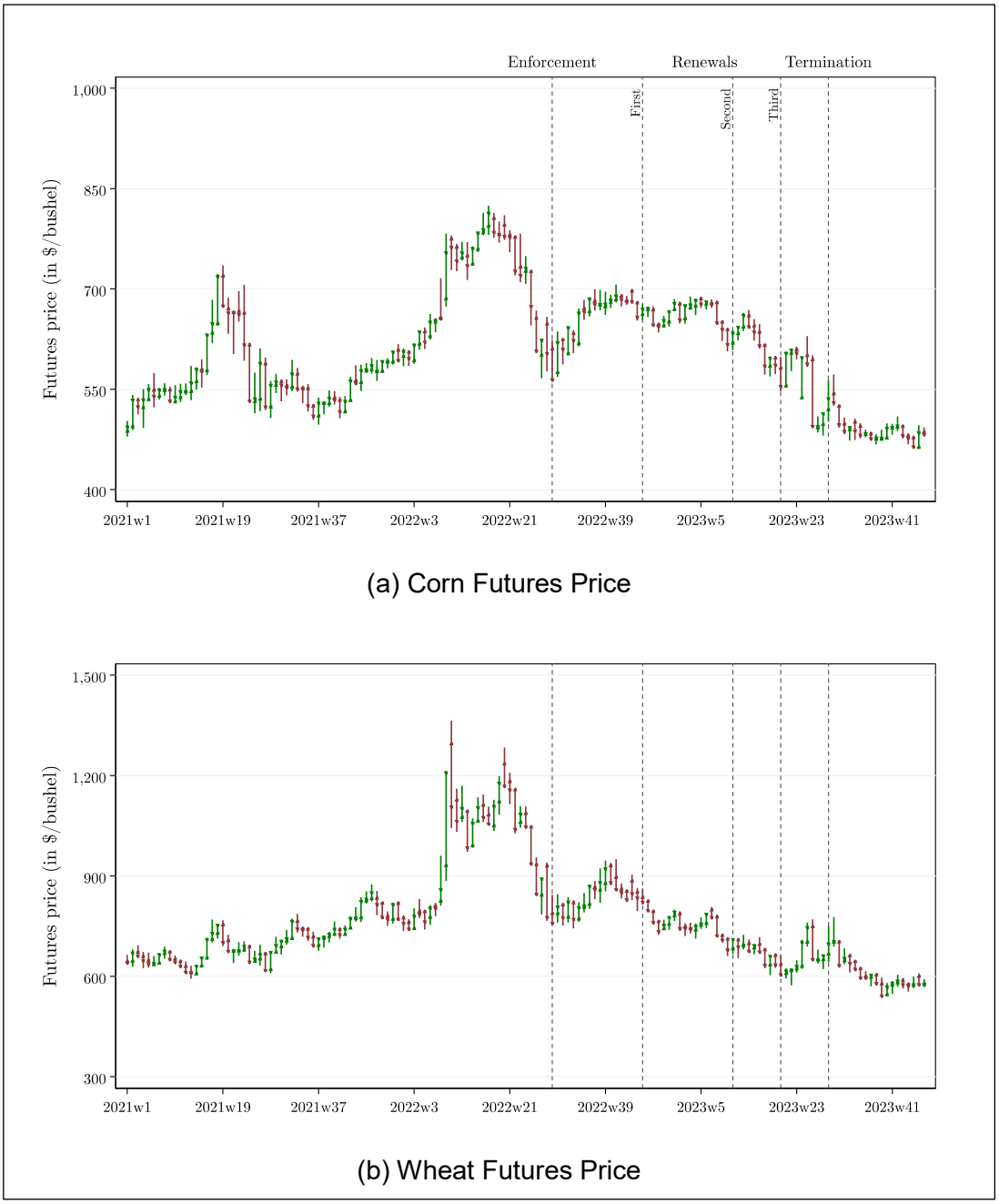

Figure 2. Corn and Wheat Futures Prices

Note: The figure shows the corn and wheat futures prices between January 2021 and November 2023. The color coding indicates rising (green) and falling (red) futures prices, while the whiskers show the high and low futures prices within the week. The five vertical lines indicate the key events during the Black Sea Grain Initiative. These events are the initial Grain Deal enforcement in July 2022, the three renewals in November 2022, March 2023, and May 2023, and the Grain Deal termination in July 2023. Source: authors' own calculations

3 Empirical Strategy and Data

We use event study methods to examine the grain futures market response to the enforcement, renewals, and termination of the Black Sea Grain Initiative. Event studies are frequently utilized to assess the ex-post treatment effects of an external shock on the outcome of interest (Miller, 2023). To capture pre-trends and assess post-event treatment dynamics, we include leads and lags relative to the event of interest in an event-study specification (Freyaldenhoven et al.,

2021). Following the prevalent narrative that highlights the influence of those events on agricultural commodities, one could expect the Black Sea Grain Initiative to have a considerable impact on commodity price dynamics (World Trade Organization, 2023). We rely on a log-linear panel regression model to test the corn and wheat futures market responses to the Russia-Ukraine war and the Black Sea Grain Initiative:

$$y_{c,t} = \alpha_{c,dy} + \alpha_{c,wk} + \alpha_{c,yr} + \sum_{m=-6}^{6} \beta_m r_{c,t-m} + \epsilon_{c,t}\,, \tag{1}$$

where c represents the commodity and t the day. The outcome of interest is denoted by $y_{c,t}$ and stands for the commodity futures price and historical volatility. We assume that all latent confounders are captured by the high-dimensional fixed effects that are defined at the commodity-event-day ($\alpha_{c,dy}$), commodity-event-week ($\alpha_{c,wk}$), and commodity-event-year ($\alpha_{c,yr}$) levels. Examples of such unobserved confounders are seasonality patterns, commodity price hikes, and other sources of drifting in the data series. The central identifying assumption is that after conditioning on the high-dimensional fixed effects, the treatment timing is independent of the error $\epsilon_{c,t}$. The term $\sum_{m=-6}^{6} \beta_m r_{c,t-m}$ measures the short-run dynamic response of grain futures to the events of interest denoted by *r*. Note that we rely on daily futures prices and volatility series but report weekly averages of the treatment effects. We follow the recommended practice in the event study literature and use a symmetric event window, which is six weeks before and after the events of interest in our analysis (Miller, 2023).[1] We center the event studies around the enforcement of the Black Sea Grain Initiative (week 8 of 2022), its three renewals (week 46 of 2022 and weeks 11 and 20 in 2023), and the Grain Deal termination (week 29 of 2023).

