

## Article

# International Price Transmission in Chinese Grain Futures Markets: Determinants, Channels, and Implications for Food Security

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## Abstract

Grain price stability is fundamental to global food security, yet the extent to which major grain futures markets contribute to international price discovery and transmit price signals across borders remains insufficiently understood. This study constructs a measurement–mechanism–pathway framework to analyze the international price transmission dynamics of four grain futures: wheat, rice, corn, and soybean. We apply the Diebold–Yilmaz spillover index, OLS regressions with mediation analysis, and fsQCA. All four crops display predominantly negative net spillover indices, with rice exhibiting the strongest transmission and soybean the weakest. At the domestic level, yield is associated with stronger price transmission through an inventory channel, while the effects of price regulation are asymmetric. Notably, soybean producer subsidies are unexpectedly associated with stronger rather than weaker international price transmission. At the international level, crude oil prices are associated with weaker grain price transmission primarily through the freight cost channel, and speculative capital is associated with reduced transmission capacity through tail-price episodes. Configuration analysis reveals two shared improvement routes, namely capacity building with policy support and risk containment via volatility suppression, together with four commodity-specific pathways. These findings provide systematic evidence and policy insights for mitigating grain price contagion and strengthening food system resilience.

**Keywords:** grain futures markets; international price transmission; asymmetric price adjustment; market integration; fsQCA



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## 1. Introduction

As economic globalization deepens alongside mounting geopolitical tensions, safeguarding food supplies has risen to the forefront of national strategic priorities. Contemporary grain markets are increasingly shaped by financial speculation and energy-market linkages, generating price swings that undermine affordability and supply reliability, a burden borne disproportionately by import-reliant developing nations [1–3]. Advanced economies, spearheaded by the United States, dominate global grain price determination through well-established futures infrastructures. Developing economies such as China, despite occupying a major share of trade volumes, find themselves constrained to a price-taking role, continually subject to spillovers from crude oil volatility and speculative capital

flows. This structural imbalance in pricing authority magnifies the propagation of external price disturbances into domestic food supply chains, posing direct challenges to food security governance.

Strengthening the pricing leverage of grain futures is therefore vital, not only for buffering external market disturbances and preserving price stability, but also for curtailing cross-border price contagion and protecting domestic food systems. Unpacking the drivers and channels behind this pricing subordination is crucial in formulating policies that enhance food system resilience. Yet the existing literature exhibits three notable shortfalls. On the measurement front, rigorous quantitative indicators and dynamic, time-varying assessments remain scarce [4–6]. On the mechanism front, how domestic supply-side factors (grain yield, price regulation) and external disturbances (crude oil prices, financial speculation) jointly shape pricing power has received limited systematic attention. On the pathway front, multi-factor configurational effects and crop-differentiated improvement routes have largely gone unidentified [7,8].

International pricing power refers to a country's ability to lead, rather than follow, price discovery in international grain markets. It is distinct from price transmission, which describes the bilateral flow of price signals without indicating which side dominates. The Diebold–Yilmaz net spillover index operationalizes this distinction by netting the spillover from the Chinese futures market to the international market against the reverse flow. A positive (or less negative) index means that Chinese quotations are, on balance, the source of the information incorporated into international prices; a negative index means that Chinese prices chiefly absorb foreign signals. A higher index therefore signals stronger pricing power.

Recent studies closest to this paper nonetheless address only part of its scope. TVP-VAR connectedness and risk-spillover frameworks have measured spillovers across global grain markets and between Chinese and US futures [9,10], and PLS-SEM has been applied to trace corn price formation [11]. None, however, isolates a crop-specific net pricing-power index, or combines domestic drivers, external shocks, and configurational pathways in a single framework. This investigation differs from these studies in measurement, mechanism, and pathway—and in using a longer four-crop monthly panel.

To fill these gaps, the present paper develops an integrated measurement–mechanism–pathway framework centered on China's four principal grain futures. First, the Diebold–Yilmaz (DY) spillover index [12] is adopted to construct a time-varying pricing power metric derived from the dynamic net spillover between domestic and international futures quotations. Throughout this report, “international pricing power”, “pricing authority”, and “pricing leverage” are used interchangeably to denote the same construct, operationalized as the net spillover index; a higher (more positive) net spillover from the Chinese to the international market is interpreted as stronger pricing power. Second, a two-dimensional domestic-drive–external-shock framework is built to trace the transmission channels involving yield, policy interventions, crude oil prices, and speculative capital. Third, fuzzy-set qualitative comparative analysis (fsQCA) [13] is applied to uncover improvement pathways through a configurational lens.

This study provides three principal contributions. Methodologically, it bridges time-varying econometric estimation with causal configuration analysis by jointly deploying the DY spillover index and fsQCA. Theoretically, it offers a unified framework encompassing four internal and external factor categories, uncovering heterogeneous policy effects and distinct transmission pathways for external shocks. Empirically, it identifies two broadly shared improvement routes, namely capacity building coupled with policy reinforcement and risk buffering through volatility dampening, alongside crop-specific configurations [14,15]; notably, the counterintuitive positive impact of soybean producer

subsidies is rationalized via a price–subsidy decoupling mechanism. From a food-systems vantage, the results illuminate how domestic production capacity, price regulation, and external energy and financial disturbances jointly shape a country’s susceptibility to international grain price fluctuations, yielding actionable insights for food security policymaking.

The rest of this paper proceeds as follows. Section 2 reviews the relevant literature. Section 3 lays out the theoretical foundation and develops the research hypotheses. Section 4 describes the methodological approach. Section 5 details the data sources and reports the empirical findings. Section 6 discusses the results, draws conclusions, and identifies directions for future inquiry.

## 2. Literature Review

### 2.1. Conceptual Foundations of Grain Pricing Authority and Cross-Market Price Diffusion

Scholarly inquiry into commodity pricing authority has shifted from an early emphasis on supply–demand fundamentals and information leadership toward exposing its financial and geopolitical underpinnings, highlighting the pivotal roles of currency denomination, futures platform supremacy, and interstate rivalry. Building on the structural power thesis, several researchers contend that commodity pricing leverage is embedded in the interplay of four dimensions: production, finance, knowledge, and security. Fundamentally, a country’s international grain pricing strength is gauged by how far its domestic quotations shape global grain prices and the degree of initiative it exercises in that bilateral interaction [1–3].

On the transmission side, earlier studies stressed the direct pass-through of import cost variations stemming from trade flows and exchange rate adjustments. Subsequent work uncovered information-driven channels, showing that international grain price fluctuations not only induce cross-commodity demand reallocations via substitution effects but also generate panic-driven supply-shortage expectations that indirectly elevate domestic grain prices [4,16]. A broad body of empirical evidence confirms that, as agricultural trade integration deepens, the penetration of global grain prices into domestic markets has become increasingly pronounced [17]. Nonetheless, some findings indicate that state procurement and reserve policies, along with import scale restrictions, can effectively buffer such external disturbances [18,19].

### 2.2. Determinants of Cross-Border Grain Price Pass-Through

The efficiency with which international grain prices propagate to domestic markets hinges on a confluence of interacting factors. To begin with, physical infrastructure and market microstructure lay the groundwork. Port facilities, warehousing capacity, and related logistics lower spatial arbitrage costs and facilitate cross-regional price alignment; yet large multinational grain merchants exploit their network dominance to mediate transmission and capture trade margins, generating substantial pass-through asymmetry.

Second, national trade policy and state intervention have attracted increasing scholarly interest. Heavy import reliance exposes certain grain types more directly to global market volatility [5]. Instruments such as tariff barriers, import quotas, and export bans substantially reshape price transmission routes: measured intervention can dampen external disturbances [6], yet counter-cyclical trade restrictions risk severing the domestic–international price nexus and sparking retaliatory protectionism at the global scale, thereby heightening instability across the international grain price system [20,21].

Third, exogenous disturbances and financial factors stand out as particularly salient drivers. Severe weather episodes directly impair supply, while crude oil quotations exert a pronounced, asymmetric upward pressure on grain prices by inflating agricultural production costs and stimulating biofuel demand [22–26]. As grain markets become increasingly financialized, the surge in international speculative capital distorts price formation and magnifies risk resonance between commodity and financial markets, intensifying volatility contagion [27,28].

### 2.3. Research Gaps

Taken together, prior scholarship has established a solid foundation for understanding commodity pricing authority and cross-border price transmission, yet three notable lacunae persist. First, on the measurement front, systematic dynamic assessment of the directional and net-intensity properties of price information spillovers remains absent [11,29–31]. Second, on the mechanism front, an integrated analysis that jointly considers domestic supply-side factors and external disturbances within a dual-dimensional framework is still lacking [9,32,33]. Third, on the pathway front, multi-factor configurational effects and crop-differentiated improvement routes have yet to be systematically identified from a configurational standpoint [7,8,34–36].

The present study tackles these gaps on three fronts: it deploys the DY spillover index [9] to capture the time-varying dynamics and net spillover structure of grain pricing power; it builds a systematic analytical framework anchored in the structural power thesis across the production, finance, knowledge, and security dimensions; and it applies fsQCA [13] to discern, from both the high-outcome and low-outcome ends, the conjunctural pathways that shape pricing power. The resulting evidence enriches our understanding of the evolving trajectory and multi-factor underpinnings of Chinese grain pricing authority.

## 3. Theoretical Basis and Research Hypotheses

Figure 1 sets out the structure of our analysis, which proceeds in three connected steps. We begin by measuring the international pricing power of Chinese grain futures, using the Diebold–Yilmaz spillover approach to obtain a net spillover index (NS) that we take as the dependent variable *Y*. We then ask how this pricing power comes about, and finally consider what could strengthen it or keep it from eroding; because the third step acts on *Y* itself, its effects can again be measured, closing the loop. In examining formation, we concentrate on four drivers and the routes through which they reach *Y*. Grain yield works mainly by shaping inventory buffers, while grain-price regulation operates more directly through price floors and policy insulation. The international crude oil price is transmitted along two routes, shipping costs and biofuel demand, and speculative capital makes itself felt through episodes of extreme price volatility, with the dollar index, the RMB index, EPU and China–US M2 held as controls. It is worth distinguishing the second step from the third. The mechanism analysis asks what one driver does to *Y* once the others are held fixed, whereas the enhancement path is concerned with how the drivers combine, so the two are better read as successive perspectives than as a single exercise repeated twice.

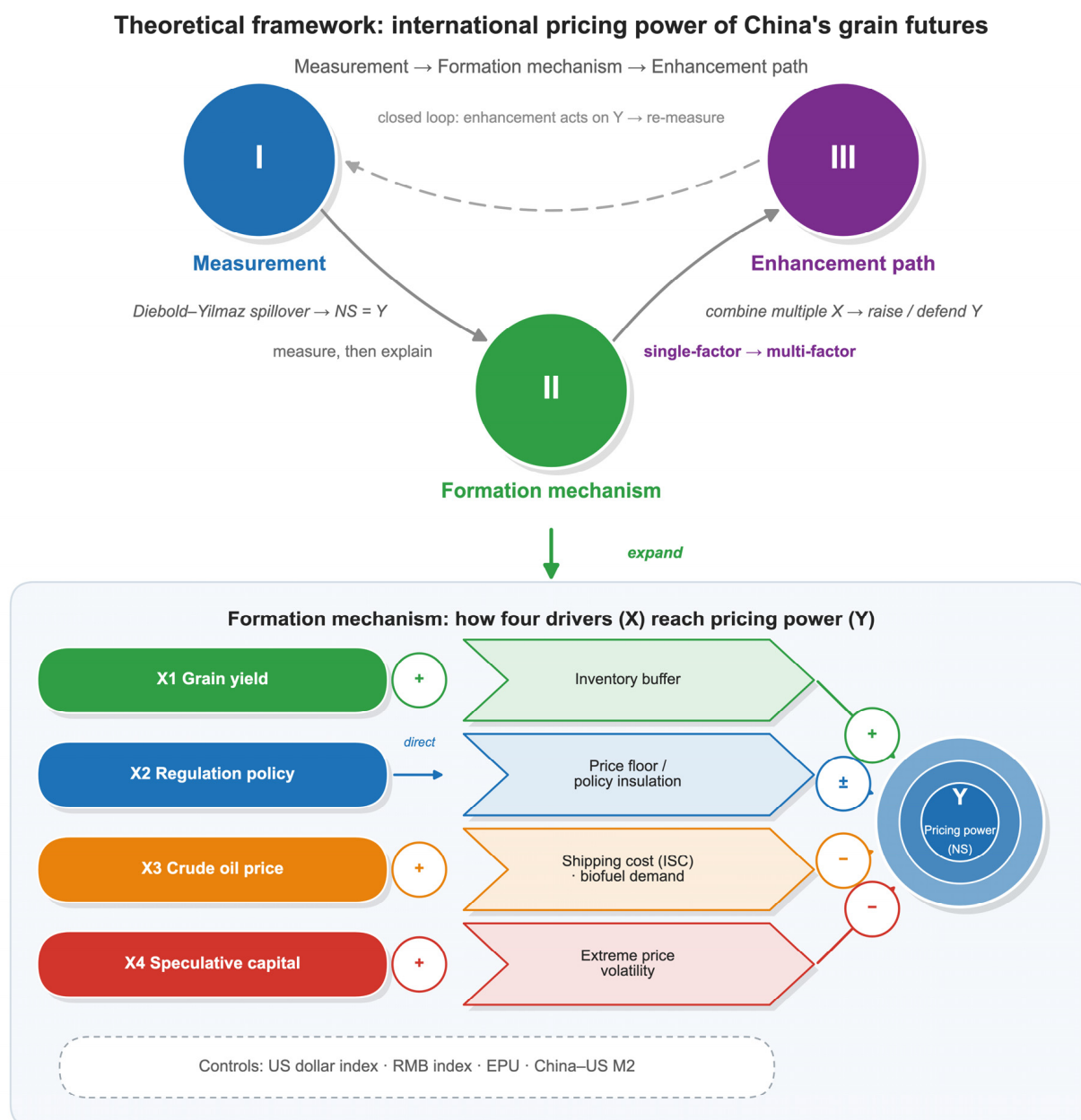


**Figure 1.** Theoretical framework for the international pricing power of Chinese grain futures: measurement, formation mechanism, and enhancement path.

### 3.1. How Grain Yield Shapes International Pricing Authority

Advances in grain yield provide the material bedrock for futures price discovery. Higher output is associated with a mediated pathway through an inventory buffering mechanism: sufficient reserves counteract externally originated risks, bolster the spot-hedging capacity underpinning futures markets, and constrain opportunistic manipulation by international capital. Accordingly, we posit:

**Hypothesis 1 (H1).** Grain yield is positively associated with the international pricing authority of Chinese grain futures, operating in part through the mediating channel of rising grain stocks.

