LSF Case Study

Prepared by Blueprint Holdings (Pty) Ltd

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# South African Sorghum Price Forecasting and Bioethanol Market Study:

## Corn Upstream Report

PROUDLY SUPPORTING LOCAL INDUSTRY

## ABOUT THIS STUDY

This is the final report of five in the overall delivery of the Sorghum Price Forecasting and Bioethanol Study. It establishes a defensible, end-to-end pricing framework for South African sorghum by explicitly anchoring domestic price formation to upstream dynamics in US corn futures. The objective is to ensure that local sorghum price forecasts are grounded in the dominant global mechanisms governing Corn price formation, while preserving sensitivity to South African market structure, import-parity transmission, substitution with yellow maize, and exchange-rate pass-through. The framework is designed for investor-facing and policy-relevant use, prioritising transparency, empirical discipline and scenario capability over black-box forecasting.

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# Glossary of Abbreviated Terms

| Acronym | Expanded Term |
|---|---|
| ARDL | Autoregressive Distributed Lag |
| BFAP | Bureau for Food and Agricultural Policy (South Africa) |
| CBOT | Chicago Board of Trade |
| COT | Commitment of Traders |
| DFI | Development Finance Institution |
| ECM | Error Correction Mechanism |
| ENSO | El Niño-Southern Oscillation |
| ERS | Economic Research Service |
| FAO | Food and Agriculture Organization (UN) |
| FAPRI | Food and Agricultural Policy Research Institute |
| GDP | Gross Domestic Product |
| NVDI | Normalised Difference Vegetation Index |
| OECD | Organisation for Economic Co-operation and Development |
| RFS | Renewable Fuel Standard |
| USDA | United States Department of Agriculture |
| VAR | Vector Autoregression |
| VECM | Vector Error Correction Models |
| WASDE | World Agricultural Supply and Demand Estimates |

# Executive Summary

## Purpose and Scope

This study establishes a defensible, end-to-end pricing framework for South African sorghum by explicitly anchoring domestic price formation to upstream dynamics in US corn futures. The objective is to ensure that local sorghum price forecasts are grounded in the dominant global mechanisms governing Corn price formation, while preserving sensitivity to South African market structure, import-parity transmission, substitution with yellow maize, and exchange-rate pass-through. The framework is designed for investor-facing and policy-relevant use, prioritising transparency, empirical discipline and scenario capability over black-box forecasting.

## Analytical Rationale

Sorghum prices in South Africa are not formed autonomously. They are anchored to yellow maize parity and procurement behaviour, which in turn are shaped by international maize benchmarks, particularly US corn futures. The framework therefore formalises a three-layer transmission chain from global corn price formation to domestic maize and onward to sorghum. This nesting allows upstream shocks in energy markets, global supply tightness, cross-commodity substitution and policy regimes to propagate coherently into local sorghum price dynamics. By design, the approach ensures that the sorghum outlook responds early and proportionately to global signals that historically dominate grain price cycles, including energy–agriculture linkages, stocks-to-use tightness and weather-driven supply shocks.

## Recommended Upstream Architecture and Options

Two[1] technically credible existing upstream anchoring options have been identified, each with distinct implications for how the sorghum forecast behaves in practice.

The primary option is to anchor the framework to a global structural baseline for corn price formation, with the OECD–FAO AGLINK-COSIMO framework augmented by a transparent market-price linkage. This option provides a coherent global equilibrium path for corn prices under explicit assumptions on oil prices, yields, stocks, trade and policy regimes. Its principal value lies in scenario coherence and driver traceability: decision-makers can observe how energy shocks, supply tightness or policy changes propagate through global markets into local sorghum prices. The trade-off is that near-term volatility and market sentiment are not native to the baseline; short-run dynamics must be captured through basis and timing adjustments. For strategic planning and policy stress-testing, this option produces smoother, more interpretable sorghum price paths grounded in fundamentals.

[1] It is assumed that the client does not want to build a bespoke model. This is possible and this option is contained in the Annexures with some high level guidance.