The identification of causal treatment effects relies on a comparison group that exhibits similar trends in the pre-treatment period. This is also called the parallel trends assumption (Marcus and Sant'Anna, 2021). Additionally, this comparison group must be unaffected by the market uncertainty caused by the Black Sea Grain Initiative. Using futures price series of other commodities during the same period as a control group to recover the treatment effects is inappropriate since the same market uncertainty likely influences them. They may also show different pre-event trends than the treatment group (Rambachan and Roth, 2023). To resolve this empirical challenge, we utilize grain futures outcomes from previous years as the comparison group. Previous studies, such as those investigating the trade implications of maritime shipping disruptions and the Russia-Ukraine war, have employed similar research designs (see, e.g., Carter, Steinbach and Zhuang, 2023; Steinbach, 2022; Ahn, Kim and Steinbach, 2023; Steinbach, 2023). An advantage of using futures price series from earlier years is that they exhibit similar seasonal patterns as the outcomes of interest.

A challenge lies in selecting a comparison group that exhibits the same patterns in the pre-treatment period (Miller, 2023). Since we have access to daily time series available for all outcomes dating back to 2000, we could use a myriad of tuples to construct this comparison group.[2] Therefore, to identify the tuple that best replicates the treatment group in the pre-event period, we perform an *F*-test to examine the null hypothesis that the pre-event coefficients are jointly zero (Griffiths et al., 1985). By selecting the tuple with the lowest *F*-statistic, we can identify the comparison group that most closely resembles the treatment group in the pre-

[1] We decided to include six weeks before and after the event because it allows testing for anticipatory and leveling-off treatment effects.

[2] A tuple is a finite ordered list of elements, which are event years in our dataset. An *n*-tuple is a sequence (or ordered list) of n elements, where *n* is a non-negative integer.

treatment period.[3] This approach resembles the synthetic difference-in-differences methods, which aim to match pre-event trends to reduce reliance on the parallel trends assumption (Arkhangelsky et al., 2021). Lastly, we adjust for heteroskedasticity following standard practice in the related literature (Cameron and Miller, 2015).

We follow the previous literature and rely on a log-linear regression specification to identify the relationship of interest (e.g., Kristoufek and Vosvrda, 2014; Main et al., 2018; Kuruppuarachchi, Lin and Premachandra, 2019). The outcomes of interest are the futures price and historical volatility for corn and wheat. We also look at soybean and rice futures for the robustness checks.[4] Our sample consists of daily observations of Chicago futures contracts covering January 2000 to November 2023 from Barchart (2024).[5] We used the daily closing price and calculated the historical volatility based on a 30-day window. This measure tells us about the level of risk associated with trading grain futures. Appendix Table A.4 compares the main outcomes six weeks before and after the enforcement, three renewals, and termination of the Black Sea Grain Initiative. This comparison shows that the corn and wheat futures prices were 9.6 percent and 15.6 percent lower after the enforcement of the Grain Deal. At the same time, we observe increases in the historical volatility for corn and wheat during that period. There is evidence for lesser movement in grain futures prices and historical volatility after the Black Sea Grain Initiative was renewed for the first. For instance, corn futures were 3.2 percent lower, while wheat futures decreased by 9.2 percent. Similar patterns are observable for the other two Grain Deal renewals. Interestingly, once the Black Sea Grain Initiative was terminated, there was limited movement in corn and wheat futures prices. While the corn futures price decreased by 8.5 percent, wheat fell by less than 1.7 percent. Both futures prices saw a considerable increase in historical volatility at the end of the Grain Deal.[6]

4 Results

Figures 3 and 4 present event studies for the impact of the Black Sea Grain Initiative's enforcement, renewals, and termination on corn and wheat futures prices and historical volatilities. Each event plot shows the dynamic treatment estimates, 95-% confidence intervals, and uniform sup-t bands (Montiel Olea and Plagborg-Møller, 2019). We also overlay dashed red lines representing static regression model estimates. Each subfigure reports Wald test statistics for pre-trends and static effect p-values. Beginning with the enforcement of the deal, the dynamic treatment estimates reveal statistically significant pre-trends in the weeks preceding the Black Sea Grain Initiative.

[3] To ensure computational feasibility, we require each tuple to include at least ten event years. Applying this constraint results in 1,401,292 potential tuples per outcome, encompassing event years from 2000 to 2021. Next, we estimate each model and conduct an *F*-test to examine the null hypothesis that the pre-event coefficients are jointly zero. The test is conducted for each commodity and event separately. We then select the tuple with the lowest *F*-statistic for the subsequent statistical analysis.

[4] We present results of the augmented Dickey-Fuller test for each outcome in Appendix Table A.1. We reject the null hypothesis of a unit root for all outcomes, which implies that a stationary process generated those time series.

[5] Futures exchanges and delivery months for each commodity are presented in Appendix Table A.2. We rely on the SRW futures series because its market is more liquid. The data series shows the same patterns as the HRW, but fewer observations are missing, essential for identifying the grain futures price response to the Black Sea Grain Initiative. Descriptive statistics are provided in Appendix Table A.3.

[6] Potential treatment anticipation and trending are endogeneity concerns for a simple before and after comparison. For instance, as shown in Figure 2, corn and wheat futures prices were upward trending before the first renewal of the Black Sea Grain Initiative, and the war increased market uncertainty considerably. In this regard, a simple comparison of averages before and after the event could be misleading and obstruct the true nature of the treatment effect. Therefore, we rely on the statistically more demanding dynamic treatment model specification to infer the treatment effects of the enforcement, renewals, and termination of the Black Sea Grain Initiative.