### 3.2. How Price Regulation Policy Shapes International Pricing Authority

Chinese grain price regulation regime has evolved from rigid floor-price support toward market-oriented adjustment. Floor-support instruments (minimum purchase prices, temporary procurement reserves) set a price floor buttressed by state credibility, severing the transmission of external risks and bolstering pricing leverage. The subsequent shift to target price subsidies re-exposed domestic grain prices to global market forces, coinciding with weaker pricing authority. The later move to producer subsidies inaugurated a price–subsidy decoupling phase. The net directional impact of soybean producer subsidies remains an open empirical question. Accordingly, we posit:

**Hypothesis 2 (H2).** *Floor-support policies are associated with stronger pricing authority, the transition to target price subsidies with weaker pricing authority, and a further shift to producer subsidies with additional weakening. The net association of soybean producer subsidies is subject to empirical determination.*

### 3.3. How International Crude Oil Prices Shape International Pricing Authority

Crude oil quotations are associated with weaker pricing authority through two distinct channels. The first is a cost-push pathway: higher oil prices are associated with elevated freight expenses, skewing the domestic–international price basis and constraining pricing initiative. The second is a substitution-demand pathway: elevated oil prices are associated with higher biofuel consumption, diverting grain from food to energy uses, which coincides with sharp rises in corn and soybean demand and quotations that the Chinese futures market can scarcely absorb. Accordingly, we posit:

**Hypothesis 3 (H3).** *Higher international crude oil prices are associated with weaker pricing authority through two mediating routes: higher oil prices are associated with higher shipping costs and thus with weaker pricing leverage, while simultaneously corresponding to stronger biofuel demand that is further associated with weaker corn and soybean pricing authority.*

### 3.4. How International Speculative Capital Shapes International Pricing Authority

International speculative capital, proxied by CFTC non-commercial net long positions, displays procyclicality, yield-chasing tendencies, and herding behavior that readily trigger extreme price movements (EPMs) in global grain futures, severing their link to fundamentals. These irrational disturbances breach the defenses of the Chinese futures market through cross-border financial networks, are associated with impaired price discovery and a substantially reduced capacity for international price leadership. Accordingly, we posit:

**Hypothesis 4 (H4).** *Higher volatility in speculative capital within international grain futures is associated with weaker international pricing authority for China through amplified extreme price movements.*

## 4. Methods

Figure 2 illustrates the overall methodological architecture, organized around a three-stage sequence: pricing power quantification, mechanism uncovering, and pathway exploration. In the first stage, the DY spillover index captures dynamic net spillover effects between domestic and international grain futures quotations, yielding time-varying pricing power indices for the four target crops. In the second stage, regression models probe the formation mechanisms along two dimensions, namely domestic drivers and external shocks. In the final stage, fsQCA discerns improvement pathways from a configurational standpoint.

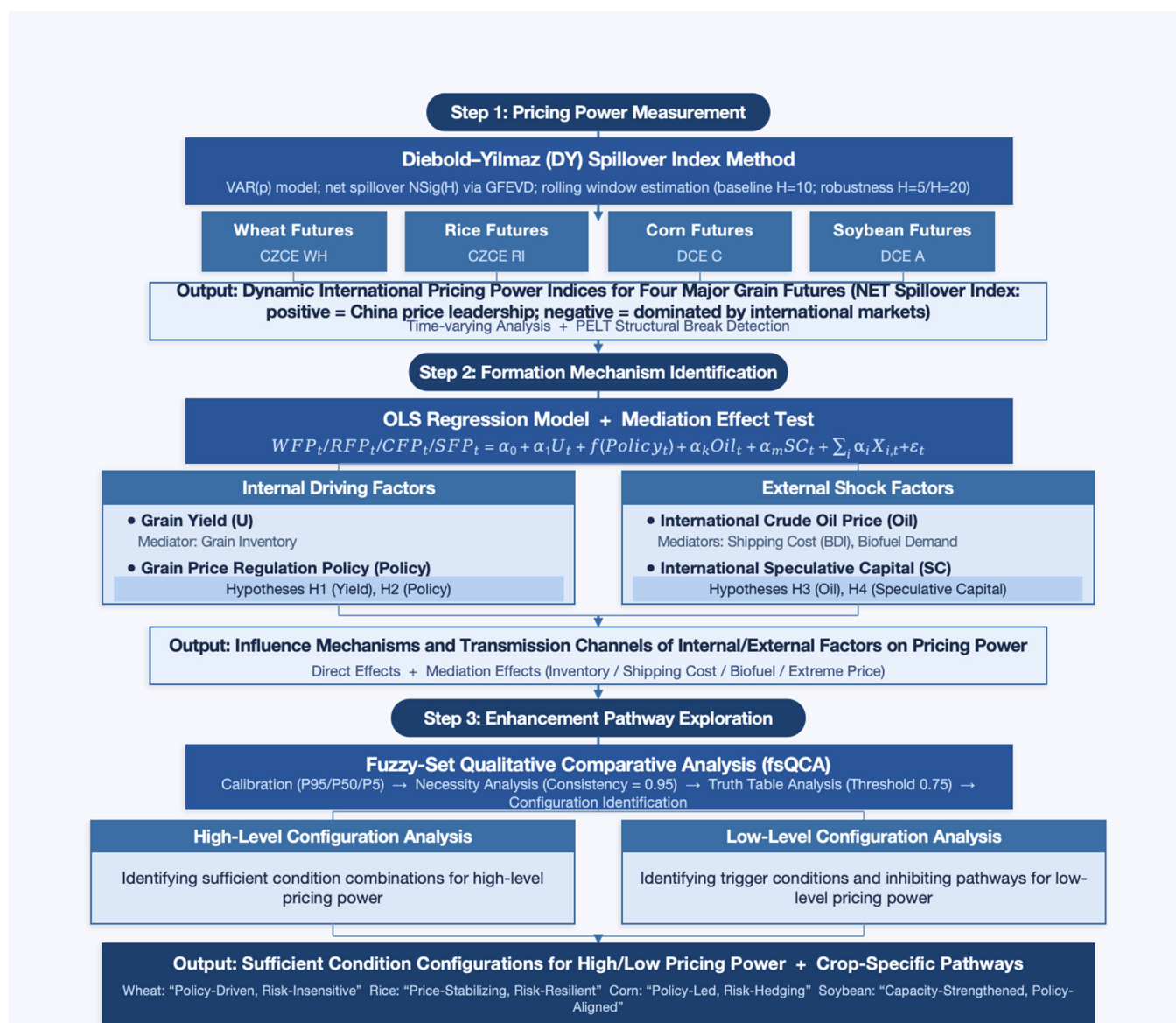


**Figure 2.** Research methodology flowchart. Note:  $WFP_t/RFP_t/CFP_t/SFP_t$  denote the international pricing power (dynamic net spillover index) for wheat, rice, corn, and soybean futures, respectively. CZCE: Zhengzhou Commodity Exchange; DCE: Dalian Commodity Exchange; GFEVD: generalized forecast error variance decomposition; PELT: pruned exact linear time; BDI: Baltic Dry Index;  $EPM_{i,t}$ : extreme price movement index of international grain futures, calculated as  $(High_{i,t} - Low_{i,t}) / Low_{i,t}$ .

#### 4.1. DY Spillover Index Approach

This paper adopts the DY spillover index framework introduced by Diebold and Yilmaz [12] to jointly model the international and domestic futures price series for each grain commodity. As a first step, the raw price sequences are transformed into logarithmic returns:

$$r_t = \ln(P_t \div P_{t-1}) \quad (1)$$

A vector autoregression (VAR) model is then estimated for each international–domestic futures return pair:

$$X_t = \phi_1 X_{t-1} + \phi_2 X_{t-2} + \cdots + \phi_p X_{t-p} + \varepsilon_t \quad (2)$$

In Equation (2),  $\phi_i (i = 1, 2, \dots, p)$  is an  $N \times N$  parameter matrix and  $\varepsilon_t \sim \text{i.i.d.}(0, \Sigma)$ . Generalized forecast error variance decomposition (GFEVD) is performed under this VAR framework to yield the share  $\theta_{ij}^g(H)$  of the  $H$ -step-ahead forecast error variance of market  $i$  attributable to shocks from market  $j$ . The normalized form is:

$$\tilde{\theta}_{ij}^g(H) = \theta_{ij}^g(H) \div \sum_{j=1}^N \theta_{ij}^g(H) \quad (3)$$

Based on the normalized matrix, the total spillover index TS (Equation (4)), directional spillover indices DS (Equations (5) and (6)), and net spillover index NS (Equation (7)) are constructed:

$$TS^g(H) = \left( \sum_{\substack{j=1 \\ i \neq j}}^N \tilde{\theta}_{ij}^g(H) \div \sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H) \right) \times 100 = \left( \sum_{\substack{j=1 \\ i \neq j}}^N \tilde{\theta}_{ij}^g(H) \div N \right) \times 100 \quad (4)$$

$$DS_{\cdot \rightarrow i}^g(H) = \left( \sum_{\substack{j=1 \\ j \neq i}}^N \tilde{\theta}_{ij}^g(H) \div \sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H) \right) \times 100 = \left( \sum_{\substack{j=1 \\ j \neq i}}^N \tilde{\theta}_{ij}^g(H) \div N \right) \times 100 \quad (5)$$

$$DS_{i \rightarrow \cdot}^g(H) = \left( \sum_{\substack{j=1 \\ j \neq i}}^N \tilde{\theta}_{ji}^g(H) \div \sum_{i,j=1}^N \tilde{\theta}_{ji}^g(H) \right) \times 100 = \left( \sum_{\substack{j=1 \\ j \neq i}}^N \tilde{\theta}_{ji}^g(H) \div N \right) \times 100 \quad (6)$$

$$NS_i^g(H) = DS_{i \rightarrow \cdot}^g(H) - DS_{\cdot \rightarrow i}^g(H) \quad (7)$$

When  $NS_i^g(H)$  is negative, Chinese grain futures price is primarily influenced by international prices, indicating weak pricing power; when positive, Chinese futures price actively influences international prices.  $NS_i^g(H)$  serves as the pricing power indicator in this study. Rolling window estimation (baseline  $H = 10$ ; robustness checks  $H = 5$  and  $H = 20$ ) is used to capture time-varying characteristics.

#### 4.2. Regression Specification

The four core variable groups map onto the four dimensions of the structural power thesis: grain yield corresponds to the production structure, price regulation policy to the security structure, international crude oil prices to the knowledge structure, and international speculative capital to the financial structure.

International crude oil prices are assigned to the knowledge structure because, in the structural power thesis, this dimension captures control over information, technology, and price-benchmarking institutions. Oil prices are set on exchanges dominated by developed-economy actors and therefore embody their informational advantage in energy price discovery. China prices grain partly in reference to these international benchmarks and receives the oil-price signal passively, so its exposure to oil movements reflects the knowledge-structure dominance of developed economies rather than a domestic production or security channel.

The international pricing authority of each grain futures contract is the dependent variable. In the baseline direct-effect specification (Equations (8)–(11)), the explanatory variables of interest are grain yield ( $U$ ), grain-price regulation policy (Policy, introduced through 0–1 policy dummy variables and post-policy time-trend terms), the international crude oil price (Oil), and international speculative capital (SC). Each specification also includes five macroeconomic controls: the US dollar index, the RMB index, economic policy uncertainty (EPU), and the M2 money supply of the United States and China. Because policy interventions are represented by 0–1 dummy variables combined with baseline and post-policy time trends, Equations (8)–(11) are best characterized as an interrupted time-series (segmented regression) specification rather than a regression-discontinuity design. The regression specifications are:

$$\begin{aligned} WFP_t = & \alpha_{w,0} + \alpha_{w,1}U_{w,t} + \alpha_{w,2}Time1_t + \sum_{i=3,4} \alpha_{w,i}Policy_{w,it} + \sum_{i=5,6} \alpha_{w,i}Time_{wap,it} \\ & + \alpha_{w,7}Oil_t + \alpha_{w,8}SC_{w,t} + \sum_{i=9}^{13} \alpha_{w,i}X_{i,t} + \varepsilon_t \end{aligned} \quad (8)$$

$$\begin{aligned} RFP_t = & \alpha_{r,0} + \alpha_{r,1}U_{r,t} + \alpha_{r,2}Time1_t + \alpha_{r,3}Policy_{r,t} + \alpha_{r,4}Time_{rap,t} + \alpha_{r,5}Oil_t \\ & + \alpha_{r,6}SC_{r,t} + \sum_{i=7}^{11} \alpha_{r,i}X_{i,t} + \varepsilon_t \end{aligned} \quad (9)$$

$$\begin{aligned} CFP_t = & \alpha_{c,0} + \alpha_{c,1}U_{c,t} + \alpha_{c,2}Time1_t + \sum_{i=3,4} \alpha_{c,i}Policy_{c,it} + \sum_{i=5,6} \alpha_{c,i}Time_{cap,it} + \alpha_{c,7}Oil_t \\ & + \alpha_{c,8}SC_{c,t} + \sum_{i=9}^{13} \alpha_{c,i}X_{i,t} + \varepsilon_t \end{aligned} \quad (10)$$

$$\begin{aligned} SFP_t = & \alpha_{s,0} + \alpha_{s,1}U_{s,t} + \alpha_{s,2}Time1_t + \sum_{i=3-5} \alpha_{s,i}Policy_{s,it} + \sum_{i=6-8} \alpha_{s,i}Time_{sap,it} \\ & + \alpha_{s,9}Oil_t + \alpha_{s,10}SC_{s,t} + \sum_i \alpha_{s,i}X_{i,t} + \varepsilon_t \end{aligned} \quad (11)$$

In Equations (8)–(11),  $WFP_t$ ,  $RFP_t$ ,  $CFP_t$ , and  $SFP_t$  represent the international pricing power (net spillover index) of wheat, rice, corn, and soybean futures, respectively;  $U_{w,t}$ ,  $U_{r,t}$ ,  $U_{c,t}$ , and  $U_{s,t}$  are the crop-specific yield variables;  $Time1_t$  and  $Time_{it}$  are policy time trend terms;  $Policy_{i,t}$  is a 0–1 policy dummy variable; and  $\varepsilon_t$  is the residual.

We then examine the channels through which each driver is associated with pricing power. Four are considered: yield operating through grain stocks; the crude oil price through the international shipping cost (ISC), proxied by the Baltic Dry Index (BDI); the crude oil price through biofuel demand; and speculative capital through extreme price movements ( $\xi$ ). Each channel is assessed with the causal-steps procedure: the baseline regression above provides the total effect of the driver on pricing power; a second regression relates the driver to the mediator; and a third regresses pricing power on the mediator, so that the product of the two coefficients gives the indirect effect. The speculative capital and crude-oil price variables enter in first lags ( $t - 1$ ), while yield and policy variables enter contemporaneously.

$$M_t = \alpha_a + aX_t + \hat{C}_t\gamma + \varepsilon_{a,t} \quad (12)$$

$$NS_t = \alpha_b + bM_t + \hat{C}_t\varphi + \varepsilon_{b,t} \quad (13)$$

$$Indirect\ effect = a \times b \quad (14)$$

The 95% confidence interval for the indirect effect is obtained by nonparametric bootstrap with 5000 resamples, reporting both percentile and bias-corrected and accelerated intervals. Both auxiliary regressions carry the same five macroeconomic controls as the baseline model. Because the analysis rests on observational time-series data, the indirect effects are reported as indirect associations.

The channels examined are crop-specific; the rice model, for example, excludes the biofuel channel. The extreme-price mediator  $\xi$  is calculated as:

$$\text{EPM}_{i,t} = (\text{High}_{i,t} - \text{Low}_{i,t}) \div \text{Low}_{i,t} \quad (15)$$

where  $\text{High}_t$  and  $\text{Low}_t$  denote the daily high and low prices of international grain futures, respectively.

#### 4.3. fsQCA Configurational Analysis

Grounded in Ragin's [13] configurational logic, this study applies fsQCA with the four core variables from Section 3 as causal conditions and the monthly mean pricing power of each grain futures contract as the outcome. Because the price regulation policy dimension is operationalized through multiple 0–1 dummy variables together with pre- and post-policy time-trend terms, each crop's configurational table contains between six and ten condition columns rather than four. The analytical procedure comprises three steps.

- (1) Calibration. Each variable is mapped to a fuzzy membership score on the [0, 1] interval via direct calibration. Three anchor points are specified: full membership at the 95th percentile (P95), the crossover point at the median (P50), and full non-membership at the 5th percentile (P5). Binary 0–1 policy indicators are treated as crisp sets and are not calibrated; the crop-specific anchor values are reported in Table A1 (Appendix A).
- (2) Necessity analysis. Each condition is individually assessed as a necessary condition for both high and low pricing power outcomes, applying a consistency threshold of 0.9.
- (3) Configuration identification. A truth table is constructed with a frequency threshold of 1 and a consistency threshold of 0.75. Boolean minimization then yields the sufficient condition combinations; consistency, coverage, and PRI scores are reported for each pathway.