A credible second-best option is to anchor the upstream corn input to the USDA ERS Baseline supplemented by WASDE balance-sheet updates. This option combines a transparent structural projection with high-frequency revisions to yields, stocks, exports and use that closely mirror how futures markets update expectations. Its principal value is operational responsiveness: the sorghum forecast becomes more sensitive to emerging supply shocks and demand surprises, improving early-warning capability for procurement and risk management. The trade-off is weaker between endogenous global closure relative to a fully global equilibrium model, requiring explicit augmentation for non-US shocks and policy scenarios. In practice, this option yields more revision-sensitive, market-adjacent sorghum paths.

## Model Structure and Expected Performance

The downstream sorghum model is calibrated on observed import-parity relationships and substitution behaviour with yellow maize, with exchange-rate pass-through and lag structures reflecting market microstructure and procurement cycles. Across specifications, US corn futures are the dominant external driver, with empirically meaningful elasticities that transmit upstream shocks into sorghum prices. The nested architecture improves temporal granularity by translating early global signals into local price trajectories, strengthening early-warning capability for investors and policymakers. Non-linear responses under tight stock regimes are explicitly accommodated, which is critical for risk assessment during droughts or demand surges.

## Strengths of the Framework

The principal strengths are conceptual coherence and empirical discipline. The approach aligns with observed arbitrage behaviour and parity pricing, avoids double-counting upstream drivers by concentrating global dynamics in the corn layer, and preserves interpretability for decision-makers. It is modular, allowing upgrades to the upstream anchor as better data or institutional models become available, and improves governance of assumptions by separating global price formation from domestic transmission. The explicit option set for the upstream anchor allows users to choose between scenario coherence and market responsiveness without compromising methodological legitimacy.

## Limitations and Risks

Several limitations require active governance. Forcing discrete upstream variables for narrative coherence, where statistical optimisation would down-weight them, can reduce explanatory power and must be transparently disclosed. Structural breaks associated with biofuel policy regimes and climate-driven yield volatility imply that historical elasticities may not be stable. Periodic re-estimation and regime testing are therefore essential. Futures prices embed expectations and risk premia that can overshoot fundamentals in the short run; even with dynamic adjustment, near-term volatility will remain difficult to forecast precisely. Weather impacts are proxied through yields and stocks rather than explicit climate variables, which can delay the model’s response to emerging climatic risks when production data revisions lag reality. Exchange-rate pass-through and basis risk in the South African market vary with logistics constraints and policy changes, requiring ongoing recalibration of transmission lags and margins.

## Implications for Users

For investors, the framework provides a transparent mechanism to translate global shocks into local price risk, improving procurement timing, hedging strategies and margin planning. For policymakers, it offers a defensible basis for stress-testing the resilience of sorghum competitiveness to energy price spikes, droughts and trade disruptions. For sector stakeholders, it clarifies why sorghum prices co-move with global maize cycles and where domestic interventions can and cannot dampen volatility. The choice of upstream anchor allows users to align the forecast behaviour with decision needs, whether medium-term strategic planning or near-term operational risk management.

## Conclusion and Next Steps

The end-to-end framework is analytically sound, empirically grounded and operationally practical. Its principal value lies in making global drivers of grain prices explicit within local sorghum forecasting, strengthening scenario analysis and early-warning capability. The preferred upstream anchor is a global structural baseline with market-price linkage for scenario coherence and policy credibility, with a validated alternative that leverages USDA/WASDE for greater near-term responsiveness. To maintain credibility, the framework should be governed through periodic re-estimation, regime testing for structural breaks, transparent treatment of stakeholder-mandated variables that weaken fit, and routine back-testing against realised price outcomes.

## The Brief

a) Review the principal models and approaches currently used to forecast US Corn Futures;
b) Identify the key independent variables typically used in these models;
c) Present the estimated coefficients (or typical ranges) and explain the relative significance of these drivers;
d) Comment on qualitative relationships, and quantitative parameters that underpin price formation; and
e) Recommend an appropriate model structure that can be used as the upstream foundation for Blueprint's sorghum pricing work, provide a validated recommendation of a corn futures model framework.

Once this US Corn Futures framework is defined the sorghum pricing model developed by Blueprint will be layered on top of the recommended corn futures model to create an end-to-end view. This will allow an understanding of how movements in upstream variables are likely to translate into sorghum price dynamics.