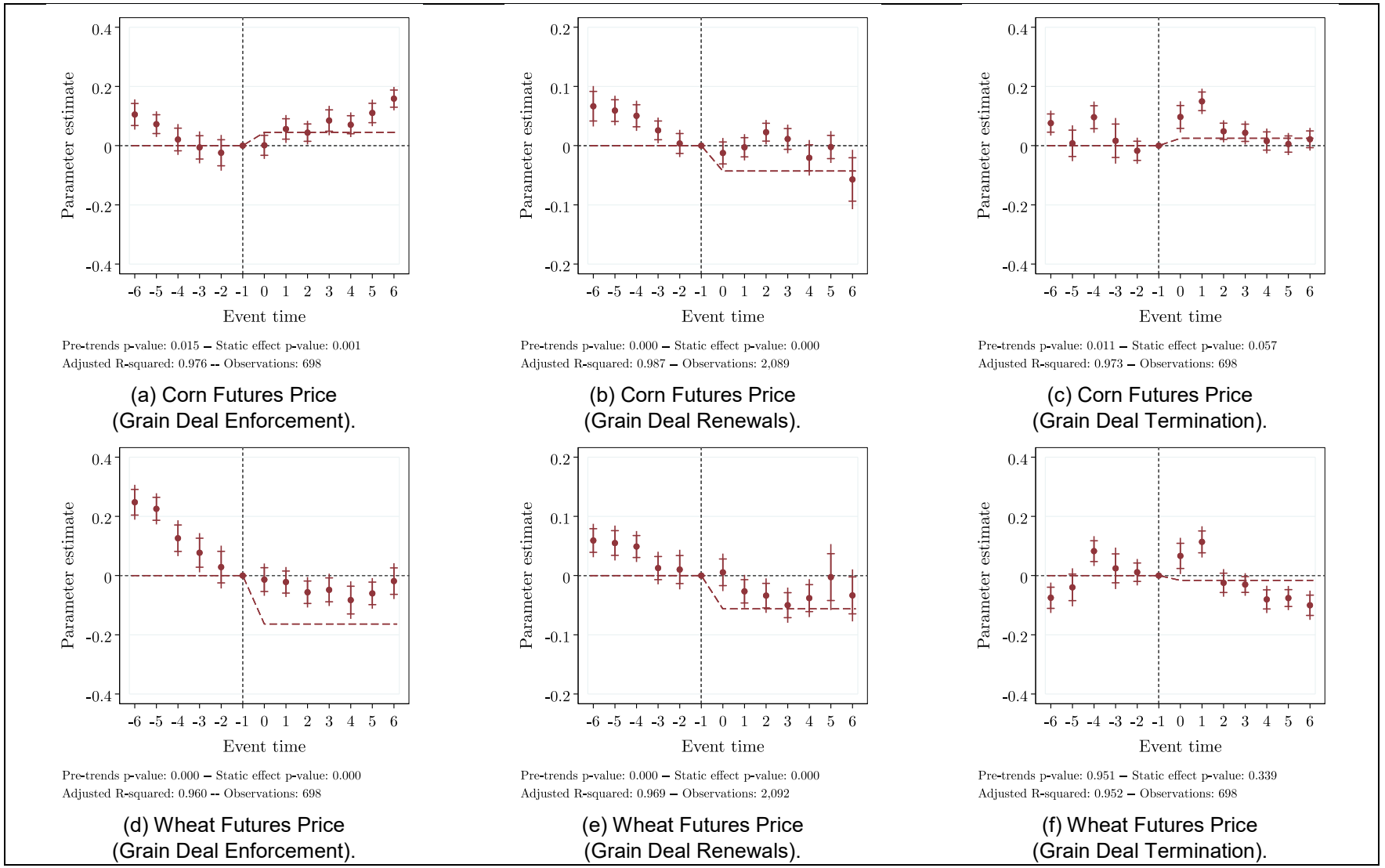

Figure 3. Event Studies for Corn and Wheat Futures Prices

Note: The figure shows the dynamic treatment estimates, 95 percent confidence intervals, and uniform sup-t bands for the event-time coefficients. The event time is measured in weeks relative to the treatment. We centered the event studies around key events during the Black Sea Grain Initiative timeline. These events are the Grain enforcement in week 29 of 2022, the three renewals treated as one event (week 46 of 2022, week 11 of 2023, and week 20 of 2023), and the Grain Deal termination in week 29 of 2023. We report several Wald tests and regression statistics in the figure notes and overlay estimates for a linear regression specification as a dotted line. We used a log-linear regression specification and included commodity-event-day, commodity-event-week, and commodity-event-year fixed effects in each regression.
Source: authors' own calculations

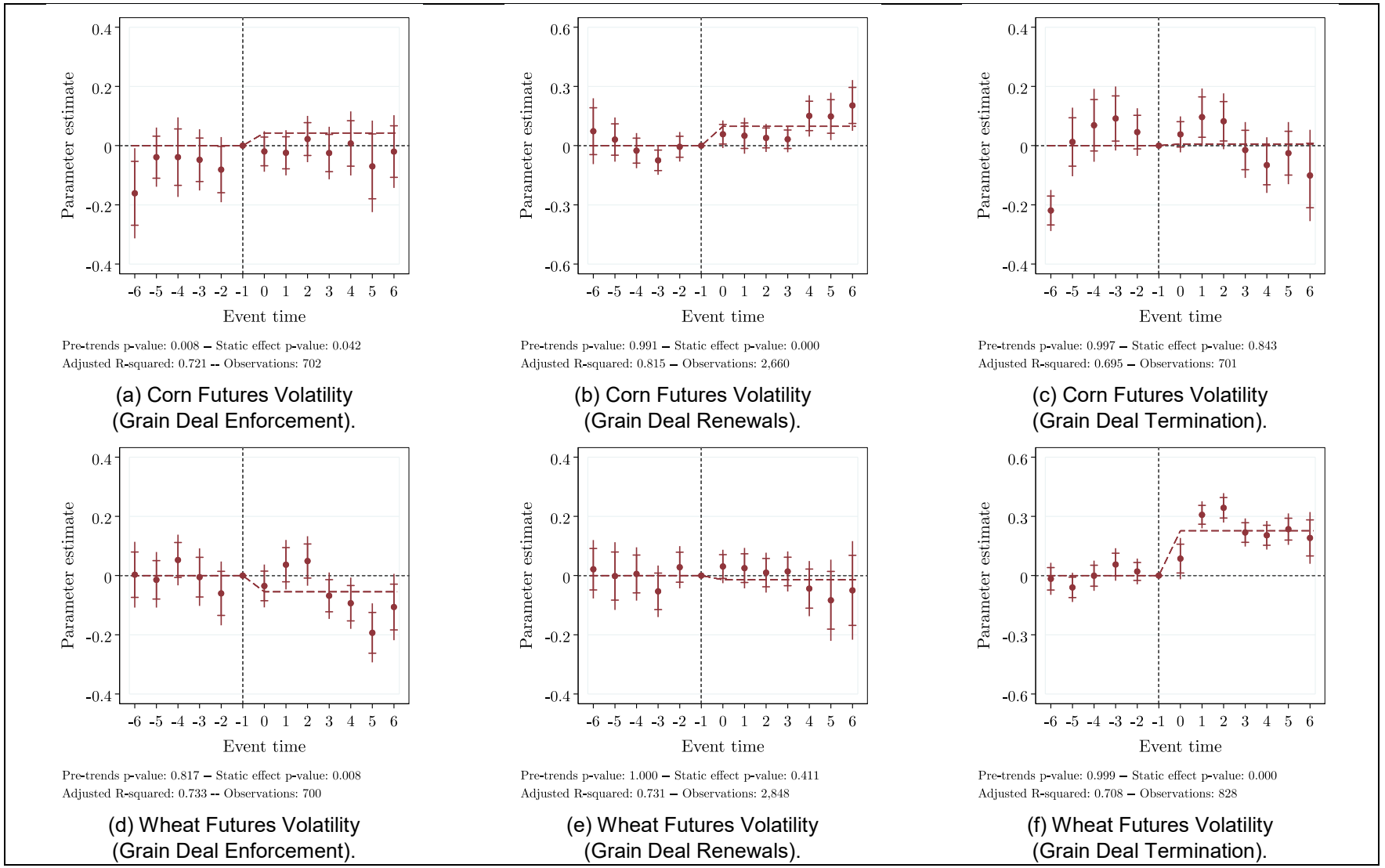

Figure 4. Event Studies for Corn and Wheat Futures Historical Volatility

Note: The figure shows the dynamic treatment estimates, 95 percent confidence intervals, and uniform sup-t bands for the event-time coefficients. The event time is measured in weeks relative to the treatment. We centered the event studies around key events during the Black Sea Grain Initiative timeline. These events are the Grain enforcement in week 29 of 2022, the three renewals treated as one event (week 46 of 2022, week 11 of 2023, and week 20 of 2023), and the Grain Deal termination in week 29 of 2023. We report several Wald tests and regression statistics in the figure notes and overlay estimates for a linear regression specification as a dotted line. We used a log-linear regression specification and included commodity-event-day, commodity-event-week, and commodity-event-year fixed effects in each regression.
Source: authors' own calculations