## 5. Empirical Results and Analysis

### 5.1. Data Description and Summary Statistics

The primary futures quotations are sourced from the Wind database. Sample windows differ across crops: wheat spans March 2004 to March 2023, rice December 2010 to September 2022, corn September 2005 to February 2025, and soybean November 2002 to February 2025. Domestic and international futures prices are aggregated into monthly arithmetic means for the regression and fsQCA stages. Yield and ending-stock figures come from USDA WASDE monthly releases. International crude oil is represented by WTI spot quotations; biofuel consumption data are obtained from the EIA. Freight costs are captured by the Baltic Dry Index (BDI) retrieved from Bloomberg. Non-commercial net long positions are drawn from CFTC Commitments of Traders filings. Extreme price movements (EPMs) are computed from CBOT daily high and low quotations. Grain price regulation policies are encoded as dummy variables anchored to key dates from official Chinese Ministry of Agriculture and Rural Affairs announcements. For the control set, the USD index, RMB index, and M2 for both China and the United States are from Wind, while the global economic policy uncertainty (EPU) index originates from policyuncertainty.com.

Futures price series are constructed from the dominant contract—the contract with the largest open interest (and, where available, trading volume) on each trading day—for each of the four commodities. The domestic reference contracts are CZCE WH (wheat), CZCE RI (rice), DCE C (corn), and DCE A (soybean), each paired with its corresponding CBOT contract—CBOT W (wheat), CBOT RR (rough rice), CBOT C (corn), and CBOT S (soybeans); a position rolls from the incumbent contract to the new dominant contract once the latter's open interest exceeds the former's, and prices are back-adjusted at each rollover to remove the level gap, yielding a continuous, gap-free daily series. Domestic and international daily prices are aligned by calendar date on the intersection of the two markets' trading days—dates on which either market is closed are dropped—with no additional time-zone conversion beyond this calendar-date matching.

Two data frequencies are used. The DY spillover index and the extreme price movement (EPM) indicator are built from daily futures prices, while the regression and fsQCA stages use monthly data. Daily prices are converted to logarithmic returns; the DY index is estimated over a 220-day rolling window and then averaged within each month to obtain the monthly pricing-power series. EPM is aggregated the same way, and all remaining variables are monthly, so every regression and fsQCA specification operates on a common monthly sample.

Table 1 and Figure 3 report summary statistics and time-series trends for the principal variables. On average, yield has climbed steadily for all four crops, with soybean recording the lowest mean at 1.78 ton/ha. Corn stocks display pronounced volatility (standard deviation: 73.03 million tons), linked to the 2016 phasing-out of the temporary storage program. Among external factors, corn speculative positions are the largest across the four commodities, averaging 192,311 contracts. The mean EPM for wheat is  $2.91 \times 10^{-2}$ , spiking during the 2008 global food crisis and the 2022 Russia–Ukraine conflict. Unit-root tests confirm that all core series attain stationarity at the 5% significance level or better. The DY-based pricing power trajectory for each crop is examined in Section 5.2.

**Table 1.** Descriptive statistics and stationarity tests for key variables.

| Category                                  | Variable                               | Mean    | Std. Dev. | Max.      | Min.   | ADF Test |
|-------------------------------------------|----------------------------------------|---------|-----------|-----------|--------|----------|
| Internal Factors<br>Yield (ton/ha)        | Wheat yield (Yield <sub>w,t</sub> )    | 5.03    | 0.52      | 5.91      | 3.91   | I(0) *** |
|                                           | Rice yield (Yield <sub>r,t</sub> )     | 6.84    | 0.16      | 7.11      | 6.55   | I(0) *** |
|                                           | Corn yield (Yield <sub>c,t</sub> )     | 5.75    | 0.45      | 6.44      | 4.81   | I(0) *** |
|                                           | Soybean yield (Yield <sub>s,t</sub> )  | 1.78    | 0.15      | 1.98      | 0.00   | I(0) *** |
| Internal Factors<br>Stock (mn tons)       | Wheat stock (Stock <sub>w,t</sub> )    | 75.38   | 38.82     | 151.68    | 34.89  | I(0) **  |
|                                           | Rice stock (Stock <sub>r,t</sub> )     | 71.78   | 30.72     | 116.50    | 38.90  | I(0) **  |
|                                           | Corn stock (Stock <sub>c,t</sub> )     | 108.99  | 73.03     | 223.02    | 32.48  | I(0) **  |
|                                           | Soybean stock (Stock <sub>s,t</sub> )  | 14.20   | 9.47      | 32.34     | 2.10   | I(0) **  |
| External Factors<br>Energy &<br>Transport | WTI crude oil price (Oil, USD/bbl)     | 68.25   | 22.95     | 133.93    | 16.70  | I(0) *** |
|                                           | BDI shipping cost (index pts)          | 2329.73 | 1967.18   | 10,843.65 | 306.90 | I(0) **  |
|                                           | Fuel ethanol consump. (EFD, mn gal)    | 1144.54 | 88.24     | 1306.37   | 667.25 | I(0) **  |
|                                           | Biodiesel consump. (IBD, trillion BTU) | 0.02    | 0.02      | 0.07      | 0.00   | I(0) *** |

Table 1. Cont.

| Category         | Variable                                 | Mean                  | Std. Dev.            | Max.                  | Min.                  | ADF Test |
|------------------|------------------------------------------|-----------------------|----------------------|-----------------------|-----------------------|----------|
| External Factors | Wheat net long ( $\text{Spec}_{w,t}$ )   | 29,311.23             | 22,362.09            | 101,283.50            | 96.25                 | I(0) **  |
| Speculative      | Rice net long ( $\text{Spec}_{r,t}$ )    | 1847.21               | 1335.62              | 6565.00               | 15.25                 | I(0) **  |
| Capital          | Corn net long ( $\text{Spec}_{c,t}$ )    | 192,310.68            | 137,624.94           | 534,887.00            | 674.20                | I(0) **  |
| (contracts)      | Soybean net long ( $\text{Spec}_{s,t}$ ) | 89,680.95             | 68,937.31            | 276,509.75            | 13.00                 | I(0) **  |
| External Factors | Wheat EPM ( $\text{EPM}_{w,t}$ )         | $2.91 \times 10^{-2}$ | $8.9 \times 10^{-3}$ | $7.18 \times 10^{-2}$ | $1.26 \times 10^{-2}$ | I(0) **  |
| Extreme Price    | Rice EPM ( $\text{EPM}_{r,t}$ )          | $1.88 \times 10^{-2}$ | $5.8 \times 10^{-3}$ | $3.84 \times 10^{-2}$ | $6.8 \times 10^{-3}$  | I(0) **  |
| Movement         | Corn EPM ( $\text{EPM}_{c,t}$ )          | $2.37 \times 10^{-2}$ | $8.5 \times 10^{-3}$ | $5.79 \times 10^{-2}$ | $9.4 \times 10^{-3}$  | I(0) **  |
|                  | Soybean EPM ( $\text{EPM}_{s,t}$ )       | $2.08 \times 10^{-2}$ | $1.9 \times 10^{-2}$ | $5.94 \times 10^{-2}$ | $9.6 \times 10^{-3}$  | I(0) **  |

Notes: ADF null hypothesis: series contains a unit root; I(0) = stationary in levels; lag length selected by AIC; \*\*\*, \*\* denote significance at 1% and 5% levels. Statistics computed over each crop's actual sample period. Yield and stock: USDA WASDE monthly reports. BDI: Bloomberg Terminal. Speculative capital: CFTC COT reports. Soybean yield minimum of 0.00 reflects a data-recording anomaly in March 2002, which precedes the regression sample window (November 2002–February 2025) and is retained only in the descriptive statistics. Fuel ethanol consumption is reported in million gallons.

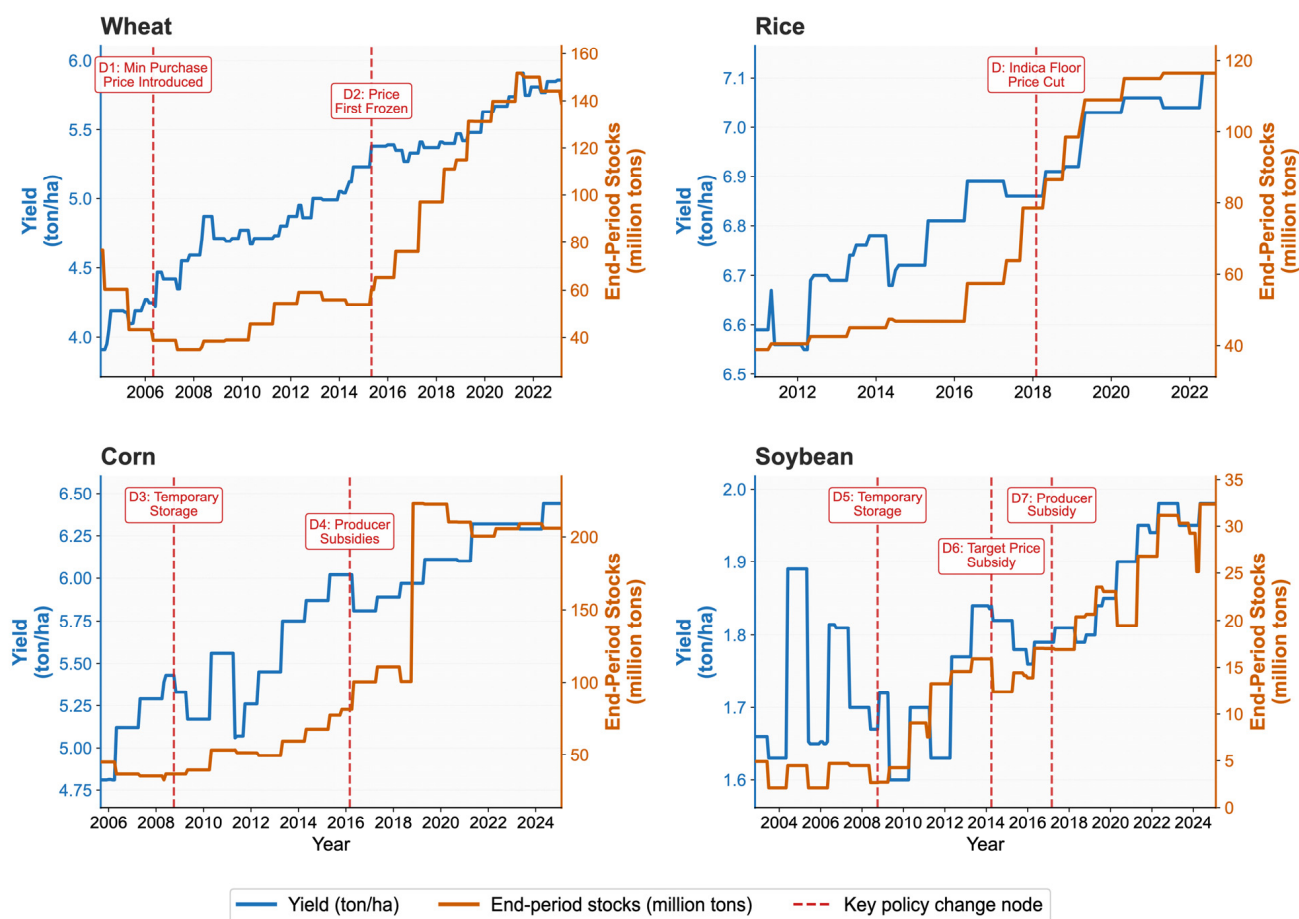


**Figure 3.** Time-series trends in yield and stocks of four major grain crops. Note: Vertical dashed lines indicate key policy change nodes in grain price regulation. Data source: USDA WASDE monthly reports. Left y-axis: yield (ton/ha); right y-axis: end-period stocks (million tons).

Figure 4 presents three external energy and transport variables, crude oil prices, shipping costs, and US biofuel demand, all of which exhibit pronounced swings during 2008 and 2020–2022. These co-movements underpin the oil-to-shipment-cost and oil-to-biofuel channels tested in Section 5.3. Figure 5 displays speculative capital flows and the extreme-price index for each crop, revealing a pattern of simultaneous peaks around the same episodes, most visibly for corn and soybean.

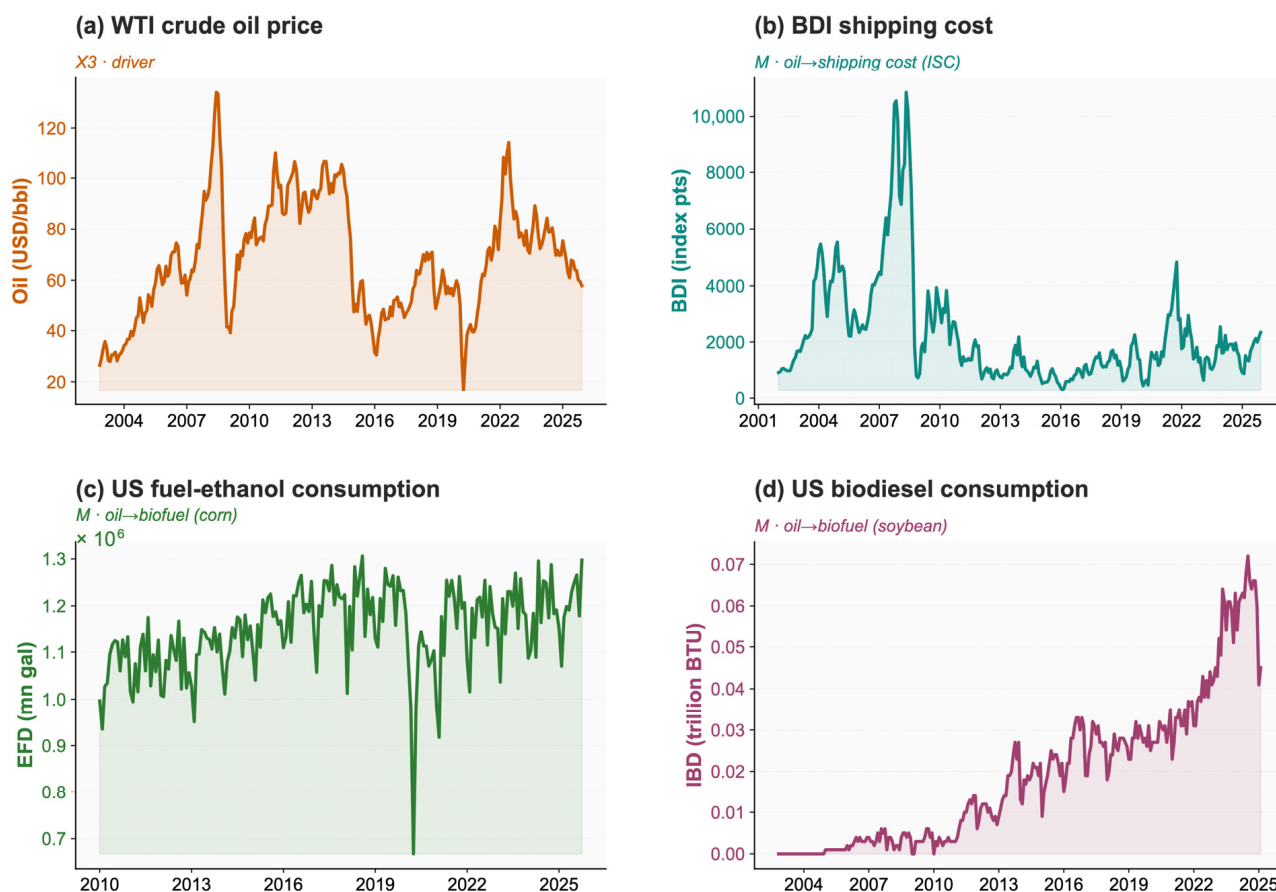


**Figure 4.** External energy and transport drivers of grain-futures pricing power. Note: (a) WTI crude oil price (USD/barrel), the energy driver X3; (b) the Baltic Dry Index (BDI), a proxy for international shipping cost; (c) US fuel-ethanol consumption; (d) US biodiesel consumption. The BDI and the two biofuel series are the channels through which the oil price reaches pricing power; fuel ethanol and biodiesel enter the corn and soybean models, respectively. All series are shared across the four crops and span 2002–2025. Sources: Wind; US Energy Information Administration.