# Section 1: Principal Models & Approaches Currently Used to Forecast US Corn Futures

The principal models and approaches currently used to forecast US corn futures prices can be broadly classified into structural econometric models, statistical time-series models, and baseline scenario projection models used by major institutions. These frameworks draw on a range of variables including energy prices, agricultural supply-demand fundamentals, and climate factors, with a growing emphasis on inter-commodity linkages and macroeconomic trends.

While several of the models reviewed do not explicitly forecast futures prices, they provide equilibrium price paths and structural relationships that underpin how futures markets form expectations. In practice, corn futures prices reflect these underlying supply–demand fundamentals alongside market expectations, risk premia, and timing effects. For the purposes of this review, institutional and academic corn price models are therefore treated as upstream frameworks that inform the drivers embedded in observed corn futures prices.

Other important models are the World Agricultural Supply and Demand Estimates (WASDE) model, which, while not a forecasting model per se, provides core inputs for models such as the USDA Baseline. It offers monthly updates on US and global supply-demand balances, exports, use, and stock-to-use ratios, which many models incorporate as leading indicators.

Private sector proprietary models developed by major commodity houses and agri-investors, including firms like Cargill, ADM, and Bunge, often rely on variants of econometric models such as Vector Autoregression (VAR), Vector Error Correction Models (VECM), and machine learning hybrids. These are referenced as being proprietary but structurally similar in terms of variable inputs (e.g., energy prices, yield outlooks, acreage estimates, exchange rates).

Academic models are typically rooted in cointegration and error correction approaches, which provide both short-run and long-run dynamics between corn futures prices and key drivers such as crude oil prices, exchange rates, ethanol demand, and crop acreage. Several econometric studies apply autoregressive distributed lag (ARDL) structures or dynamic panel models, often using monthly or quarterly time series data.[2]

Below is an analysis of the key models, including those developed by the USDA, OECD-FAO, BFAP, and ABSA, a summary of their methods, variables, strengths and limitations.

[2] VECM suits cointegrated agriculture prices (e.g., Doria thesis), VAR for spillovers, ARDL for Brent crude impacts on ethanol demand

**Table 1: Comparative overview of main Corn Futures models.**

| Model / Organisation | Methodological approach | Key variables | Strengths | Limitations |
|---|---|---|---|---|
| ABSA AgriBusiness 5-Year Forecast | Econometric and expert judgement | Oil, fertiliser, macroeconomic outlook, rainfall, stocks | Regularly updated,[3] practical for investors | Proprietary, limited model transparency |
| BFAP Baseline (South Africa-linked) | Partial equilibrium model and stochastic risk layer | Weather, oil, fertiliser, currency, global trends | Southern Africa calibrated, aligned with USDA | Not US-specific, fewer published coefficients |
| OECD-FAO Agricultural Outlook | AGLINK-COSIMO multi-market model | Similar to USDA and global macro drivers, oil, fertiliser, climate | Global integration, medium-term foresight | Model assumptions updated annually, limited short-term use |
| USDA Agricultural Baseline (ERS) | Partial equilibrium structural model | Area, yield, stocks, use (feed, ethanol, exports), prices, macro assumptions, policy | High transparency, widely accepted, long-term projections | Not intended for short-term volatility forecasting |
| VAR / VECM statistical models (literature) | Time-series econometrics | Lagged prices, oil, exchange rates, stocks, seasonality | Strong for short-term shocks, lag structures | Less suitable for structural policy analysis |
| WASDE / USDA (World Agricultural Supply and Demand Estimates) | Not a formal econometric model. A composite forecasting system integrating USDA sub-agency inputs (ERS, FAS, NASS), trend projections, expert judgement, satellite and survey data. No explicit published econometric structure | Domestic and global planted area, yields (trend and survey), beginning stocks, production, consumption (feed, ethanol, exports), ending stocks, global trade flows, weather impacts, policy developments. | Official and widely cited; monthly updates; authoritative reference for global supply/demand; high policy visibility; central to market consensus. | Lacks transparency on methodology; expert-judgement driven; no explicit coefficient disclosure; cannot be directly integrated into investor models; less suitable for scenario testing or simulation without supplementary modelling. |

It is possible to specify the corn price that is being forecast and how these prices along the value chain are related. Different corn forecasting models project prices at different points along the value chain, ranging from farm-gate producer prices to internationally traded benchmark prices such as CBOT futures or export-parity prices. These price levels are economically linked through basis relationships reflecting transport, storage and handling costs, meaning that forecasts at one level can be translated to others through well-established price transmission mechanisms.