This finding suggests that a static regression model may not fully capture the actual event's effect (Freyaldenhoven, Hansen and Shapiro, 2019; Sun and Abraham, 2021; Roth, 2022). The futures prices for both commodities exhibited a downward trend before the enforcement. The establishment of the EU Solidarity Lanes in May 2022, enabling expanded Ukrainian agricultural shipments via road, rail, and Danube ports (Carter and Steinbach, 2023a), likely influenced these trends. Additionally, under mounting international pressure, Russia's move to a more moderate stance on safe grain exports from Ukrainian ports might have contributed to these trends (Associated Press, 2022). While the latter is closely relevant to the enforcement of the deal and thus to our estimation, it is important to acknowledge that it was not a risk-free environment for commodity traders, particularly considering the ongoing political and regional tensions. The event studies also show that post-event, corn futures prices were 7.8 percent above the counterfactual, while wheat prices were 4.2 percent lower. Although the signs of the coefficients are as anticipated for wheat, their magnitudes are not as substantial as expected, given the significant surge in Ukrainian wheat shipments beginning in August 2022. We observe that prices had already decreased to pre-war levels before enforcement. Also, the rise in corn futures prices following implementation, despite the increased Ukrainian corn supply in the global market, does not align with the hypothesis. Furthermore, following the enforcement of the Grain Deal, a notable decrease in historical volatility was observed, with reductions of 1.8 percent for corn and 5.7 percent for wheat. This trend indicates that the Black Sea Grain Initiative enforcement had a relatively minor influence on the historical volatility of corn and wheat futures prices.

Focusing on the three Grain Deal renewals, we find they had a minimal market impact, with corn futures averaging 0.9 percent below and wheat 2.5 percent below the counterfactual. This pattern suggests that commodity traders did not view the recurring Russian threats of canceling the agreement as credible during this period. Despite the expectation that the deal renewals would stabilize prices, it is not entirely surprising that we do not observe a notable price decrease, even in the face of Russian threats to terminate the agreement. One possible explanation for this low market response is the already settled prices before the agreement. Additionally, the perceived importance of the deal to both parties might have influenced market responses, as the deal also provided Russia with a crucial outlet for its agricultural exports. According to our counterfactual estimates, the historical volatility for corn futures displayed a marked increase after the renewals of the Grain Deal. Specifically, the volatility for corn was approximately 10.2 percent higher than the counterfactual level within the first six weeks following the renewals, whereas wheat exhibited a slight reduction of about 1.4 percent. The observed differences in historical volatility for corn and wheat futures following the renewals could be attributed to various factors specific to the commodities rather than the deal itself.

Following the Grain Deal termination, corn futures prices rose 5.6 percent above the counterfactual within six weeks, while wheat prices were 1.9 percent below. Initially, grain futures prices spiked for two weeks post-termination. However, as it became apparent that grain shipments via Danube ports were not ultimately threatened, corn and wheat futures prices returned to pre-termination levels. During the period from the Russian invasion to the termination of the Black Sea Grain Initiative, the enhanced connectivity and transportation capacity for Ukrainian agricultural products, facilitated by significant infrastructure investments through the EU-Ukraine Solidarity Lanes, reduced Ukraine's dependency on the Black Sea routes (European Commission, 2023). Additionally, Russia's relatively moderate approach to renegotiation, possibly in exchange for the lifting of Western sanctions, and its commitment to supplying free grain to African nations after the withdrawal helped mitigate significant price volatilities in the market. Upon the termination of the Black Sea Grain Initiative, the historical volatility for corn remained relatively stable, while wheat's volatility surged by 25.4 percent. This divergence in volatility trends is attributable to the market's anticipation of disruptions in wheat exports from all Black Sea ports, reflecting the significant role of Ukraine and Russia in the global wheat market. While Ukraine and Russia have a combined market share of about 24.0 percent in global wheat markets, their combined share in the global corn market is less than 13.0 percent,

implying that the larger response in the wheat futures market is likely driven by the expectation of a potential complete shutdown of wheat exports via Black Sea ports (United Nations, 2023).

5 Robustness Checks

Linear Pre-Trend Adjusted Post-Event Treatment Paths — The potential of statistically meaningful pre-trends before the Black Sea Grain Initiative, its renewals, and the Grain Deal termination requires us to be cautious about a causal interpretation of the post-event treatment paths (Freyaldenhoven, Hansen and Shapiro, 2019; Marcus and Sant'Anna, 2021). One of the benefits of a dynamic model specification is that it allows us to avoid estimation bias from averaging over the pre-event periods. At the same time, we have to assume that treated units would have continued on the same growth path as non-treated units after the events. To account for the potential impact of pre-trends and treatment anticipation, we estimate Equation 1 under the alternative assumption that treated units would have continued on their pre-event paths. We follow the approach developed by Dobkin et al. (2018) and fit a deterministic linear trend in event time with a commodity-specific slope. We overlay the estimated linear pre-trends in Appendix Figure A.1 and show post-event treatment paths with subtracted linear pre-trends in Appendix Figure A.2.[7] We report the commodity-specific slope coefficients for each event in the sub-figure notes. The estimated linear pre-trends are statistically significant for most outcomes. After subtracting the linear pre-trends from the post-event treatment estimates, we find considerable evidence of treatment anticipation for the Black Sea Grain Initiative. Assuming that corn and wheat futures prices would have contained on their pre-event paths, they would have been 22.3 percent and 20.6 percent, respectively, above the counterfactual level after the event.[8] After accounting for pre-trends, there is little evidence of a statistically significant impact of the Grain Deal renewals on corn and wheat futures prices. Once the Black Sea Grain Initiative was terminated, the corn futures price was 12.8 percent above and the wheat futures price 10.2 percent below the counterfactual level after accounting for linear pre-trends.

Falsification Tests — A potential concern regarding our identification strategy is the availability of a reliable and transparent control group. To address this concern, we followed earlier work on the response of global trade to the Russian invasion of Ukraine (see, e.g., Ahn, Kim and Steinbach, 2023; Steinbach, 2023) and constructed the counterfactual using corn and wheat futures time series from previous years. These time series have the advantage of exhibiting similar seasonality patterns as the outcomes of interest. At the same time, it would be inappropriate to use time series for other commodities to construct the control group since they may also be affected by the enforcement, renewals, and termination of the Black Sea Grain Initiative. First, we assigned a pseudo-treatment to 2007 based on the calendar weeks of the four events and replicated the main results. The results of this analysis are presented in Appendix Figure A.3. Focusing on the response of grain futures markets to the Black Sea Grain Initiative, we find limited evidence of statistically significant post-event treatment effects for corn and wheat, with average treatment effects of 5.4 percent and 2.1 percent, respectively. At the same time, these average post-event treatment effects are statistically insignificant at conventional levels. Second, we use soybeans and rice as alternative outcomes. Since the combined share of Russia and Ukraine is less than 2 percent for soybeans and negligible for rice, these outcomes should be unaffected by market uncertainty caused by the Russia-Ukraine war. The results of this analysis are presented in Appendix Figure A.4 and provide no evidence for statistically significant post-event treatment effects for both outcomes. This pattern suggests that the Russia-Ukraine conflict did not affect soybean and rice futures markets. There is little evidence that the Black Sea Grain Initiative or the three renewals of the Grain Deal changed the

[7] Event studies for historical volatility that control for linear pre-trends are available upon requests from the authors. Excepting the one for the corn futures price before the Grain Deal enforcement, the linear trend coefficients for all other regressions are statistically insignificant at conventional levels.