## 5.2. Pricing Power Index Estimation and Structural Break Detection

China's pricing leverage is captured through the dynamic net spillover index (NS) derived from international and domestic grain futures quotations, where a positive NS signals active price leadership and a negative NS denotes passive price acceptance. Figure 6 applies the PELT algorithm to pinpoint structural breaks, distinguished by shock origin: blue markers for policy nodes (wheat: D1–D2; rice: D; corn: D3–D4; soybean: D5–D7), orange for crude oil–energy shocks, red for speculative capital shocks, and shaded bands for major global episodes. Average NS readings stand at  $-3.21$  (wheat),  $-1.87$  (rice),  $-4.06$  (corn), and  $-7.43$  (soybean), collectively pointing to a broadly subordinate pricing stance. The 2007–2008 global food crisis, the 2020 COVID-19 pandemic, and the 2022 Russia–Ukraine conflict emerge as shared shock nodes that coincided with simultaneous declines in pricing authority across all four commodities.

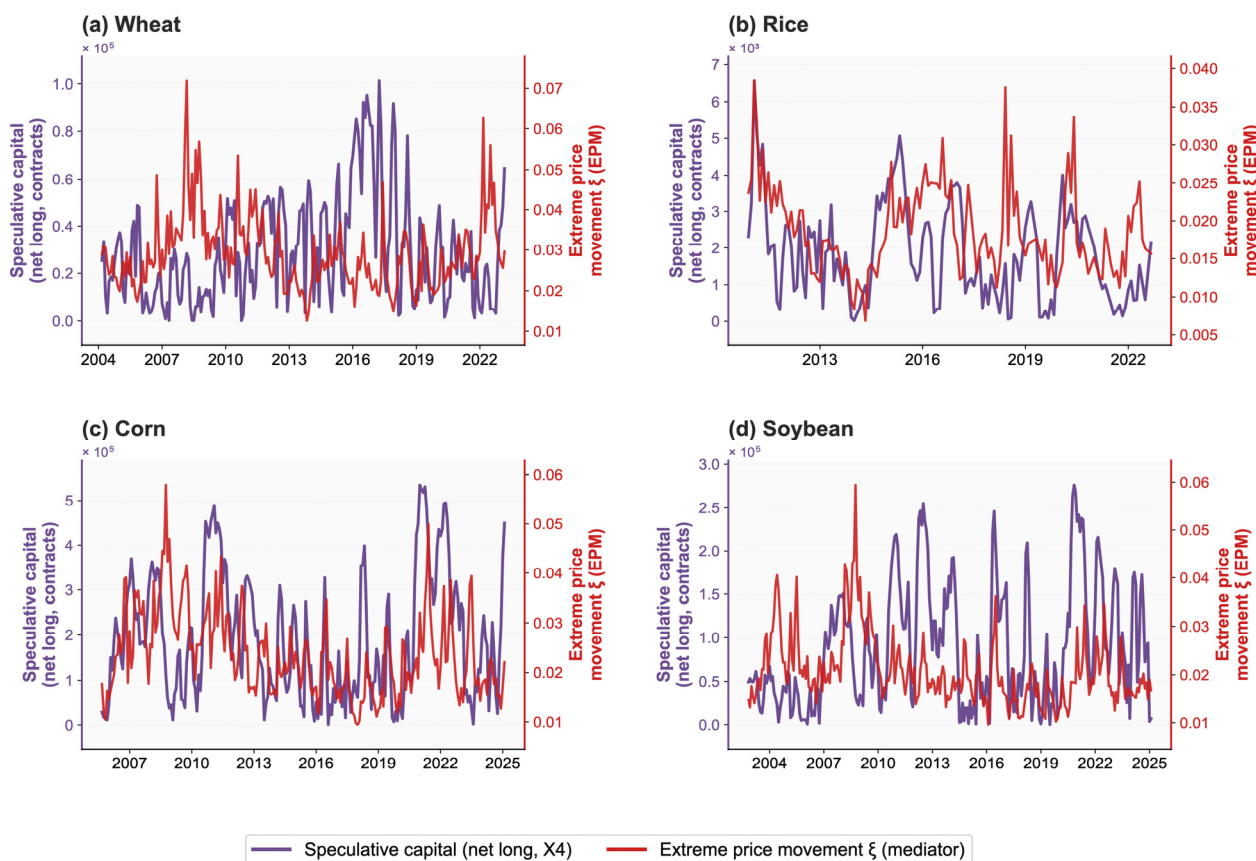


**Figure 5.** Speculative capital and extreme price movements across four grain futures. Note: Left axis (purple), net-long positions in contracts (speculative capital,  $\times 4$ ); right axis (red), the extreme price movement index  $\xi$ . Panels: (a) wheat; (b) rice; (c) corn; (d) soybean, each over its sample period. Sources: US Commodity Futures Trading Commission; authors' calculations.

Wheat (mean NS:  $-3.21$ ) displays the greatest policy responsiveness. Introduction of the minimum purchase price in May 2006 (D1) temporarily lifted the index to  $+2.14$  (breaks: 24 January 2006, 12 April 2006). Speculative fund inflows into CBOT between March and June 2008 pulled the index down to  $-5.83$  (breaks: 4 March 2008, 12 June 2008). After the first freeze on minimum price increases in May 2015 (D2), domestic–international transmission corridors were gradually reopened (breaks: 20 April 2016, 8 August 2016). The March 2022 Russia–Ukraine conflict transmitted via the crude oil channel, dragging the index to  $-6.47$  (break: 4 March 2022).

Rice (mean NS:  $-1.87$ ) retains the strongest pricing leverage among the four crops. CBOT rice net long positions hit a historical apex in the first half of 2013, coinciding with elevated international price turbulence (break: 26 June 2013). The minimum purchase price for early indica rice was reduced in February 2018 (break: 5 July 2018). Vietnam's export embargo from March to June 2020 sent the index plunging to  $-12.60$ , though it swiftly rebounded to  $-1.30$  once trade flows normalized (breaks: 16 March 2020, 15 June 2020).

Corn (mean NS:  $-4.06$ ) pricing authority closely mirrors the temporary storage policy cycle. Although the temporary storage rollout in October 2008 (D3) falls within the sample window, the regression in Section 5.3.3 indicates its contemporaneous impact was insignificant. A severe US drought in July 2012 sent CBOT corn soaring, with the index falling to roughly  $-8.83$  (break: 11 July 2012). The 2014 Crimean crisis disrupted Ukrainian shipments (breaks: 30 April 2014, 16 July 2014). The March 2016 abolition of temporary storage and shift to producer subsidies (D4) structurally opened cross-border transmission channels (breaks: 18 January 2017, 13 June 2017). A feed demand recovery paired with

a surge in fund net long positions in October 2020 coincided with stronger cross-market linkages (break: 12 October 2020). By late 2022 the index had slipped to  $-10.49$  (break: 27 September 2022).

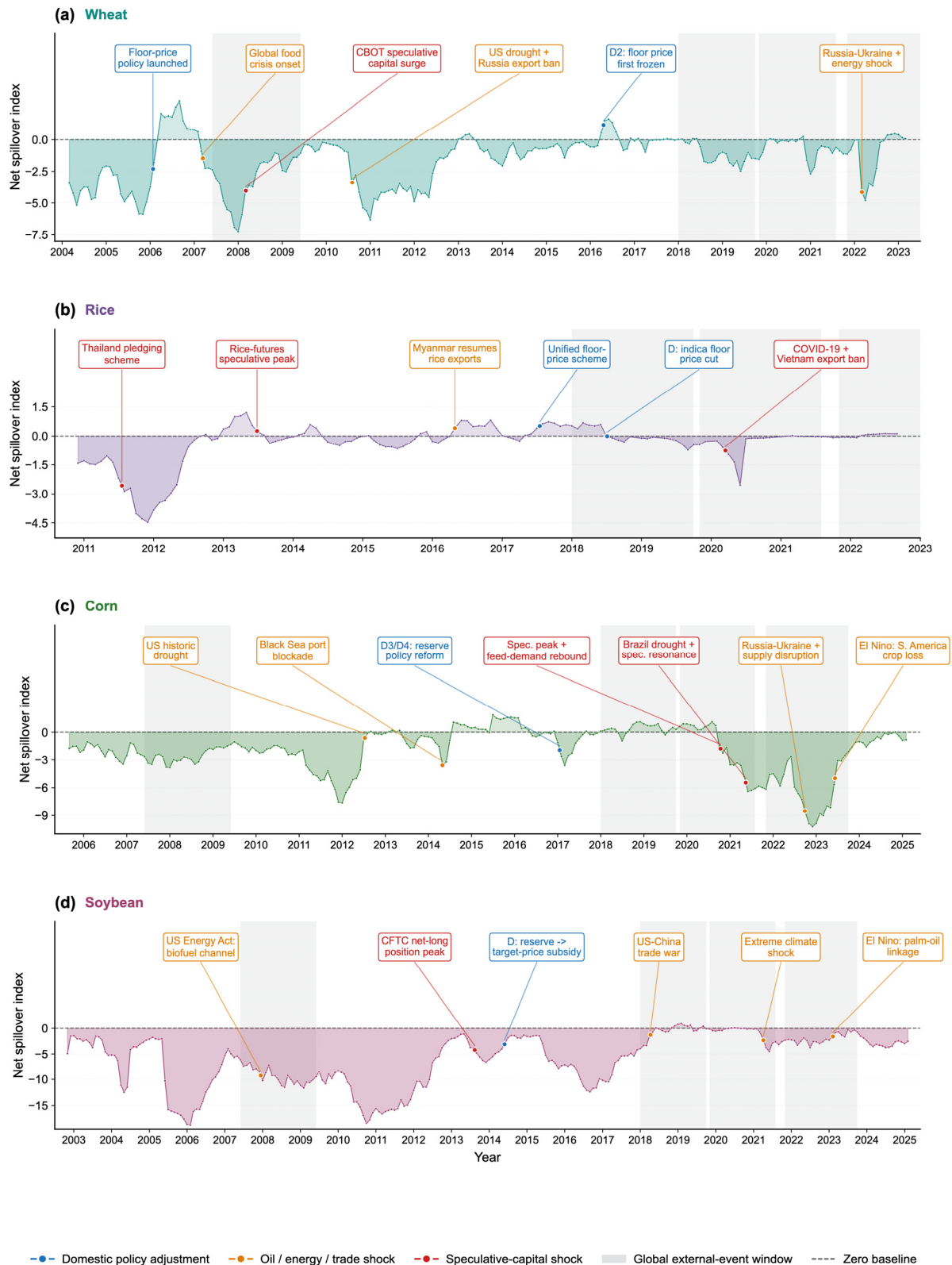


**Figure 6.** Dynamic evolution and structural break identification of international pricing power indices for Chinese four major grain futures. (a) wheat; (b) rice; (c) corn; (d) soybean. Note: A positive (negative) net spillover index indicates that Chinese futures prices actively lead (passively follow) the

international market. Blue markers on each crop's panel correspond to crop-specific policy break-points, which map to the policy dummy variables in Section 5.3 as follows: wheat D1 (May 2006, minimum purchase price introduced), D2 (May 2015, first freeze on price increase); rice D (February 2018, significant reduction in minimum purchase price); corn D3 (October 2008, temporary storage policy introduced), D4 (March 2016, transition to producer subsidies); soybean D5 (October 2008, temporary storage policy introduced), D6 (April 2014, target price subsidy), D7 (March 2017, producer subsidy). To preserve legibility, each panel labels only representative event nodes—major policy, energy, and speculative episodes—rather than the exhaustive set of PELT-detected breakpoints. Series are plotted as monthly averages; the mean indices and extreme values cited in the main text refer to the underlying daily net-spillover estimates. Data sources: Wind, CBOT, USDA WASDE; authors' calculations.

Soybean (mean NS:  $-7.43$ ), the weakest among the four crops, registers six pivotal break points. The December 2007 US Energy Act expanded biodiesel demand, transmitting a disturbance through the biofuel channel (break: 14 December 2007). Temporary storage commenced in October 2008 (D5); Section 5.3.4 reveals an approximately 44-month lag before the effect turned significantly positive at the sample midpoint. CFTC net long positions peaked historically in August 2013, coinciding with a marked decline in pricing authority (break: 14 August 2013). Temporary storage was withdrawn and replaced by target price subsidies in April 2014 (D6) (break: 29 May 2014). The move to producer subsidies followed in March 2017 (D7) (break: 3 May 2017). A 25% tariff on US soybeans imposed in April 2018 pushed Brazilian soybean premiums to USD 120/ton and fundamentally reconfigured the domestic–international price nexus (break: 10 April 2018).

These break points align closely with the three transmission channels—domestic policy adjustment, crude oil shocks, and speculative capital. Minor divergences between PELT-detected break dates and policy announcement months reflect market reaction delays. The regression analysis adopts official policy announcement dates as breakpoints, whereas the pricing power estimation relies on actual market reaction dates. This discrepancy stems from policy transmission lags and does not compromise the robustness of the empirical conclusions. The breakpoints identified above serve as temporal anchors for the formation mechanism analysis in Section 5.3.

### 5.3. Empirical Results: Formation Mechanisms

This section employs OLS regressions coupled with stepwise mediation tests to systematically evaluate H1 (grain yield), H2 (price regulation policy), H3 (international crude oil prices), and H4 (international speculative capital) advanced in Section 3, and to uncover the core drivers of pricing authority for each crop.

#### 5.3.1. Determinants of Wheat Futures Pricing Authority

Building on the two breakpoints identified in Section 5.2 (D1: minimum purchase price introduction, May 2006; D2: first price freeze, May 2015), a direct-effects specification is estimated to assess two mediating routes: grain yield operating through grain stocks, and crude oil prices operating through international freight costs. Results appear in Table 2.

Grain yield shows a significantly positive association with pricing authority, with a coefficient of 4.78 at the 5% significance level, and the stock indirect association is statistically supported (95% CI excludes zero). On the policy front, D1's contemporaneous jump of 1.44 does not attain significance under the Newey–West HAC standard errors, suggesting that constrained market liquidity during the early period limited the policy effect's sustainability. D2 registers a significant negative contemporaneous level of  $-2.52$  and a negative trend of  $-0.04$ , both at conventional significance thresholds, indicating that relaxing the price floor was associated with deeper domestic–international price linkages.

Crude oil shows a negative association through the ISC channel with a coefficient of  $-0.04$  at the 1% level. The speculative capital variable does not attain significance, consistent with the dampening role of import quotas on cross-border capital flows. These findings suggest that policy-driven inventory accumulation was associated with a price buffer, with the minimum purchase price insulating domestic markets by establishing a floor. The D2 loosening was simultaneously associated with reduced inventory buffering and policy insulation, consistent with the shipping cost transmission channel, whereas high self-sufficiency and quota controls contained the cross-market reach of speculative capital.