## 1.1 OECD–FAO Agricultural Outlook (AGLINK-COSIMO)

This joint model is a dynamic partial equilibrium model covering global agricultural markets. It is maintained by the OECD and FAO, using the AGLINK-COSIMO framework to simulate global cereal markets, including corn. The model explicitly incorporates Brent crude oil prices, energy inputs, and biofuel policies. It also accounts for government support, input prices (fertiliser), and trade policies

[3] Published annually, with periodic quarterly updates or commentary notes

(OECD-FAO, 2023). It simulates the global balance sheets for corn with macroeconomic assumptions including GDP growth, oil prices, and policy settings. Notably the following:

a) Corn price paths are determined by a recursive dynamic framework incorporating yield, area harvested, and trade responses;
b) Elasticities are specified rather than estimated in the model and include oil price elasticity of ethanol production (0.45) and cross-price elasticities for feed substitution (typically ~0.2–0.3).; and
c) Brent crude prices are used exogenously to affect fertiliser input costs and ethanol production, feeding through to corn prices indirectly (OECD-FAO, 2024).

Elasticities are specified rather than statistically estimated because the objective of the model is not to derive new structural parameters from raw data, but to construct a transparent forecasting linkage between corn and sorghum prices using well-established empirical relationships already documented in the literature. Estimating elasticities within this study would require a large historical dataset, careful treatment of endogeneity between prices, supply variables and policy drivers, and the development of a full structural econometric model. That level of estimation falls outside the scope of the present exercise.

### 1.1.1 KEY DRIVERS AND PARAMETERS

a) Oil price elasticity of ethanol use: +0.35[4] [5]
b) Fertiliser price elasticity of yield: −0.10
c) Trade elasticity (price sensitivity): −0.25
d) Exchange rate pass-through to export competitiveness: Moderate to high

The global nature of AGLINK-COSIMO allows for indirect insights into US corn futures dynamics, especially under supply chain disruptions or geopolitical events.

## 1.2 USDA Agricultural Baseline Projections Model/WASDE

The USDA's Economic Research Service (ERS) publishes annual baseline projections using a partial equilibrium model of US agricultural markets. This is often regarded as the benchmark model by global agri-investors, policy planners, and commercial actors (USDA, 2024). The model integrates planted area, expected yields, domestic demand (feed, food, ethanol), export demand, and stock-use ratios to project future prices. Key macroeconomic assumptions such as exchange rates, GDP growth, and energy prices (Brent crude) are exogenously set and feed into demand components, especially for ethanol.

[4] Note it is reasonable and defensible to specify different elasticities for oil price effects on ethanol *production* (0.45) and ethanol *use* (0.35), While both elasticities are influenced by the same underlying price mechanism (oil prices), they affect different points in the value chain and may respond differently due to i) Regulatory constraints (e.g., blending mandates can cap demand growth even if production is profitable) ii) Infrastructure limitations (e.g., ethanol storage or retail capacity) and/or iii) Export markets (production may respond more if producers anticipate export opportunities)

[5] Delta EtOH%/Delta Brent% = 0.35

The USDA ERS model forms the backbone of the 10-year Agricultural Baseline Projections and is widely respected due to its transparency, comprehensive scope, and alignment with policy instruments such as the Farm Bill and Renewable Fuel Standards (USDA, 2024). Structurally, it operates as a partial equilibrium model where the corn market is modelled in relation to supply and demand projections across key countries. Critical inputs include the following.

a) Planted area and yields, determined using trend-based projections and weather-normalised productivity data;
b) Prices are endogenously derived based on stock-to-use ratios, trade balances, and biofuel mandates; and
c) Estimated coefficients linking ethanol demand to corn prices are typically between 0.3 and 0.6, depending on the shock scenario applied (Westhoff *et al.*, 2018).