[8] Note that due to anticipation effects, the true treatment effects of the Black Sea Grain Initiative are likely in between the main estimates and those adjusted for linear pre-trends.

expectations in soybean and rice futures markets. At the same time, there is also no evidence of significant post-event treatment effects after the termination of the Grain Deal.

6 Conclusion

This paper assessed the response of grain futures markets to the Black Sea Grain Initiative. We utilized detailed futures price data series, counterfactual statistical techniques, and event study methods. Our analysis revealed that within the first six weeks following the enforcement of the Grain Deal, the corn futures price increased by 7.8 percent, while the wheat futures price decreased by 4.2 percent. Grain traders likely anticipated the successful enforcement of the Black Sea Grain Initiative, with corn and wheat futures prices starting to come down after the establishment of the EU Solidarity Lanes in May 2022. The agreement allowed Ukraine to resume agricultural exports via road, rail, and the Danube ports. In addition, favorable growing conditions in other grain production regions and relatively high global stocks made up for any shortfalls in grain exports from Ukraine (Ahn, Kim and Steinbach, 2023). The subsequent minimal impact of the Grain Deal renewals, with corn futures averaging 0.9 percent below and wheat 2.5 percent below the counterfactual, contrasts with the previous narrative that highlights the influence of those events on agricultural commodity prices (World Trade Organization, 2023). Terminating the Black Sea Grain Initiative caused a temporary shift in grain futures market dynamics. Following its termination, the increase of the corn futures price to 5.6 percent above and the decrease of the wheat futures price to 1.9 percent below the counterfactual level highlight the short-lasting response to increased market uncertainty. The surge in wheat volatility by 25.4 percent post-event is particularly revealing. This reaction underscores the crucial role of the Black Sea region in global wheat trade (Carter and Steinbach, 2023*b*).

The applied event studies approach contrasts with traditional time series and static regression approaches by providing a more nuanced understanding of the grain futures market dynamics in response to the Black Sea Grain Initiative. We rely on the recently developed approach by Carter and Steinbach (2023a) to identify reliable counterfactuals for causal inference based on pretreatment trends. This methodological advancement contributes to a more causal analysis of how such events influence agricultural commodity markets, expanding upon previous studies that have typically adopted static regression approaches. Our findings contribute to the existing body of knowledge by highlighting the complex impacts of the Black Sea Grain Initiative on grain futures markets. In line with Carter and Steinbach (2023a) and Goyal and Steinbach (2023), we show that the Grain Deal was not the predominant factor driving price declines. Instead, corn and wheat prices declined before the Grain deal became effective. Furthermore, our analysis indicates a lack of contagion effects for agricultural commodities not directly impacted by the Russian invasion of Ukraine. Specifically, we observe only marginal change in soybean and rice futures prices in response to the Grain Deal and no change after the termination. The findings suggest that market participants acted rationally by anticipating that the disruptions in global grain markets would be temporary and only localized, resulting in limited contagion effects for agricultural commodities not directly impacted by the Russia-Ukraine war.

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Appendix

Table A.1. Augmented Dickey-Fuller Unit Root Tests

	Corn	Wheat	Rice	Soybeans
Panel (a): Futures Price				
Z(t)	−2.042	−2.560	−1.843	−2.029
p-value for Z(t)	0.021	0.005	0.033	0.021
Panel (b): Historical Volatility				
Z(*t*)	−5.564	−5.423	−6.541	−5.811
p-value for Z(t)	0.000	0.000	0.000	0.000

Note: The table shows augmented Dickey-Fuller unit root tests for the futures price and historical volatility of all commodities. The null hypothesis is a random walk with non-zero drift. We use the MacKinnon approximation of the *p*-value for Z(t) based on the critical value of 1%.
Source: authors' own calculations

Table A.2. List of Commodities, Future Exchanges, and Delivery Months

Commodity	Commodity Exchange	Maturity Dates	Delivery Months
Corn	Chicago Board of Trade	All are the last trading day of the current contract	March, May, July, September, December
Rice	Chicago Board of Trade		January, March, May, July, September, November
Soybeans	Chicago Board of Trade		January, March, May, July, August, September, November
Wheat	Chicago Board of Trade		March, May, July, September, December

Note: The table shows where agricultural commodities are traded in futures exchanges, detailing the maturity dates and delivery months of the contracts. We collected data on every agricultural futures contract with specific delivery months from 2000 to 2023. To create a continuous price series, we use the *n*-th nearest contract method and switch between contracts on their final trading days. Thus, the dataset reflects actual values for each trading day.
Source: authors' own calculations

Table A.3. Descriptive Statistics

	Obs.	Mean	SD	Min	Max
Corn Futures Price	6,979	407.41	154.14	184.50	838.75
Corn Historical Volatility	6,979	21.61	8.24	6.79	48.85
Rice Futures Price	6,979	11.54	3.73	3.50	24.82
Rice Historical Volatility	6,979	19.15	8.82	5.84	71.14
Soybeans Futures Price	6,979	980.21	314.76	420.75	1,763.50
Soybeans Historical Volatility	6,979	18.61	8.45	6.99	60.80
Wheat Futures Price	6,979	533.11	172.09	242.75	1,282.50
Wheat Historical Volatility	6,979	23.62	7.09	8.81	55.91

Note: The table presents the number of observations, mean, standard deviation (SD), minimum, and maximum values of the time series used in the analysis.
Source: authors' own calculations