**Table 2.** Estimation results: formation mechanism of wheat futures international pricing power.

| Panel A Direct Effects (Dep. Var.: WFP <sub>t</sub> )                  |                                     |                                     |                                                  |                     |
|------------------------------------------------------------------------|-------------------------------------|-------------------------------------|--------------------------------------------------|---------------------|
| Variable                                                               |                                     |                                     | Coefficient                                      |                     |
| Wheat yield (U <sub>w,t</sub> )                                        |                                     |                                     | 4.78 ** (2.09)                                   |                     |
| Policy D1                                                              |                                     |                                     | 1.44 (1.43)                                      |                     |
| (Min. purchase price, May 2006)                                        |                                     |                                     |                                                  |                     |
| D1 time trend                                                          |                                     |                                     | −0.02 (0.08)                                     |                     |
| Policy D2 (Price freeze, May 2015)                                     |                                     |                                     | −2.52 ** (1.04)                                  |                     |
| D2 time trend                                                          |                                     |                                     | −0.04 ** (0.02)                                  |                     |
| Crude oil price (Oil <sub>t</sub> )                                    |                                     |                                     | −0.04 *** (0.01)                                 |                     |
| Speculative capital (SC <sub>w,t</sub> )                               |                                     |                                     | $-4.26 \times 10^{-6}$ ( $5.52 \times 10^{-6}$ ) |                     |
| Control variables                                                      |                                     |                                     | Controlled                                       |                     |
| Adj. R <sup>2</sup>                                                    |                                     |                                     | 0.43                                             |                     |
| Observations N                                                         |                                     |                                     | 228                                              |                     |
| Panel B Mediation Path 1: Yield → Stock → WFP <sub>t</sub>             |                                     |                                     |                                                  |                     |
| Step                                                                   | Dep. Var.                           | Key Indep. Var.                     | Coefficient                                      | Adj. R <sup>2</sup> |
| Step 1                                                                 | Wheat stock (Stock <sub>w,t</sub> ) | Wheat yield (U <sub>w,t</sub> )     | 64.59 ***                                        | 0.91                |
| Step 2                                                                 | WFP <sub>t</sub>                    | Wheat stock (Stock <sub>w,t</sub> ) | $1.35 \times 10^{-2}$ **                         | 0.25                |
|                                                                        | Indirect effect (a × b)             |                                     | 0.87                                             |                     |
|                                                                        | 95% bootstrap CI                    |                                     | [0.27, 1.50]                                     |                     |
|                                                                        | Direct effect (c' = c − a × b)      |                                     | 3.91                                             |                     |
| Panel C Mediation Path 2: Oil → Shipping Cost (ISC) → WFP <sub>t</sub> |                                     |                                     |                                                  |                     |
| Step                                                                   | Dep. Var.                           | Key Indep. Var.                     | Coefficient                                      | Adj. R <sup>2</sup> |
| Step 1                                                                 | Shipping cost (ISC/BDI)             | Crude oil price (Oil <sub>t</sub> ) | 577.15 ***                                       | 0.41                |
| Step 2                                                                 | WFP <sub>t</sub>                    | Shipping cost (ISC)                 | $-8.25 \times 10^{-6}$ ***                       | 0.26                |
|                                                                        | Indirect effect (a × b)             |                                     | $-4.8 \times 10^{-3}$                            |                     |
|                                                                        | 95% bootstrap CI                    |                                     | $[-9.1 \times 10^{-3}, -6.0 \times 10^{-4}]$     |                     |
|                                                                        | Direct effect (c' = c − a × b)      |                                     | −0.035                                           |                     |

Notes: \*\*\*, \*\* denote significance at the 1% and 5% levels, respectively. In Panel A, parentheses contain Newey–West HAC standard errors (lag length  $L = \lfloor 4(T/100)^{2/9} \rfloor = 4$ ). Control variables include the USD index, RMB index, EPU, and M2 (US and China). Data sources: Wind, CBOT, USDA/WASDE (same for all tables). For each mediation channel, the indirect effect  $a \times b$  is reported with a 95% bootstrap confidence interval (5000 resamples; percentile and bias-corrected and accelerated). Panel A reports the total effect of each driver before mediation; the direct effect after controlling for the mediator equals the total effect minus the indirect effect ( $c' = c - a \times b$ ).

### 5.3.2. Determinants of Rice Futures Pricing Authority

Leveraging the single breakpoint identified in Section 5.2 (a substantial purchase price reduction in February 2018), an OLS specification is estimated to examine two mediating channels: grain yield operating through grain stocks, and speculative capital operating through extreme price movements. Results are reported in Table 3.

**Table 3.** Estimation results: formation mechanism of rice futures international pricing power.

| Panel A Direct Effects (Dep. Var.: RFP <sub>t</sub> )                                 |                                    |                                          |                                                        |                     |
|---------------------------------------------------------------------------------------|------------------------------------|------------------------------------------|--------------------------------------------------------|---------------------|
| Variable                                                                              |                                    |                                          | Coefficient                                            |                     |
| Rice yield (U <sub>r,t</sub> )                                                        |                                    |                                          | 7.79 *** (2.18)                                        |                     |
| Policy D (Price cut, Feb. 2018)                                                       |                                    |                                          | −0.90 *** (0.26)                                       |                     |
| D time trend                                                                          |                                    |                                          | −0.07 *** (0.02)                                       |                     |
| Crude oil price (Oil <sub>t</sub> )                                                   |                                    |                                          | 2.1 × 10 <sup>−3</sup> (5.41 × 10 <sup>−3</sup> )      |                     |
| Speculative capital (SC <sub>r,t</sub> )                                              |                                    |                                          | 9.75 × 10 <sup>−5</sup> * (5.13 × 10 <sup>−5</sup> )   |                     |
| Control variables                                                                     |                                    |                                          | Controlled                                             |                     |
| Adj. R <sup>2</sup>                                                                   |                                    |                                          | 0.70                                                   |                     |
| Observations N                                                                        |                                    |                                          | 135                                                    |                     |
| Panel B Mediation Path 1: Yield → Stock → RFP <sub>t</sub>                            |                                    |                                          |                                                        |                     |
| Step                                                                                  | Dep. Var.                          | Key Indep. Var.                          | Coefficient                                            | Adj. R <sup>2</sup> |
| Step 1                                                                                | Rice stock (Stock <sub>r,t</sub> ) | Rice yield (U <sub>r,t</sub> )           | 153.36 ***                                             | 0.91                |
| Step 2                                                                                | RFP <sub>t</sub>                   | Rice stock (Stock <sub>r,t</sub> )       | 1.24 × 10 <sup>−2</sup> **                             | 0.34                |
|                                                                                       | Indirect effect (a × b)            |                                          | 1.90                                                   |                     |
|                                                                                       | 95% bootstrap CI                   |                                          | [0.31, 3.55]                                           |                     |
|                                                                                       | Direct effect (c' = c − a × b)     |                                          | 5.89                                                   |                     |
| Panel C Mediation Path 2: Speculative Capital → EPM <sub>r,t</sub> → RFP <sub>t</sub> |                                    |                                          |                                                        |                     |
| Step                                                                                  | Dep. Var.                          | Key Indep. Var.                          | Coefficient                                            | Adj. R <sup>2</sup> |
| Step 1                                                                                | EPM <sub>r,t</sub>                 | Speculative capital (SC <sub>r,t</sub> ) | 1.08 × 10 <sup>−6</sup> ***                            | 0.22                |
| Step 2                                                                                | RFP <sub>t</sub>                   | EPM <sub>r,t</sub>                       | −53.49 ***                                             | 0.38                |
|                                                                                       | Indirect effect (a × b)            |                                          | −5.78 × 10 <sup>−5</sup>                               |                     |
|                                                                                       | 95% bootstrap CI                   |                                          | [−1.09 × 10 <sup>−4</sup> , −1.27 × 10 <sup>−5</sup> ] |                     |
|                                                                                       | Direct effect (c' = c − a × b)     |                                          | 1.55 × 10 <sup>−4</sup>                                |                     |

Note: \*\*\*, \*\*, \* denote significance at 1%, 5%, 10% levels. Significance levels and Newey–West HAC standard errors as in Table 2.

Yield shows a significantly positive association with a coefficient of 7.79 at the 1% level, stronger than that observed for wheat, and the stock indirect association is statistically supported (95% CI excludes zero), indicating that the state procurement and reserve system swiftly translates output gains into pricing buffers. On the policy side, the 2018 purchase price cut was associated with a significant contemporaneous decline of −0.90 and an adverse trend of −0.07, both at the 1% level. The crude oil variable fails to reach significance. The direct effect of speculative capital is significant at the 10% level, while its indirect association is significant, with a Step 2 coefficient of −53.49 at the 1% level. This pattern mirrors rice's transport profile: predominantly moved in short-sea containers, rice shows a low correlation with the BDI, rendering the freight cost channel inert. Yet the thin liquidity of international rice futures creates fertile ground for speculative capital to generate extreme price swings, which then propagate through domestic–international price linkages. Consequently, rice pricing authority remains vulnerable to financialization spillovers that trade barriers alone cannot fully contain.

### 5.3.3. Determinants of Corn Futures Pricing Authority

Drawing on the two breakpoints from Section 5.2 (D3: temporary storage launch, October 2008; D4: shift to producer subsidies, March 2016), an OLS specification is estimated to test four mediating routes: grain yield through grain stocks, crude oil prices through international freight costs, crude oil prices through fuel ethanol demand, and speculative capital through extreme price movements. Results are displayed in Table 4.

**Table 4.** Estimation results: formation mechanism of corn futures international pricing power.

| Panel A Direct Effects (Dep. Var. : $CFP_t$ )                                                  |                                          |                                    |                                                     |            |
|------------------------------------------------------------------------------------------------|------------------------------------------|------------------------------------|-----------------------------------------------------|------------|
|                                                                                                | Variable                                 |                                    | Coefficient                                         |            |
|                                                                                                | Corn yield ( $U_{c,t}$ )                 |                                    | 3.37 * (1.99)                                       |            |
|                                                                                                | Policy D3 (Temporary storage, Oct. 2008) |                                    | -                                                   |            |
|                                                                                                | Policy D4 (Producer subsidy, Mar. 2016)  |                                    | -1.55 (0.99)                                        |            |
|                                                                                                | D4 time trend                            |                                    | -0.10 *** (0.03)                                    |            |
|                                                                                                | Crude oil price ( $Oil_t$ )              |                                    | -0.05 *** (0.02)                                    |            |
|                                                                                                | Speculative capital ( $SC_{c,t}$ )       |                                    | $-3.71 \times 10^{-6}$ ** ( $1.46 \times 10^{-6}$ ) |            |
|                                                                                                | Control variables                        |                                    | Controlled                                          |            |
|                                                                                                | Adj. $R^2$                               |                                    | 0.42                                                |            |
|                                                                                                | Observations N                           |                                    | 233                                                 |            |
| Panel B Mediation Path 1 : Yield $\rightarrow$ Stock $\rightarrow$ $CFP_t$                     |                                          |                                    |                                                     |            |
| Step                                                                                           | Dep. Var.                                | Key Indep. Var.                    | Coefficient                                         | Adj. $R^2$ |
| Step1                                                                                          | Corn stock ( $Stock_{c,t}$ )             | Corn yield ( $U_{c,t}$ )           | 97.43 ***                                           | 0.86       |
| Step2                                                                                          | $CFP_t$                                  | Corn stock ( $Stock_{c,t}$ )       | $-1.28 \times 10^{-2}$                              | 0.11       |
|                                                                                                | Indirect effect ( $a \times b$ )         |                                    | -1.24                                               |            |
|                                                                                                | 95% bootstrap CI                         |                                    | [-2.47, -0.21]                                      |            |
|                                                                                                | Direct effect ( $c' = c - a \times b$ )  |                                    | 4.61                                                |            |
| Panel C Mediation Path 2 : Oil $\rightarrow$ Shipping Cost (ISC) $\rightarrow$ $CFP_t$         |                                          |                                    |                                                     |            |
| Step                                                                                           | Dep. Var.                                | Key Indep. Var.                    | Coefficient                                         | Adj. $R^2$ |
| Step1                                                                                          | Shipping cost (ISC/BDI)                  | Crude oil price ( $Oil_t$ )        | 27.51 ***                                           | 0.41       |
| Step2                                                                                          | $CFP_t$                                  | Shipping cost (ISC)                | $-0.3 \times 10^{-3}$ ***                           | 0.12       |
|                                                                                                | Indirect effect ( $a \times b$ )         |                                    | $-8.4 \times 10^{-3}$                               |            |
|                                                                                                | 95% bootstrap CI                         |                                    | $[-1.54 \times 10^{-2}, -3.0 \times 10^{-3}]$       |            |
|                                                                                                | Direct effect ( $c' = c - a \times b$ )  |                                    | -0.042                                              |            |
| Panel D Mediation Path 3 : Oil $\rightarrow$ Fuel Ethanol Demand (EFD) $\rightarrow$ $CFP_t$   |                                          |                                    |                                                     |            |
| Step                                                                                           | Dep. Var.                                | Key Indep. Var.                    | Coefficient                                         | Adj. $R^2$ |
| Step1                                                                                          | Fuel ethanol demand (EFD)                | Crude oil price ( $Oil_t$ )        | 821.93 **                                           | 0.28       |
| Step2                                                                                          | $CFP_t$                                  | Fuel ethanol demand (EFD)          | $-1.06 \times 10^{-6}$                              | 0.18       |
|                                                                                                | Indirect effect ( $a \times b$ )         |                                    | $-9 \times 10^{-4}$                                 |            |
|                                                                                                | 95% bootstrap CI                         |                                    | $[-9.4 \times 10^{-3}, 2.1 \times 10^{-3}]$         |            |
|                                                                                                | Direct effect ( $c' = c - a \times b$ )  |                                    | -0.049                                              |            |
| Panel E Mediation Path 4 : Speculative Capital $\rightarrow$ $EPM_{c,t}$ $\rightarrow$ $CFP_t$ |                                          |                                    |                                                     |            |
| Step                                                                                           | Dep. Var.                                | Key Indep. Var.                    | Coefficient                                         | Adj. $R^2$ |
| Step1                                                                                          | $EPM_{c,t}$                              | Speculative capital ( $SC_{c,t}$ ) | $1.27 \times 10^{-8}$ ***                           | 0.25       |
| Step2                                                                                          | $CFP_t$                                  | $EPM_{c,t}$                        | -85.83 ***                                          | 0.15       |
|                                                                                                | Indirect effect ( $a \times b$ )         |                                    | $-1.09 \times 10^{-6}$                              |            |
|                                                                                                | 95% bootstrap CI                         |                                    | $[-2.38 \times 10^{-6}, -2.51 \times 10^{-7}]$      |            |
|                                                                                                | Direct effect ( $c' = c - a \times b$ )  |                                    | $-2.62 \times 10^{-6}$                              |            |

Notes: \*\*\*, \*\*, \* denote significance at 1%, 5%, 10% levels. Significance levels and Newey–West HAC standard errors as in Table 2. The Step 1 coefficient in Panel C (27.51) is based on the raw Baltic Dry Index, whereas the wheat ISC equation uses the rescaled BDI (577.15); the difference in Step 2 magnitude reflects different sample periods and variable scaling.

Yield shows the weakest association among the four crops, with a coefficient of 3.37 at the 10% level, reflecting the persistent diversion of output toward feed and deep-processing demand that is associated with weaker inventory buffering capacity. On the policy front, the D3 temporary storage effect does not attain significance. Following the D4 transition to producer subsidies, pricing authority deteriorates steadily, showing a contemporaneous decline of -1.55 that does not attain significance and an adverse trend of -0.10 at the 1% level. Crude oil shows an association through the ISC mediation pathway, while the

fuel ethanol channel does not attain significance (its 95% bootstrap confidence interval contains zero). Speculative capital also shows a significant impact, carrying the largest Step 2 coefficient across the four crops at  $-85.84$  at the 1% level. This outcome reflects corn's dual identity as both a feed grain and an energy grain: rising oil prices are associated with elevated freight costs, magnifying the reach of international price shocks. The D4 policy shift, by removing the temporary storage price floor, was further associated with stronger transmission of external disturbances.

#### 5.3.4. Determinants of Soybean Futures Pricing Authority

Using the three breakpoints from Section 5.2 (D5: temporary storage launch, October 2008; D6: target price subsidies, April 2014; D7: producer subsidies, March 2017), an OLS specification is estimated to assess four mediating channels: grain yield through grain stocks, crude oil prices through international freight costs, crude oil prices through biodiesel demand, and speculative capital through extreme price movements. Results are shown in Table 5.