Crude oil prices are integrated via their effect on ethanol margins and hence on corn demand. This energy-agriculture linkage is assumed rather than directly estimated, limiting short-run responsiveness but capturing long-run price pressure (USDA, 2024).

### 1.2.1 KEY VARIABLES AND TYPICAL ELASTICITIES

a) Ethanol demand elasticity: +0.30 to +0.50
b) Export demand elasticity: −0.20 to −0.35
c) Yield response to prices (lagged): +0.15
d) Stocks-to-use ratio and price- inverse non-linear relationship
e) Brent Crude (through ethanol)- indirect positive correlation

The model forecasts nominal and real farm prices for corn over a 10-year horizon. For instance, the 2024 Baseline projected US corn prices to range between USD4.50 and USD5.00/bushel through 2033, with upside risks from energy and fertiliser costs.

## 1.3 Bureau for Food and Agricultural Policy (BFAP) Baseline

Though focused on Southern Africa, the BFAP model incorporates international price trends, and references USDA and OECD assumptions. It includes stochastic elements to assess climate risk, oil markets, and fertiliser inputs. The baseline simulations generally align with global trends and provide a link between US market expectations and South African feed grain markets. BFAP employs a modified version of the FAPRI-US model with South African calibration. Corn prices are linked to yellow maize parity prices via border price parity calculations, with global drivers fed through.
Key variables include Chicago Board of Trade (CBOT) corn futures, domestic transport costs, local exchange rate, and border protection instruments (e.g., tariffs; and Brent crude price indirectly influences prices via fertiliser costs, transport costs, and ethanol blending mandates.

While not a futures forecasting tool per se, the model offers a pragmatic linkage between global trends and local policy levers.

### 1.3.1 MODEL PARAMETERS *(INDICATIVE RANGES)*

a) Oil price elasticity of SA maize- +0.15 to +0.25
b) Exchange rate effect: +0.30
c) Sorghum/corn substitution ratio: Variable depending on rainfall

BFAP's linkage to the Blueprint sorghum pricing model is valuable because of its dual consideration of international drivers and local agro-ecological risk It captures both global market forces and South African agricultural conditions, which together determine sorghum price dynamics.

## 1.4 ABSA 5-Year Agricultural Forecast

ABSA's agricultural forecasting model incorporates econometric relationships calibrated to recent trends, complemented by internal commodity desk analysis. Though proprietary, their public outlooks cite oil prices, La Niña / El Niño impacts, fertiliser costs, and US corn futures as central inputs.
For example, their 2023/24 forecast found that a USD10/barrel increase in Brent crude is associated with a ~3% rise in US corn futures over a 6–9-month horizon, primarily via ethanol blending incentives and input inflation. ABSA's internal commodity desk produces medium-term forecasts (5 years) that combine fundamental modelling with financial market techniques. The key elements include:

a) Regression models linking US Corn Futures to oil prices, USD/ZAR exchange rates, and South African maize and sorghum parity prices;
b) Incorporation of speculative positioning and market sentiment via Commitment of Traders (COT) report; and
c) Short-term price elasticity of Brent Crude on US Corn Futures has been estimated in the range of 0.15–0.25 (ABSA, 2023).

ABSA's framework is considered practical and well-aligned with investor needs, though not publicly documented.

### 1.4.1 KEY INSIGHTS

a) Rainfall anomaly correlation with yield - ~0.6.
b) Brent crude to ethanol to corn futures lag- ~2 quarters.
c) Dollar Index effect: high inverse correlation with futures.

ABSA's model is trusted by South African agri-lenders and grain processors and provides a strong bridge between international and domestic forecasts. ABSA's agricultural commodity outlook is widely used within the South African grain sector as a reference for medium-term price expectations, supporting credit risk assessments by agricultural lenders and procurement and hedging decisions by grain processors and traders. ABSA maintains one of the largest agricultural lending portfolios in South Africa, and its commodity outlooks are produced by a dedicated AgriBusiness research and commodity desk that supports both internal credit analysis and external market engagement with clients across the grain value chain.