Table A.4. Descriptive Comparison

	In 2022		In 2023		
	Week 29	**Week 46**	**Week 11**	**Week 20**	**Week 29**
Panel (a): Before the Event					
Corn Futures Price	668.00	682.03	660.01	614.08	552.76
	(62.69)	(10.59)	(23.24)	(26.69)	(48.07)
Corn Futures Historical Volatility	27.28	13.28	11.77	15.37	32.15
	(5.29)	(2.18)	(0.56)	(1.32)	(6.89)
Wheat Futures Price	946.98	860.69	740.94	662.12	666.30
	(111.49)	(32.62)	(36.63)	(27.35)	(40.70)
Wheat Futures Historical Volatility	35.37	34.16	18.31	20.79	29.33
	(2.04)	(1.66)	(0.87)	(1.08)	(2.61)
Soybean Futures Price	1,465.87	1,403.54	1,521.82	1,450.41	1,326.33
	(107.85)	(31.88)	(14.25)	(39.40)	(45.89)
Soybean Futures Historical Volatility	28.05	16.40	11.38	12.29	33.11
	(3.99)	(2.91)	(0.56)	(0.43)	(8.26)
Rice Futures Price	16.58	17.03	17.44	16.72	15.28
	(0.25)	(0.54)	(0.53)	(0.84)	(0.29)
Rice Futures Historical Volatility	17.69	11.12	13.72	21.75	19.67
	(1.20)	(2.09)	(0.98)	(7.53)	(9.76)
Panel (b): After the Event					
Corn Futures Price	622.46	660.11	631.79	580.46	505.42
	(29.79)	(12.19)	(19.37)	(28.96)	(26.97)
Corn Futures Historical Volatility	30.14	10.83	13.71	24.78	34.16
	(4.92)	(0.52)	(1.40)	(7.07)	(6.63)
Wheat Futures Price	798.76	778.97	682.53	648.87	655.81
	(21.98)	(32.67)	(20.93)	(47.40)	(44.20)
Wheat Futures Historical Volatility	36.20	25.65	20.44	26.88	40.35
	(3.25)	(4.39)	(0.91)	(2.13)	(3.56)
Soybean Futures Price	1,406.60	1,464.20	1,469.50	1,323.25	1,360.49
	(40.97)	(27.65)	(31.31)	(43.12)	(38.56)
Soybean Futures Historical Volatility	27.92	13.67	11.62	23.25	24.35
	(3.26)	(0.61)	(1.02)	(10.84)	(8.59)
Rice Futures Price	17.18	17.63	17.21	15.19	15.93
	(0.34)	(0.58)	(0.35)	(0.34)	(0.34)
Rice Futures Historical Volatility	14.03	13.49	17.12	27.28	14.92
	(1.25)	(1.17)	(1.12)	(9.81)	(0.99)

Note: The table shows a before and after the event comparison for the main outcomes. The statistics were calculated for the pre-event and post-event period of six weeks around the enforcement of the Black Sea Grain Initiative (week 29 of 2022), the first renewal of the Grain Deal (week 46 of 2022), the second renewal of the Grain Deal (week 11 of 2023), the third renewal of the Grain Deal (week 20 of 2023), and the termination of the Grain Deal (week 29 of 2023). The calculated mean and standard deviation are reported in brackets.
Source: authors' own calculations

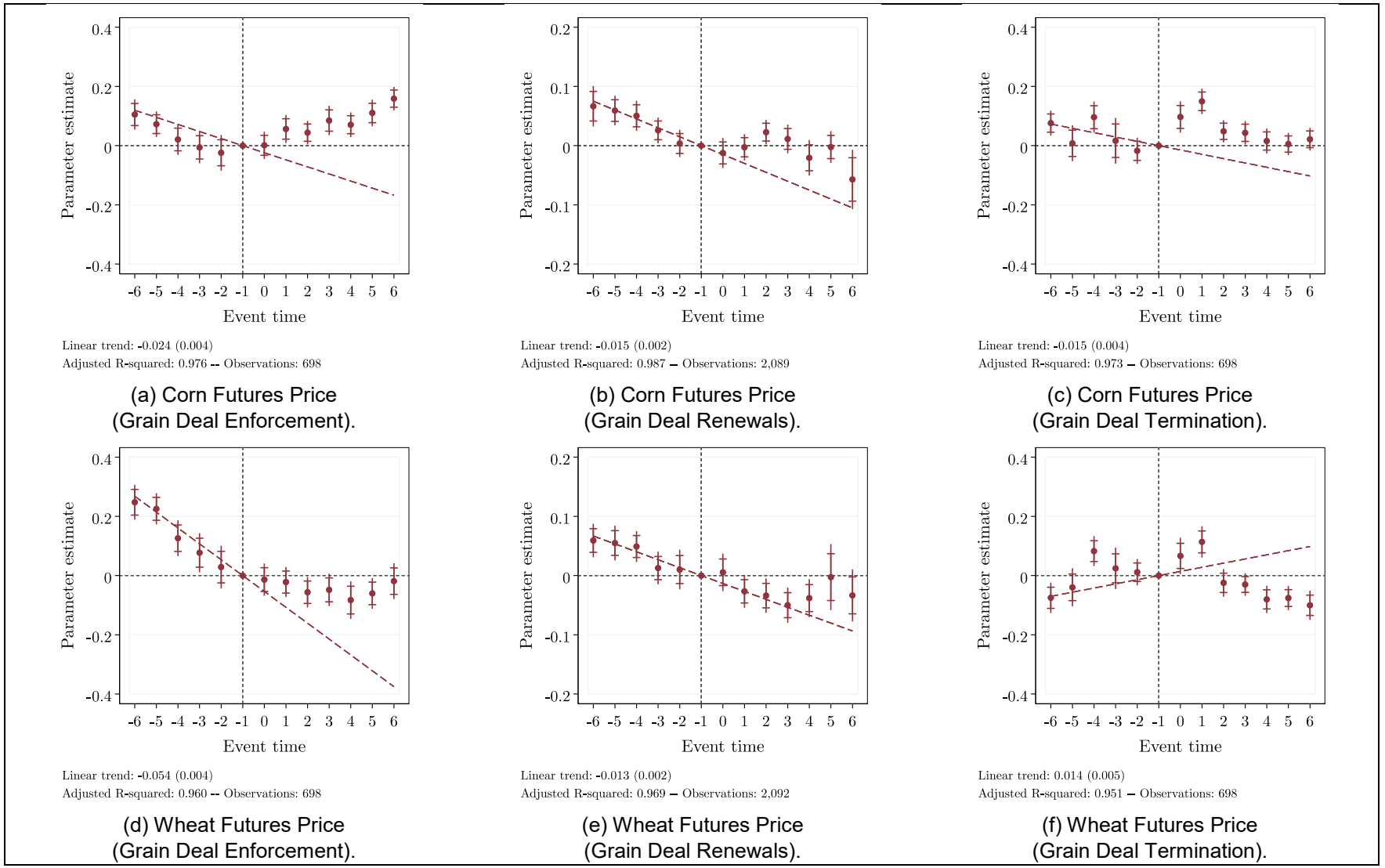

Figure A.1. Overlaid Linear Pre-Trends for Corn and Wheat Futures Prices

Note: The figure shows the dynamic treatment estimates, 95 percent confidence intervals, and uniform sup-t bands for the event-time coefficients. The event time is measured in weeks relative to the treatment. We centered the event studies around key events during the Black Sea Grain Initiative timeline. These events are the Grain enforcement in week 29 of 2022, the three renewals treated as one event (week 46 of 2022, week 11 of 2023, and week 20 of 2023), and the Grain Deal termination in week 29 of 2023. We report several Wald tests and regression statistics in the figure notes and overlay estimates for a linear regression specification as a dotted line. We used a log-linear regression specification and included commodity-event-day, commodity-event-week, and commodity-event-year fixed effects in each regression.
Source: authors' own calculations