**Table 5.** Estimation results: formation mechanism of soybean futures international pricing power.

| Panel A Direct Effects (Dep. Var. : $SFP_t$ )                                        |                                          |                                 |                                                  |            |
|--------------------------------------------------------------------------------------|------------------------------------------|---------------------------------|--------------------------------------------------|------------|
|                                                                                      | Variable                                 |                                 | Coefficient                                      |            |
|                                                                                      | Soybean yield ( $U_{s,t}$ )              |                                 | 17.85 *** (5.75)                                 |            |
|                                                                                      | D5 Temporary storage (Oct. 2008)—jump    |                                 | $-5.92$ ** (2.58)                                |            |
|                                                                                      | D5 time trend                            |                                 | 0.24 *** (0.06)                                  |            |
|                                                                                      | D6 Target price subsidy (Apr. 2014)—jump |                                 | 2.06 (1.92)                                      |            |
|                                                                                      | D6 time trend                            |                                 | $-0.41$ *** (0.11)                               |            |
|                                                                                      | D7 Producer subsidy (Mar. 2017)—jump     |                                 | 8.88 *** (2.30)                                  |            |
|                                                                                      | D7 time trend                            |                                 | 0.33 *** (0.08)                                  |            |
|                                                                                      | Crude oil price ( $Oil_t$ )              |                                 | $-0.06$ *** (0.02)                               |            |
|                                                                                      | Speculative capital ( $SC_{s,t}$ )       |                                 | $-6.03 \times 10^{-6}$ ( $5.99 \times 10^{-6}$ ) |            |
|                                                                                      | Control variables                        |                                 | Controlled                                       |            |
|                                                                                      | Adj. $R^2$                               |                                 | 0.65                                             |            |
|                                                                                      | Observations N                           |                                 | 267                                              |            |
| Panel B Mediation Path 1 : Yield $\rightarrow$ Stock $\rightarrow SFP_t$             |                                          |                                 |                                                  |            |
| Step                                                                                 | Dep. Var.                                | Key Indep. Var.                 | Coefficient                                      | Adj. $R^2$ |
| Step1                                                                                | Soybean stock ( $Stock_{s,t}$ )          | Soybean yield ( $U_{s,t}$ )     | 27.12 ***                                        | 0.90       |
| Step2                                                                                | $SFP_t$                                  | Soybean stock ( $Stock_{s,t}$ ) | $1.69 \times 10^{-1}$ **                         | 0.36       |
|                                                                                      | Indirect effect ( $a \times b$ )         |                                 | 4.58                                             |            |
|                                                                                      | 95% bootstrap CI                         |                                 | [1.54, 8.12]                                     |            |
|                                                                                      | Direct effect ( $c' = c - a \times b$ )  |                                 | 13.27                                            |            |
| Panel C Mediation Path 2 : Oil $\rightarrow$ Shipping Cost (ISC) $\rightarrow SFP_t$ |                                          |                                 |                                                  |            |
| Step                                                                                 | Dep. Var.                                | Key Indep. Var.                 | Coefficient                                      | Adj. $R^2$ |
| Step1                                                                                | Shipping cost (ISC/BDI)                  | Crude oil price ( $Oil_t$ )     | 23.34 ***                                        | 0.43       |
| Step2                                                                                | $SFP_t$                                  | Shipping cost (ISC)             | $0.6 \times 10^{-3}$ ***                         | 0.37       |
|                                                                                      | Indirect effect ( $a \times b$ )         |                                 | $1.33 \times 10^{-2}$                            |            |
|                                                                                      | 95% bootstrap CI                         |                                 | $[5.9 \times 10^{-3}, 2.12 \times 10^{-2}]$      |            |
|                                                                                      | Direct effect ( $c' = c - a \times b$ )  |                                 | $-0.073$                                         |            |

Table 5. Cont.

| Panel D Mediation Path 3 : Oil $\rightarrow$ Biodiesel Demand (IBD) $\rightarrow$ SFP <sub>t</sub>             |                                       |                                          |                                               |                     |
|----------------------------------------------------------------------------------------------------------------|---------------------------------------|------------------------------------------|-----------------------------------------------|---------------------|
| Step                                                                                                           | Dep. Var.                             | Key Indep. Var.                          | Coefficient                                   | Adj. R <sup>2</sup> |
| Step1                                                                                                          | Biodiesel demand (IBD)                | Crude oil price (Oil <sub>t</sub> )      | $0.2 \times 10^{-3}$ ***                      | 0.80                |
| Step2                                                                                                          | SFP <sub>t</sub>                      | Biodiesel demand (IBD)                   | 23.23                                         | 0.34                |
|                                                                                                                | Indirect effect (a $\times$ b)        |                                          | $5.3 \times 10^{-3}$                          |                     |
|                                                                                                                | 95% bootstrap CI                      |                                          | $[-4.8 \times 10^{-3}, 1.53 \times 10^{-2}]$  |                     |
|                                                                                                                | Direct effect (c' = c – a $\times$ b) |                                          | –0.065                                        |                     |
| Panel E Mediation Path 4 : Speculative Capital $\rightarrow$ EPM <sub>s,t</sub> $\rightarrow$ SFP <sub>t</sub> |                                       |                                          |                                               |                     |
| Step                                                                                                           | Dep. Var.                             | Key Indep. Var.                          | Coefficient                                   | Adj. R <sup>2</sup> |
| Step1                                                                                                          | EPM <sub>s,t</sub>                    | Speculative capital (SC <sub>s,t</sub> ) | $7.29 \times 10^{-9}$                         | 0.18                |
| Step2                                                                                                          | SFP <sub>t</sub>                      | EPM <sub>s,t</sub>                       | –62.94 *                                      | 0.35                |
|                                                                                                                | Indirect effect (a $\times$ b)        |                                          | $-4.59 \times 10^{-7}$                        |                     |
|                                                                                                                | 95% bootstrap CI                      |                                          | $[-1.89 \times 10^{-6}, 0.37 \times 10^{-6}]$ |                     |
|                                                                                                                | Direct effect (c' = c – a $\times$ b) |                                          | $-5.57 \times 10^{-6}$                        |                     |

Notes: \*\*\*, \*\*, \* denote significance at 1%, 5%, and 10% levels. Significance levels and Newey–West HAC standard errors as in Table 2. The negative D5 jump coefficient turns significantly positive (+9.74,  $p < 0.10$ ) after a 44-month lag. This lag is identified by sequentially truncating the sample from October 2008 onward and re-estimating the regression: the coefficient changes sign and becomes significant when the sample begins in June 2012 (i.e., 44 months after the policy). The result is stable across the two robustness specifications in Table 6. The speculative capital indirect association is not statistically significant (the 95% bootstrap confidence interval for the indirect effect contains zero).

Table 6. Robustness check results: formation mechanism of Chinese grain futures international pricing power.

| Grain   | Key Variable                                            | Baseline                | Check 1<br>(Window = 240) | Check 2<br>(Replaced Controls) | Adj. R <sup>2</sup> |
|---------|---------------------------------------------------------|-------------------------|---------------------------|--------------------------------|---------------------|
| Wheat   | Wheat yield (U <sub>w,t</sub> )                         | 4.78 **                 | 4.23 ***                  | 5.69 ***                       | 0.43/0.48/0.54      |
|         | Min. purchase price dummy (Policy <sub>w,3t</sub> )     | 1.44                    | 1.89 **                   | 3.01 **                        |                     |
|         | Post-freeze time trend (Time <sub>wap,6t</sub> )        | –0.04 **                | –0.04 ***                 | –0.05 ***                      |                     |
|         | Crude oil price (Oil <sub>t</sub> )                     | –0.04 ***               | –0.04 ***                 | –0.02 **                       |                     |
| Rice    | Rice yield (U <sub>r,t</sub> )                          | 7.79 ***                | 6.70 ***                  | 9.18 ***                       | 0.70/0.69/0.63      |
|         | Rice policy intervention dummy (Policy <sub>r,t</sub> ) | –0.90 ***               | –0.72 ***                 | –0.53 *                        |                     |
|         | Speculative capital (SC <sub>r,t</sub> )                | $9.75 \times 10^{-5}$ * | $8.00 \times 10^{-5}$ *   | $1.00 \times 10^{-4}$ **       |                     |
| Corn    | Corn yield (U <sub>c,t</sub> )                          | 3.37 *                  | 3.66 ***                  | 2.91 ***                       | 0.42/0.44/0.61      |
|         | Producer subsidy policy (Policy <sub>c,4t</sub> )       | –1.55                   | –1.48 **                  | –1.67 ***                      |                     |
|         | Crude oil price (Oil <sub>t</sub> )                     | –0.05 ***               | –0.05 ***                 | –0.02 ***                      |                     |
| Soybean | Soybean yield (U <sub>s,t</sub> )                       | 17.85 ***               | 15.40 ***                 | 21.27 ***                      | 0.65/0.66/0.64      |
|         | Crude oil price (Oil <sub>t</sub> )                     | –0.06 ***               | –0.07 ***                 | –0.05 ***                      |                     |
|         | Speculative capital (SC <sub>s,t</sub> )                | $-6.03 \times 10^{-6}$  | $-5.58 \times 10^{-6}$ *  | $-7.95 \times 10^{-6}$ **      |                     |

Notes: \*\*\*, \*\*, \* denote significance at 1%, 5%, and 10% levels. Adj. R<sup>2</sup> reported as: Baseline/Check 1/Check 2. Check 1 uses a 240-trading-day rolling window. Check 2 replaces USD/RMB indices with USD/RMB spot rate and M2 with food-sector CPI (US and China).

Yield shows the strongest positive association among the four crops, with a coefficient of 17.85 at the 1% level, consistent with soybean's heavy import dependence, the smallest domestic supply base, and the outsized impact of marginal output changes on the supply–

demand balance. Policy effects display nonlinear dynamics: the D5 temporary storage impact is negative in the contemporaneous term but turns significantly positive roughly 44 months later. This delay reflects the fact that initial procurement prices exceeded international quotations, triggering arbitrage-based import expectations, and the policy insulation function only materialized as inventories accumulated. The D6 target price subsidy registers a significantly adverse trend of  $-0.41$  at the 1% level, as price–subsidy separation returned domestic prices to market determination and opened transmission corridors. Both the contemporaneous and trend coefficients for D7 producer subsidies are significantly positive at the 1% level, with values of 8.88 and 0.33, respectively, contrary to the hypothesized direction. A plausible interpretation is that subsidies are tied to planted area rather than market prices, accompanied by capacity expansion without distorting the price formation process, and thereby associated with enhanced futures market liquidity and price discovery. Crude oil shows the strongest external association through the ISC channel, with a direct effect of  $-0.06$  at the 1% level; the biodiesel channel and speculative capital do not attain significance. Soybean thus exhibits pronounced susceptibility to the compounded exposure of energization and financialization.

#### 5.3.5. Robustness Checks

Robustness is evaluated along two dimensions. First, the DY spillover index rolling window is extended from the 220-day baseline to 240 trading days, and the dependent variable is replaced with the re-estimated pricing power index. Second, the USD and RMB indices among the controls are substituted with the USD/RMB spot exchange rate, and M2 for both economies is replaced with food-sector CPI measures. Results are reported in Table 6.

As Table 6 shows, the core coefficients across all four crops remain broadly stable under both alternative specifications. Upon recomputation with Newey–West HAC standard errors, the rice speculative-capital coefficient is now positive and significant across the baseline ( $9.75 \times 10^{-5}$ ,  $p < 0.10$ ), Check 1 ( $8.00 \times 10^{-5}$ ,  $p < 0.10$ ), and Check 2 ( $1.00 \times 10^{-4}$ ,  $p < 0.05$ ), resolving the sign-reversal concern raised by the reviewer. All other core variables remain consistent, reinforcing the reliability of the principal findings. Wheat yield estimates range from 4.23 to 5.69; rice from 6.70 to 9.18; corn from 2.91 to 3.66; and soybean from 15.40 to 21.27. Policy and external shock variables likewise retain stability, confirming that the core conclusions withstand alternative pricing power index constructions and control variable substitutions.

#### 5.4. Empirical Findings: Configuration Pathways

This section deploys fsQCA to explore how conjunctural combinations of four conditions, namely domestic grain yield, price regulation policy, international crude oil prices, and international speculative capital, shape Chinese grain futures pricing authority. A consistency threshold of 0.75 and a frequency threshold of 1 are adopted, with the intermediate solution serving as the analytical basis. All pathways satisfy the 0.75 consistency threshold and  $\text{PRI} \geq 0.50$ , except within the low-level rice solution, where path D1 (0.741) and the overall solution consistency (0.678) fall slightly below 0.75; both are therefore interpreted with caution. Results corroborate the two shared improvement routes, namely capacity building with policy reinforcement and risk containment through volatility suppression, while also uncovering differentiated commodity-specific pathways. Configuration outcomes are displayed in Tables 7–10.

Consistent with the necessity analysis in Section 4.3 (Table A2), only three condition-forms—in raw or negated form—exceed the 0.9 consistency threshold and thus qualify as individually necessary conditions: the minimum purchase price dummy for wheat (0.977),

the temporary storage policy dummy for corn (0.930), and the absence of the post-producer-subsidy time trend for soybean (0.936). All remaining conditions fall below 0.9, indicating that pricing power is chiefly shaped by conjunctural combinations of conditions rather than by any single prerequisite, as reflected in the multi-condition pathways reported in Tables 7–10.

**Table 7.** Path analysis results of Chinese wheat futures international pricing power.

| Condition Variable                                               | High-Level Pricing Power ( $WFP_t$ ) |                       |                       | Low-Level Pricing Power ( $\sim WFP_t$ ) |                       |                       |
|------------------------------------------------------------------|--------------------------------------|-----------------------|-----------------------|------------------------------------------|-----------------------|-----------------------|
|                                                                  | A1                                   | A2                    | A3                    | B1                                       | B2                    | B3                    |
| Wheat yield ( $U_{w,t}$ )                                        | •                                    | •                     | ●                     | U                                        | U                     | ●                     |
| Pre-min. purchase price time trend ( $Time1_{w,t}$ )             | •                                    | •                     | •                     | U                                        | •                     | •                     |
| Min. purchase price dummy (0–1) ( $Policy_{w,3t}$ )              | •                                    | •                     | •                     | U                                        | •                     | •                     |
| Post-min. purchase price time trend ( $Time_{wap,5t}$ )          | •                                    | •                     | •                     | U                                        | ●                     | •                     |
| Price increase dummy (0–1) ( $Policy_{w,4t}$ )                   | •                                    | •                     | U                     | U                                        | U                     | U                     |
| Post-price increase time trend ( $Time_{wap,6t}$ )               | -                                    | ●                     | U                     | U                                        | U                     | U                     |
| International crude oil price ( $Oil_{w,t}$ )                    | U                                    | -                     | ●                     | U                                        | •                     | U                     |
| Change in int'l wheat futures speculative capital ( $SC_{w,t}$ ) | -                                    | ●                     | U                     | -                                        | ●                     | U                     |
| Consistency                                                      | $8.17 \times 10^{-1}$                | $8.12 \times 10^{-1}$ | $7.79 \times 10^{-1}$ | $9.42 \times 10^{-1}$                    | $9.42 \times 10^{-1}$ | $8.36 \times 10^{-1}$ |
| PRI                                                              | $7.73 \times 10^{-1}$                | $7.62 \times 10^{-1}$ | $6.25 \times 10^{-1}$ | 0.94                                     | $6.38 \times 10^{-1}$ | $5.32 \times 10^{-1}$ |
| Coverage                                                         | $4.46 \times 10^{-1}$                | $2.66 \times 10^{-1}$ | $2.88 \times 10^{-1}$ | $1.83 \times 10^{-1}$                    | $1.06 \times 10^{-1}$ | $0.24 \times 10^{-1}$ |
| Unique coverage                                                  | $2.24 \times 10^{-1}$                | $0.44 \times 10^{-1}$ | $0.62 \times 10^{-1}$ | $1.83 \times 10^{-1}$                    | $0.88 \times 10^{-1}$ | $0.7 \times 10^{-2}$  |
| Overall PRI/Consistency/Coverage                                 | 0.797/0.746/0.572                    |                       |                       | 0.876/0.843/0.295                        |                       |                       |

Notes: ● = core condition present; U = core condition absent; • = peripheral condition present; U = peripheral condition absent; the same notation applies to Tables 8–10.

**Table 8.** Path analysis results of Chinese rice futures international pricing power.

| Condition Variable                                              | High-Level Pricing Power ( $RFP_t$ ) |                       | Low-Level Pricing Power ( $\sim RFP_t$ ) |                       |
|-----------------------------------------------------------------|--------------------------------------|-----------------------|------------------------------------------|-----------------------|
|                                                                 | C1                                   | C2                    | D1                                       | D2                    |
| Rice yield ( $U_{r,t}$ )                                        | •                                    | •                     | •                                        | U                     |
| Pre-price cut time trend ( $Time1_{r,t}$ )                      | ●                                    | •                     | •                                        | U                     |
| Significant price cut dummy ( $Policy_{r,t}$ )                  | ●                                    | U                     | •                                        | U                     |
| Post-price cut time trend ( $Time_{rap,t}$ )                    | ●                                    | U                     | ●                                        | U                     |
| International crude oil price ( $Oil_{r,t}$ )                   | ●                                    | U                     | U                                        | ●                     |
| Change in int'l rice futures speculative capital ( $SC_{r,t}$ ) | U                                    | •                     | -                                        | ●                     |
| Consistency                                                     | $8.65 \times 10^{-1}$                | $8.27 \times 10^{-1}$ | $7.41 \times 10^{-1}$                    | 0.76                  |
| PRI                                                             | $7.71 \times 10^{-1}$                | $7.53 \times 10^{-1}$ | $6.02 \times 10^{-1}$                    | $7.33 \times 10^{-1}$ |
| Coverage                                                        | $1.83 \times 10^{-1}$                | $1.23 \times 10^{-1}$ | $2.95 \times 10^{-1}$                    | $3.04 \times 10^{-1}$ |
| Unique coverage                                                 | $1.83 \times 10^{-1}$                | $1.23 \times 10^{-1}$ | $2.95 \times 10^{-1}$                    | $3.04 \times 10^{-1}$ |
| Overall PRI/Consistency/Coverage                                | 0.849/0.763/0.306                    |                       | 0.751/0.678/0.599                        |                       |

**Table 9.** Path analysis results of Chinese corn futures international pricing power.

| Condition Variable                                                    | High-Level Pricing Power (CFP <sub>t</sub> ) |                       | Low-Level Pricing Power (~CFP <sub>t</sub> ) |                       |
|-----------------------------------------------------------------------|----------------------------------------------|-----------------------|----------------------------------------------|-----------------------|
|                                                                       | E1                                           | E2                    | F1                                           | F2                    |
| Corn yield (U <sub>c,t</sub> )                                        | •                                            | -                     | U                                            | ●                     |
| Pre-temporary storage time trend (Time1 <sub>c,t</sub> )              | •                                            | •                     | U                                            | •                     |
| Temporary storage policy dummy (Policy <sub>c,3t</sub> )              | •                                            | •                     | U                                            | •                     |
| Post-temporary storage time trend (Time <sub>cap,5t</sub> )           | ●                                            | ●                     | U                                            | •                     |
| Producer subsidy dummy (Policy <sub>c,4t</sub> )                      | •                                            | •                     | U                                            | •                     |
| Post-producer subsidy time trend (Time <sub>cap,6t</sub> )            | -                                            | U                     | U                                            | •                     |
| International crude oil price (Oil <sub>c,t</sub> )                   | U                                            | U                     | -                                            | ●                     |
| Change in int'l corn futures speculative capital (SC <sub>c,t</sub> ) | U                                            | U                     | •                                            | ●                     |
| Consistency                                                           | 0.89                                         | $8.72 \times 10^{-1}$ | $9.15 \times 10^{-1}$                        | $7.99 \times 10^{-1}$ |
| PRI                                                                   | $8.73 \times 10^{-1}$                        | $8.49 \times 10^{-1}$ | $8.93 \times 10^{-1}$                        | $7.63 \times 10^{-1}$ |
| Coverage                                                              | 0.28                                         | $1.41 \times 10^{-1}$ | $1.93 \times 10^{-1}$                        | $1.84 \times 10^{-1}$ |
| Unique coverage                                                       | 0.16                                         | $0.22 \times 10^{-1}$ | $1.93 \times 10^{-1}$                        | $1.84 \times 10^{-1}$ |
| Overall PRI/Consistency/Coverage                                      | 0.874/0.856/0.303                            |                       | 0.854/0.823/0.377                            |                       |

**Table 10.** Path analysis results of Chinese soybean futures international pricing power.

| Condition Variable                                                       | High-level Pricing Power (SFP <sub>t</sub> ) |                       | Low-level Pricing Power (~SFP <sub>t</sub> ) |                       |                       |
|--------------------------------------------------------------------------|----------------------------------------------|-----------------------|----------------------------------------------|-----------------------|-----------------------|
|                                                                          | G1                                           | G2                    | H1                                           | H2                    | H3                    |
| Soybean yield (U <sub>s,t</sub> )                                        | ●                                            | ●                     | U                                            | U                     | U                     |
| Pre-temp. storage time trend (Time1 <sub>s,t</sub> )                     | ●                                            | ●                     | U                                            | U                     | •                     |
| Temporary storage policy dummy (Policy <sub>s,3t</sub> )                 | ●                                            | ●                     | •                                            | -                     | •                     |
| Post-temp. storage time trend (Time <sub>sap,6t</sub> )                  | ●                                            | ●                     | U                                            | U                     | •                     |
| Target price subsidy dummy (Policy <sub>s,4t</sub> )                     | ●                                            | ●                     | U                                            | U                     | U                     |
| Post-target price subsidy time trend (Time <sub>sap,7t</sub> )           | ●                                            | ●                     | U                                            | U                     | •                     |
| Producer subsidy dummy (Policy <sub>s,5t</sub> )                         | ●                                            | ●                     | U                                            | U                     | U                     |
| Post-producer subsidy time trend (Time <sub>sap,8t</sub> )               | •                                            | -                     | U                                            | U                     | U                     |
| International crude oil price (Oil <sub>s,t</sub> )                      | -                                            | U                     | ●                                            | •                     | U                     |
| Change in int'l soybean futures speculative capital (SC <sub>s,t</sub> ) | -                                            | U                     | -                                            | ●                     | ●                     |
| Consistency                                                              | $9.24 \times 10^{-1}$                        | $9.13 \times 10^{-1}$ | $8.95 \times 10^{-1}$                        | 0.90                  | $9.95 \times 10^{-1}$ |
| PRI                                                                      | $9.15 \times 10^{-1}$                        | $8.87 \times 10^{-1}$ | $8.79 \times 10^{-1}$                        | $8.76 \times 10^{-1}$ | $9.93 \times 10^{-1}$ |
| Coverage                                                                 | $4.99 \times 10^{-1}$                        | $1.71 \times 10^{-1}$ | $2.62 \times 10^{-1}$                        | $3.07 \times 10^{-1}$ | $0.62 \times 10^{-1}$ |
| Unique coverage                                                          | $3.46 \times 10^{-1}$                        | $0.18 \times 10^{-1}$ | $0.68 \times 10^{-1}$                        | $1.13 \times 10^{-1}$ | $0.62 \times 10^{-1}$ |
| Overall PRI/Consistency/Coverage                                         | 0.901/0.886/0.517                            |                       | 0.927/0.911/0.437                            |                       |                       |

#### 5.4.1. Pathways to High-Level Pricing Authority

Wheat generates three functionally equivalent high-level pathways (A1–A3). A1 contains no core conditions; elevated yield and policy price increases enter as peripheral-present conditions, while non-high oil prices appear as a peripheral-absent condition. In A2, the post-price-increase time trend and rising speculative capital jointly form dual core-present conditions, with high yield and other variables serving as peripheral-supportive elements. In A3, high yield and high oil prices constitute core-present conditions, a non-increasing price trend and low speculative capital form core-absent conditions, and remaining policy variables enter as peripheral-present. Collectively, the three pathways demonstrate that either sustained policy adjustment or market-oriented capacity adaptation can serve as the primary driving force, indicating substantial pathway flexibility.

For rice, C1 designates policy stability, the policy-cycle time trend, and high oil prices as core-present conditions, with low speculative capital serving as a peripheral-absent constraint. C2 features no core conditions: elevated yield and heightened speculative capital enter as peripheral-present conditions, while all policy variables remain absent. The two pathways embody policy-led and production-capacity-adapted realization mechanisms, respectively, and are mutually complementary.

Corn pathways E1 and E2 share a nearly identical configurational structure, both singling out the post-temporary-storage time trend as the sole core-present condition and designating non-high oil prices and non-high speculative capital as dual core-absent conditions; elevated yield and policy implementation serve as peripheral-present complements. The principal distinction is that yield drops out of E2, rendering it a streamlined variant of E1. Together, the two pathways affirm that sustained temporary storage enforcement is the primary driver, while low external risk intensity constitutes a core-contextual condition.

For soybean, G1 and G2 both designate elevated yield and three-stage policy variables, seven conditions in total, as core-present conditions. In G1, the post-producer-subsidy time trend enters as a peripheral-present condition, while oil prices and speculative capital are absent from the configuration. In G2, these two conditions appear as peripheral-absent, suggesting that when the external environment is relatively benign, the demand for sustained policy enforcement may be somewhat relaxed.

Among the identified configurations, wheat A1 and soybean G1/G2 carry the strongest practical significance, as they reconcile domestic capacity-building with policy support under relatively benign external conditions; corn E1/E2 highlight that sustained temporary-storage enforcement is the pivotal driver, whereas rice C1/C2 depend on either policy stabilization or production-capacity adaptation.

The four crops display pronounced differences in pathway stringency. Wheat offers the most pathways and the greatest conditional flexibility, with both policy adjustment and market-oriented adaptation capable of serving as core drivers. Rice presents two feasible, complementary routes: a policy-led path and a production-capacity-adapted path. Corn depends heavily on temporary storage policy as the central driver, with low external risk intensity functioning as a core-contextual condition. Soybean imposes the most demanding requirements, necessitating simultaneous full-stage policy coverage and high yield, making its pathways the hardest to realize. Broadly, the greater a crop's import dependence, the more stringent the internal and external conditions needed to secure high pricing authority, and the greater the coordination demands among them.

#### 5.4.2. Scenarios of Low-Level Pricing Authority Erosion

The low-level configurations in Tables 7 and 8 reveal that when both internal pillars, production capacity and policy support, simultaneously falter, pricing authority deteriorates markedly even absent severe external shocks. In wheat pathway B3, elevated yield persists but policy adjustment mechanisms are absent and oil prices remain non-low, leaving internal support too weak to withstand external pressure. In rice pathway D1, a sharp reduction in the minimum purchase price removes policy floor protection, while capacity buffers are likewise constrained. These findings underscore that the sustained effectiveness of domestic driving conditions is a prerequisite for preserving high pricing authority.

Even when internal conditions remain relatively sound, external shocks alone are associated with pricing authority erosion. Wheat pathway B2 and rice pathway D2 (Tables 7 and 8) demonstrate that elevated oil prices and surging speculative capital are sufficient to breach existing buffer mechanisms and are associated with weaker pricing power even in the absence of visible internal deterioration. Corn pathway F2 (Table 9) stands in contrast to the high-level route E1: after the shift from temporary storage to producer subsidies, the convergence of high yield, high oil prices, and high speculative capital was jointly associated with weaker pricing authority, corroborating from the opposite direction the protective role of temporary storage price intervention against external risks.

Soybean pathways H1 and H2 (Table 10) centrally illustrate the risk exposure problem arising from policy instrument transitions. Both pathways correspond to the target price subsidy phase, with H1 characterized by elevated oil prices and H2 by heightened speculative capital volatility. Under the target price subsidy regime, domestic soybean prices became fully aligned with international markets and policy insulation was largely withdrawn, leaving pricing authority directly exposed to a single external shock. This demonstrates that when policy instruments shift from floor-support to market-oriented forms, a crop's sensitivity to external disturbances rises substantially.

The shared and crop-specific pathways derived from the configurational analysis align with those posited in the theoretical reasoning at the core-condition level, with divergences confined to peripheral-condition values, thereby confirming configurational robustness. Cross-crop comparisons highlight the heterogeneous effects of policy instruments: producer subsidies complement temporary storage synergistically in soybean yet substitute for and weaken temporary storage effects in corn, implying that agricultural policy design must accommodate differences in market structure and import dependence across commodities. When the consistency threshold is elevated to 0.80 and calibration anchors are perturbed by  $\pm 5\%$ , core conditions remain substantively intact, further affirming the robustness of the findings.

## 6. Discussion

On the measurement of pricing authority, the bulk of prior work relies on price transmission coefficients or market co-movement as indirect stand-ins [9]. Several scholars have employed TVP-VAR and DCC-GARCH frameworks to trace risk spillovers across Chinese and US grain futures markets [10,37], gauged global grain price transmission through TVP-VAR connectedness measures [27], or probed domestic–foreign market linkages via futures basis co-movement [18]. These studies, however, center on spillover intensity and symmetry without precisely delineating net spillover direction or the magnitude of pricing leverage. The existing conceptual literature on pricing authority remains largely qualitative [1–3,38] and lacks cross-crop quantitative comparability. The present study constructs a time-varying index directly grounded in the dynamic net spillover between international and domestic futures quotations, pairing rolling window estimation with

PELT structural break detection to capture both net influence magnitude and directional shifts, thereby furnishing a workable measurement instrument for mechanism analysis.

Regarding mechanism identification, most prior investigations focus on a single factor or a single crop. Earlier work has applied Bayesian VAR to trace the dynamic impact of international soybean prices on the Chinese market, or used PLS-SEM to examine multi-pathway transmission of international corn prices [11], yet these studies remain confined to the external shock dimension without integrating the yield–stock endogenous chain and the crude oil–freight cost/biofuel dual-channel mechanism into a unified framework, and without comparing the differential effects of price regulation policies across commodities. Some researchers detected a reversal in China–US corn pricing dominance around 2014 [30] but did not further probe the underlying drivers. The present study incorporates yield, policy, crude oil prices, and speculative capital into a single framework, with stocks, freight costs, biofuel demand, and extreme price movements as mediating variables, testing a compound mechanism across crops and pathways. The finding that soybean pricing authority was higher under producer subsidies and lower during the target price subsidy phase has not been systematically addressed in the existing literature.

On the empirical pathway front, the prevailing literature is dominated by single-factor effect assessments, theoretically proposing routes such as yield improvement, futures market reform, and import diversification [39,40], yet failing to address asymmetric interactions among conditional variables or to differentiate pathways across crops. This study deploys fsQCA, treating the four conditional variables as a conjunctural configuration and identifying sufficient condition combinations from both the high-outcome and low-outcome ends. Two shared pathways alongside crop-specific pathways are distilled [14,15]; low-level configurations further identify, in reverse, the typology of risk-combination patterns associated with weaker pricing authority.

Greater pricing power can benefit domestic food security through three indirect channels. First, when Chinese futures prices lead international price formation, domestic quotations react less to external shocks, dampening the pass-through of global volatility into consumer prices. Second, stronger price leadership sharpens the hedging and storage signals used by domestic producers and traders, supporting more stable supply. Third, a market that leads discovery is less exposed to imported price spikes, raising the resilience of the domestic food system. Because this study measures pricing power rather than food-security outcomes, these mechanisms are treated as potential channels rather than estimated effects.