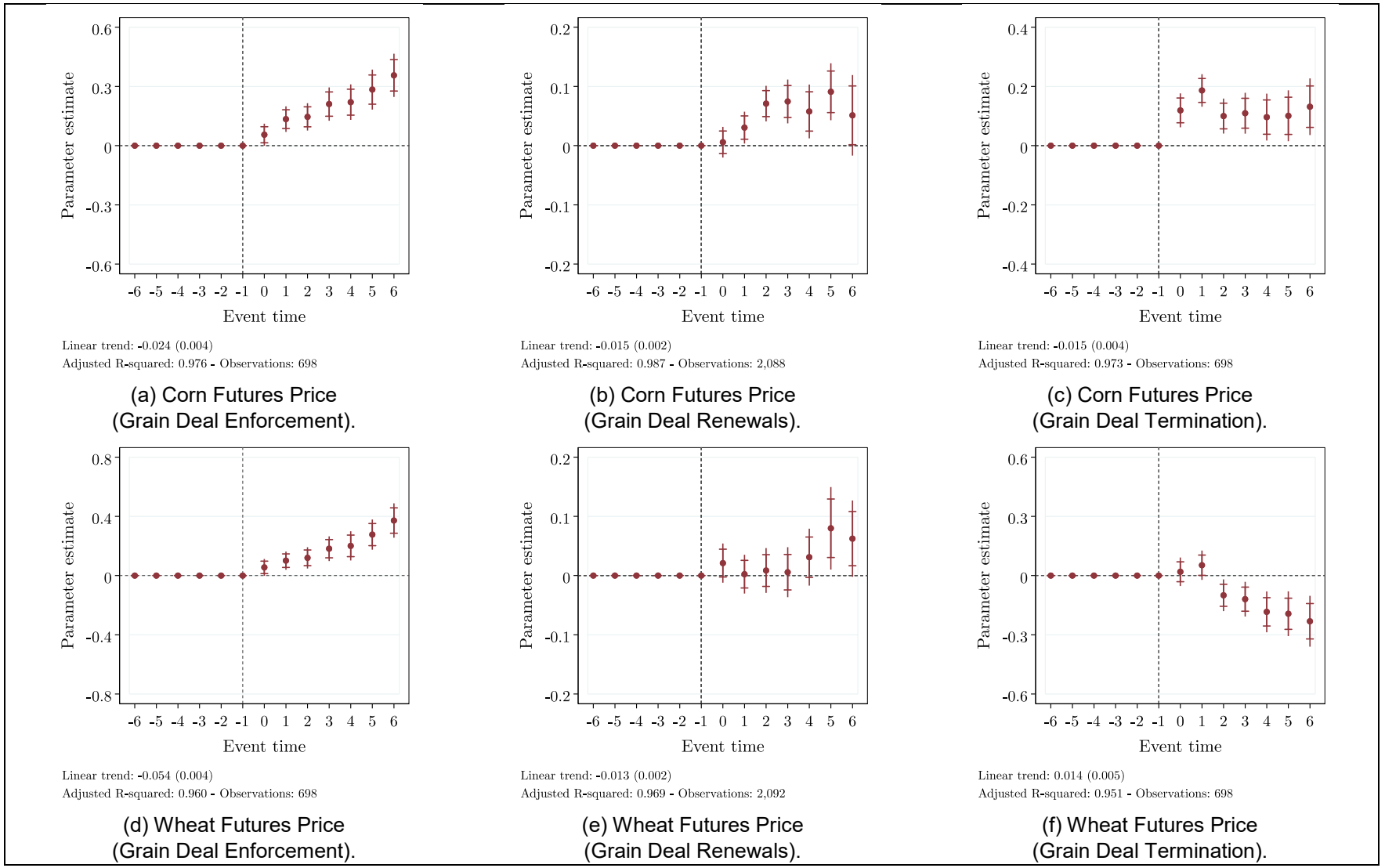

Figure A.2. Subtracted Linear Pre-Trends for Corn and Wheat Futures Prices

Note: The figure shows the dynamic treatment estimates, 95 percent confidence intervals, and uniform sup-t bands for the event-time coefficients. The event time is measured in weeks relative to the treatment. We centered the event studies around key events during the Black Sea Grain Initiative timeline. These events are the Grain enforcement in week 29 of 2022, the three renewals treated as one event (week 46 of 2022, week 11 of 2023, and week 20 of 2023), and the Grain Deal termination in week 29 of 2023. We report several Wald tests and regression statistics in the figure notes and overlay estimates for a linear regression specification as a dotted line. We used a log-linear regression specification and included commodity-event-day, commodity-event-week, and commodity-event-year fixed effects in each regression.
Source: authors' own calculations