This study positions itself against representative prior work along three dimensions: direct measurement of net pricing power, an integrated multi-crop, multi-driver mechanism, and a configurational enhancement pathway. As summarized in Table 11, existing studies have addressed these dimensions in isolation, whereas the present study brings all three together within a single framework.

**Table 11.** Contextualizing this study within the existing literature.

| Study (Year)             | Net Pricing-Power Index | Multi-Driver Mechanism (Four Crops) | Configurational Pathway | Key Findings                                                             |
|--------------------------|-------------------------|-------------------------------------|-------------------------|--------------------------------------------------------------------------|
| Jia et al. (2016) [30]   | Partial                 | No                                  | No                      | China’s futures began leading the US after 2014; soybean most integrated |
| Guo & Tanaka (2022) [40] | No                      | Partial                             | No                      | Biofuel output and speculation significantly drive food prices           |

Table 11. Cont.

| Study (Year)                   | Net Pricing-Power Index | Multi-Driver Mechanism (Four Crops) | Configurational Pathway | Key Findings                                                                                                       |
|--------------------------------|-------------------------|-------------------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------|
| Karkowska & Urjasz (2024) [27] | No                      | Partial                             | No                      | Grains dominate energy–grain volatility spillovers                                                                 |
| Wang et al. (2024) [18]        | Partial                 | No                                  | No                      | Strong futures-basis dependence; China’s linkages weaker                                                           |
| Xue et al. (2024) [9]          | Partial                 | No                                  | No                      | Soybean dominates global grain spillovers; corn most exposed                                                       |
| Zhu et al. (2024) [10]         | Partial                 | No                                  | No                      | US (CBOT) grains transmit risk; China’s (DCE) grains receive                                                       |
| Shen & Qiu (2024) [11]         | No                      | Partial                             | No                      | Domestic supply–demand drives corn price; energy acts indirectly                                                   |
| fsQCA studies [14,15]          | No                      | No                                  | Partial                 | fsQCA identifies condition configurations, but not for grain pricing                                               |
| Our research                   | Yes                     | Yes                                 | Yes                     | Rice strongest, soybean weakest; asymmetric policy and channel-specific shocks; shared plus crop-specific pathways |

Notes: “Yes”: fully addressed, “Partial”: partially addressed, “No”: not addressed. Net pricing-power index: a direct, time-varying measure of the magnitude and direction of international pricing power; multi-driver mechanism: joint identification of yield, policy, crude oil, and speculative-capital channels across all four staple crops; configurational pathway: fsQCA-based multi-factor combinations.

7. Conclusions

This paper comprehensively deploys the DY spillover index, OLS-based mediation analysis, and fsQCA to systematically quantify the international pricing authority of China’s four principal grain futures and to probe its underlying mechanisms and improvement pathways. The principal conclusions are as follows.

- (1)

The international pricing power of Chinese grain futures exhibits pronounced commodity heterogeneity and time-varying dynamics. Rice commands the strongest pricing leverage, trailed by wheat; corn exhibits marked stage-specific fluctuations; and soybean remains persistently weak. Structural breaks in each crop’s pricing trajectory align closely with domestic policy shifts and salient episodes in international energy and financial markets.
- (2)

Pricing authority formation reflects the interplay of domestic and external forces. On the domestic side, grain yield across wheat, rice, and soybean is associated with stronger pricing leverage through an inventory mediation channel, with the soybean yield effect the most pronounced. The impact of price regulation policies varies by commodity and instrument. Freezing or reducing the minimum purchase price and shifting from temporary storage to market-oriented subsidies are both associated with weaker pricing power to varying degrees, whereas soybean’s shift from target price subsidies to producer subsidies has the opposite effect. Some policy effects exhibit notable time lags. On the external side, international crude oil prices are associated

with weaker pricing authority in wheat and corn through freight cost escalation. Volatility in international speculative capital is associated with weaker pricing power in rice and corn by intensifying extreme price movements.

- (3) Improvement pathways blend shared features with commodity-specific differentiation. At the common level, two routes emerge: capacity building buttressed by policy reinforcement, and risk containment through volatility suppression. At the commodity level, wheat follows a policy intervention–low risk sensitivity route; rice a price stabilization–risk resilience route; corn a policy conservatism–risk hedging route; and soybean a capacity strengthening–policy adaptation route. Low-level configurations further reveal, in reverse, two categories of risk combination: external shock accumulation and insufficient endogenous driving force.

The marginal contributions and practical value of this paper are threefold. First, on the measurement front, a time-varying dynamic net spillover index is constructed to precisely capture the evolving trajectory and crop-level differentiation of Chinese grain futures international pricing authority. Second, on the mechanism front, the dual-dimensional domestic-drive–external-shock transmission pathway is delineated, revealing the asymmetry of policy effects and the channel-specific heterogeneity of external shock transmission. Third, on the pathway front, shared configurations and commodity-specific routes are identified, offering actionable schemes for safeguarding food security and strengthening China’s international pricing voice.

This study is subject to certain limitations. Cross-crop comparability is also limited by unequal sample windows. Wheat, corn, and soybean span roughly two decades, but rice is restricted to December 2010 through September 2022. The rice series therefore encounters fewer global shocks and policy episodes, so its pricing-power levels and policy effects are not strictly comparable with those of the other crops. We interpret cross-crop differences cautiously and treat each crop’s estimates as conditional on its own sample. Data availability for some crops means the sample window does not fully encompass recent policy adjustments, and fsQCA configurational analysis cannot incorporate exogenous uncertainties such as geopolitical conflicts. Future research may extend the temporal coverage and explore dynamic QCA (tQCA) or time-varying parameter econometric models to deepen the analysis of the complex driving mechanisms behind the evolution of Chinese grain futures pricing authority.

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## Appendix A

**Table A1.** Calibration anchors (direct method: full membership = P95, crossover = P50, full non-membership = P5).

| Variable                                                              | Full Membership (P95) | Crossover (P50) | Full Non-Membership (P5) |
|-----------------------------------------------------------------------|-----------------------|-----------------|--------------------------|
| Panel A—Outcome (international pricing power)                         |                       |                 |                          |
| Wheat                                                                 | −0.16                 | −1.01           | −2.68                    |
| Rice                                                                  | 0.11                  | −0.09           | −0.42                    |
| Corn                                                                  | −0.03                 | −1.50           | −3.09                    |
| Soybean                                                               | −1.93                 | −4.36           | −10.04                   |
| Panel B—Condition: grain yield                                        |                       |                 |                          |
| Wheat                                                                 | 5.40                  | 5.00            | 4.71                     |
| Rice                                                                  | 7.03                  | 6.86            | 6.72                     |
| Corn                                                                  | 6.11                  | 5.87            | 5.33                     |
| Soybean                                                               | 1.89                  | 1.80            | 1.70                     |
| Panel C—Condition: international crude oil price                      |                       |                 |                          |
| Wheat                                                                 | 88.25                 | 67.32           | 51.67                    |
| Rice                                                                  | 94.49                 | 67.32           | 50.38                    |
| Corn                                                                  | 88.12                 | 71.48           | 56.93                    |
| Soybean                                                               | 84.69                 | 68.63           | 49.84                    |
| Panel D—Condition: speculative capital (change in net long positions) |                       |                 |                          |
| Wheat                                                                 | 42,637                | 25,811.20       | 10,813.75                |
| Rice                                                                  | 2724.7                | 1691.6          | 755.35                   |
| Corn                                                                  | 289,876               | 167,348         | 75,042.18                |
| Soybean                                                               | 133,385               | 73,287.5        | 31,706.83                |

Note: The continuous pre- and post-policy time-trend terms are calibrated by the same direct method; their anchors are omitted for brevity.

**Table A2.** Necessary-condition analysis (consistency threshold = 0.9).

| Condition                                          | High-Level Pricing Power |          | Low-Level Pricing Power |          |
|----------------------------------------------------|--------------------------|----------|-------------------------|----------|
| Condition                                          | Consistency              | Coverage | Consistency             | Coverage |
| Wheat                                              |                          |          |                         |          |
| Wheat yield                                        | 0.731                    | 0.731    | 0.374                   | 0.362    |
| ~Wheat yield                                       | 0.362                    | 0.373    | 0.722                   | 0.723    |
| Pre-min. purchase price time trend                 | 0.715                    | 0.726    | 0.398                   | 0.392    |
| ~Pre-min. purchase price time trend                | 0.401                    | 0.407    | 0.722                   | 0.711    |
| Min. purchase price dummy (0–1)                    | 0.977                    | 0.559    | 0.794                   | 0.441    |
| ~Min. purchase price dummy (0–1)                   | 0.023                    | 0.104    | 0.206                   | 0.896    |
| Post-min. purchase price time trend                | 0.716                    | 0.726    | 0.399                   | 0.392    |
| ~Post-min. purchase price time trend               | 0.401                    | 0.407    | 0.721                   | 0.711    |
| Price increase dummy (0–1)                         | 0.610                    | 0.716    | 0.250                   | 0.284    |
| ~Price increase dummy (0–1)                        | 0.390                    | 0.349    | 0.750                   | 0.651    |
| Post-price increase time trend                     | 0.483                    | 0.685    | 0.287                   | 0.396    |
| ~Post-price increase time trend                    | 0.575                    | 0.454    | 0.772                   | 0.591    |
| International crude oil price                      | 0.471                    | 0.486    | 0.618                   | 0.619    |
| ~International crude oil price                     | 0.631                    | 0.630    | 0.486                   | 0.471    |
| Change in int'l wheat futures speculative capital  | 0.574                    | 0.590    | 0.493                   | 0.492    |
| ~Change in int'l wheat futures speculative capital | 0.506                    | 0.507    | 0.589                   | 0.573    |

Table A2. Cont.

| Condition                                         | High-Level Pricing Power |          | Low-Level Pricing Power |          |
|---------------------------------------------------|--------------------------|----------|-------------------------|----------|
| Condition                                         | Consistency              | Coverage | Consistency             | Coverage |
| Rice                                              |                          |          |                         |          |
| Rice yield                                        | 0.575                    | 0.649    | 0.430                   | 0.467    |
| ~Rice yield                                       | 0.528                    | 0.491    | 0.677                   | 0.605    |
| Pre-price cut time trend                          | 0.628                    | 0.641    | 0.451                   | 0.442    |
| ~Pre-price cut time trend                         | 0.453                    | 0.462    | 0.634                   | 0.621    |
| Significant price cut dummy                       | 0.385                    | 0.541    | 0.340                   | 0.459    |
| ~Significant price cut dummy                      | 0.615                    | 0.492    | 0.660                   | 0.508    |
| Post-price cut time trend                         | 0.351                    | 0.542    | 0.370                   | 0.549    |
| ~Post-price cut time trend                        | 0.707                    | 0.539    | 0.691                   | 0.506    |
| International crude oil price                     | 0.510                    | 0.529    | 0.579                   | 0.577    |
| ~International crude oil price                    | 0.593                    | 0.594    | 0.527                   | 0.508    |
| Change in int'l rice futures speculative capital  | 0.417                    | 0.431    | 0.651                   | 0.647    |
| ~Change in int'l rice futures speculative capital | 0.658                    | 0.663    | 0.427                   | 0.413    |
| Corn                                              |                          |          |                         |          |
| Corn yield                                        | 0.612                    | 0.642    | 0.454                   | 0.446    |
| ~Corn yield                                       | 0.472                    | 0.480    | 0.636                   | 0.605    |
| Pre-temporary storage time trend                  | 0.614                    | 0.634    | 0.449                   | 0.434    |
| ~Pre-temporary storage time trend                 | 0.452                    | 0.467    | 0.621                   | 0.601    |
| Temporary storage policy dummy                    | 0.930                    | 0.570    | 0.748                   | 0.430    |
| ~Temporary storage policy dummy                   | 0.070                    | 0.229    | 0.252                   | 0.771    |
| Post-temporary storage time trend                 | 0.617                    | 0.635    | 0.452                   | 0.436    |
| ~Post-temporary storage time trend                | 0.452                    | 0.468    | 0.621                   | 0.603    |
| Producer subsidy dummy                            | 0.524                    | 0.586    | 0.395                   | 0.414    |
| ~Producer subsidy dummy                           | 0.476                    | 0.456    | 0.605                   | 0.544    |
| Post-producer subsidy time trend                  | 0.408                    | 0.555    | 0.416                   | 0.530    |
| ~Post-producer subsidy time trend                 | 0.654                    | 0.544    | 0.650                   | 0.507    |
| International crude oil price                     | 0.409                    | 0.426    | 0.710                   | 0.693    |
| ~International crude oil price                    | 0.706                    | 0.722    | 0.413                   | 0.396    |
| Change in int'l corn futures speculative capital  | 0.398                    | 0.416    | 0.700                   | 0.686    |
| ~Change in int'l corn futures speculative capital | 0.700                    | 0.714    | 0.404                   | 0.386    |
| Soybean                                           |                          |          |                         |          |
| Soybean yield                                     | 0.761                    | 0.809    | 0.316                   | 0.314    |
| ~Soybean yield                                    | 0.355                    | 0.356    | 0.808                   | 0.760    |
| Pre-temp. storage time trend                      | 0.739                    | 0.763    | 0.349                   | 0.338    |
| ~Pre-temp. storage time trend                     | 0.359                    | 0.370    | 0.755                   | 0.730    |
| Temporary storage policy dummy                    | 0.810                    | 0.569    | 0.655                   | 0.431    |
| ~Temporary storage policy dummy                   | 0.190                    | 0.371    | 0.345                   | 0.629    |
| Post-temp. storage time trend                     | 0.750                    | 0.766    | 0.361                   | 0.345    |
| ~Post-temp. storage time trend                    | 0.359                    | 0.375    | 0.755                   | 0.739    |
| Target price subsidy dummy                        | 0.707                    | 0.747    | 0.256                   | 0.253    |
| ~Target price subsidy dummy                       | 0.293                    | 0.296    | 0.744                   | 0.704    |
| Post-target price subsidy time trend              | 0.641                    | 0.843    | 0.212                   | 0.262    |
| ~Post-target price subsidy time trend             | 0.439                    | 0.373    | 0.873                   | 0.695    |
| Producer subsidy dummy                            | 0.592                    | 0.853    | 0.109                   | 0.147    |
| ~Producer subsidy dummy                           | 0.408                    | 0.329    | 0.891                   | 0.671    |
| Post-producer subsidy time trend                  | 0.578                    | 0.907    | 0.127                   | 0.187    |
| ~Post-producer subsidy time trend                 | 0.482                    | 0.371    | 0.936                   | 0.675    |

Table A2. Cont.

| Condition                                            | High-Level Pricing Power |          | Low-Level Pricing Power |          |
|------------------------------------------------------|--------------------------|----------|-------------------------|----------|
| Condition                                            | Consistency              | Coverage | Consistency             | Coverage |
| Soybean                                              |                          |          |                         |          |
| International crude oil price                        | 0.499                    | 0.524    | 0.568                   | 0.560    |
| ~International crude oil price                       | 0.581                    | 0.590    | 0.517                   | 0.491    |
| Change in int'l soybean futures speculative capital  | 0.520                    | 0.539    | 0.578                   | 0.561    |
| ~Change in int'l soybean futures speculative capital | 0.576                    | 0.593    | 0.525                   | 0.506    |

Note: The tilde (~) denotes the negated form of a condition. With a consistency threshold of 0.9, a condition is deemed necessary when its consistency exceeds 0.9. Three condition-forms exceed this threshold—the minimum purchase price dummy for wheat (0.977), the temporary storage policy dummy for corn (0.930), and the absence of the post-producer-subsidy time trend for soybean (0.936)—and are interpreted as individually necessary conditions; all remaining conditions fall below 0.9.

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