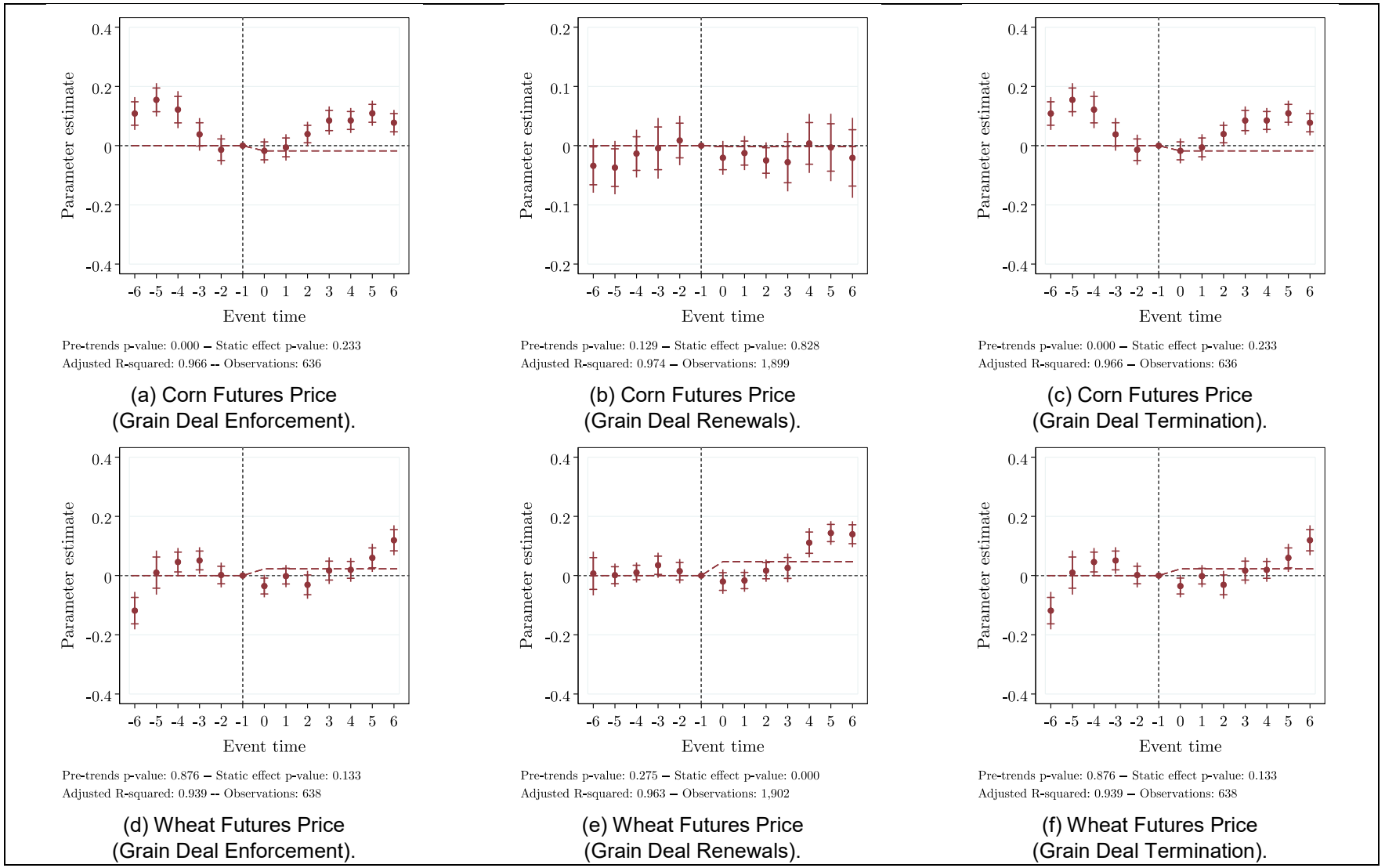

Figure A.3. Falsification Tests for Corn and Wheat Futures Prices in 2007

Note: The figure shows the dynamic treatment estimates, 95 percent confidence intervals, and uniform sup-t bands for the event-time coefficients. The event time is measured in weeks relative to the treatment. We centered the event studies around key events during the Black Sea Grain Initiative timeline. These events are the Grain enforcement in week 29 of 2022, the three renewals treated as one event (week 46 of 2022, week 11 of 2023, and week 20 of 2023), and the Grain Deal termination in week 29 of 2023. We report several Wald tests and regression statistics in the figure notes and overlay estimates for a linear regression specification as a dotted line. We used a log-linear regression specification and included commodity-event-day, commodity-event-week, and commodity-event-year fixed effects in each regression.
Source: authors' own calculations

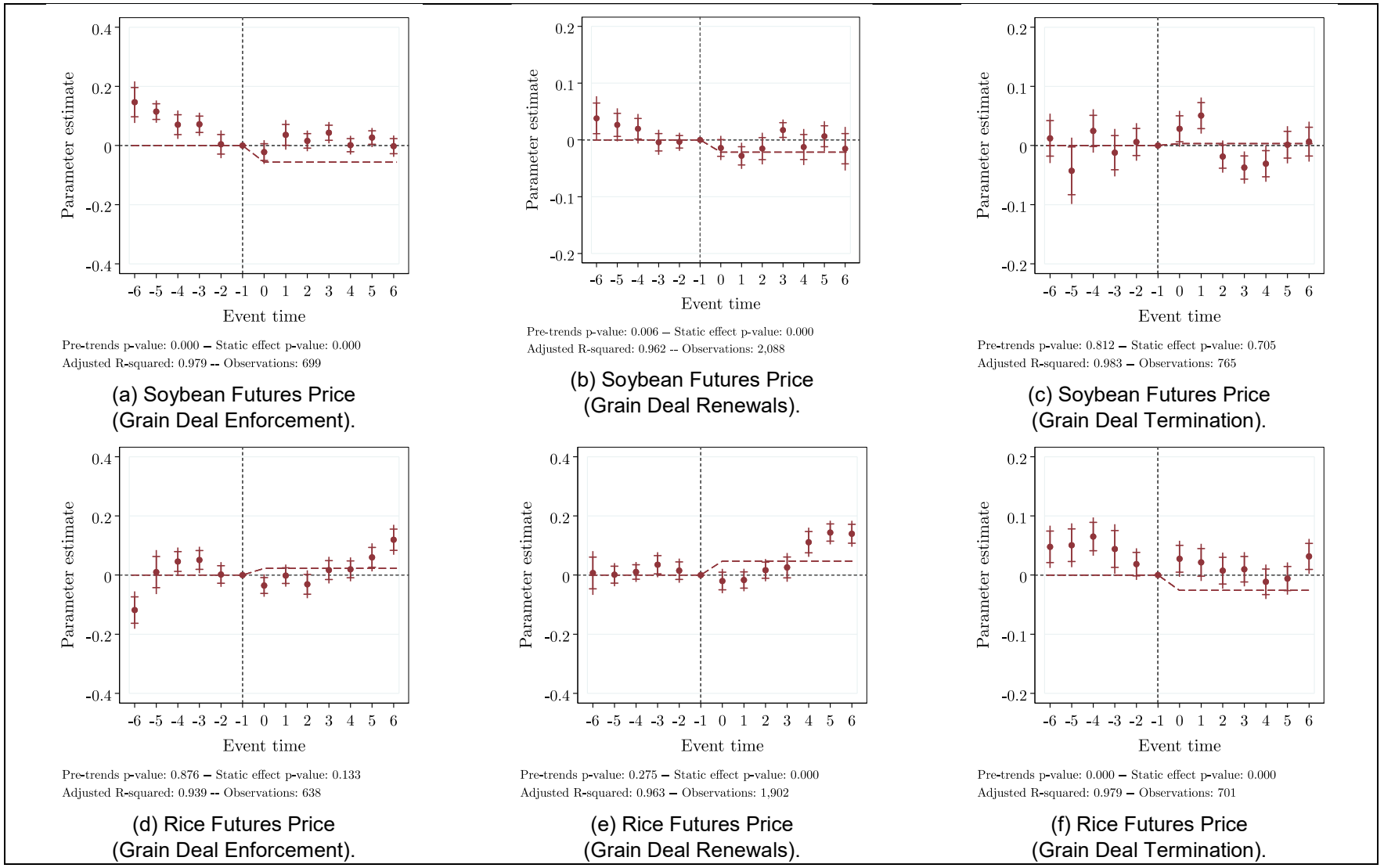

Figure A.4. Falsification Tests for Soybean and Rice Futures Prices

Note: The figure shows the dynamic treatment estimates, 95 percent confidence intervals, and uniform sup-t bands for the event-time coefficients. The event time is measured in weeks relative to the treatment. We centered the event studies around key events during the Black Sea Grain Initiative timeline. These events are the Grain enforcement in week 29 of 2022, the three renewals treated as one event (week 46 of 2022, week 11 of 2023, and week 20 of 2023), and the Grain Deal termination in week 29 of 2023. We report several Wald tests and regression statistics in the figure notes and overlay estimates for a linear regression specification as a dotted line. We used a log-linear regression specification and included commodity-event-day, commodity-event-week, and commodity-event-year fixed effects in each regression.
Source: authors' own calculations