In practice, the forecasts are used by several categories of market participants. Agricultural lenders use the outlook to inform credit risk assessments, collateral valuations and farm viability analysis, particularly where borrower repayment capacity depends on forward commodity prices. Grain processors and traders use the projections as reference scenarios for procurement planning, hedging strategies and input cost forecasting, especially in feed grain markets where price movements in maize and corn strongly influence substitution with sorghum. Input suppliers and large commercial producers also monitor these forecasts to guide planting decisions, capital investment and working capital planning over multi-season horizons.

## 1.5 Academic and Proprietary Models

Many academic and institutional models adopt VAR, VECM, or ARDL specifications. These models treat US corn futures prices as a function of the following-

a) Brent crude (proxy for energy costs and ethanol demand);
b) US dollar index (trade competitiveness);
c) Corn ending stocks and stocks-to-use ratios (price expectations);
d) Planted acreage and yield estimates (supply-side); and
e) Ethanol demand mandates (policy variable).

In a study by Nazlioglu & Soytas (2012), Brent crude was found to Granger-cause corn futures prices, with impulse response functions showing significant reactions within 2–4 months. Estimated coefficients range from 0.18 to 0.4, depending on the lag structure and data frequency. ADM and Cargill are known to integrate these structures with proprietary real-time satellite data and weather models, though model specifications remain confidential.

For medium-term structural price anchoring under explicit supply–demand and policy assumptions, the USDA ERS Agricultural Baseline provides one of the most transparent and widely accepted equilibrium frameworks. This could be complemented by insights from the OECD-FAO model and ABSA short-term market forecasts to triangulate volatility and oil price transmission.

### 1.5.1 Other Models

Several other models and studies have quantified corn price determinants. The main and most widely cited include the following:

#### 1.5.1.1 The World Bank Long-Term Drivers Model (Baffes & Dennis, 2013)

This is a reduced-form econometric model using annual data (1960–2012) to explain prices of major food commodities (including corn) with macroeconomic and market variables. Key independent variables are the stocks-to-use ratio, crude oil price, global manufacturing costs/prices, the U.S. dollar exchange rate, interest rates, and income.
The authors report long-run elasticity estimates of approximately +0.25 for crude oil and –0.25 for the stocks-to-use ratio, meaning a 1% increase in oil raises corn price ~0.25% and a 1% increase in global corn stock-to-use lowers price ~0.25% (Baffes & Dennis, 2013). The elasticity with respect to the U.S.

dollar is about –1.25, indicating a 1% USD depreciation is associated with a 1.25% increase in corn prices (i.e. weaker dollar boosts commodity prices).

Other factors like interest rates and income have much smaller elasticities in this model. Using these coefficients, the World Bank authors attributed over 50% of the 2005–2012 corn price surge to rising crude oil prices, with lesser contributions (~15% each) from declining stocks and dollar weakness. This model had strong explanatory power for the 2000s commodity boom, underlining the dominant role of energy prices in corn's price formation.

#### 1.5.1.2 The Integrated Energy–Agriculture Model (Zolotnytska *Et Al.*, 2025)

A recent study in *Sustainability* (covering 2000–2023) used a multiple linear regression to link world corn prices with a combination of energy, agricultural, and climate-related variables. The final corn equation included Brent crude oil price (USD/barrel), global wheat price (USD/tonne) as a related commodity, world biodiesel production per capita (as a biofuel indicator), and corn yield (kg/ha).

All coefficients were statistically significant with an $R^2$ of 0.92, indicating the model explains over 90% of corn price variation. Notably, a USD1 increase in Brent oil per barrel is estimated to raise the corn price by USD0.43 per metric tonne. Likewise, a USD1/tonne increase in wheat price increases corn by about USD0.57/tonne (reflecting substitution between these grains). Higher biofuel output drives corn prices up – for example, an increase of 1 barrel of biodiesel per million people adds USD0.82/tonne to corn prices. Conversely, better yields suppress prices so that a 1 kg/ha gain in corn yield lowers price by about USD0.078/tonne (i.e. –0.078 coefficient).

This model underscores energy-agriculture linkages such as rising oil and biofuel production which both put upward pressure on corn, while improved crop yields (often climate- and technology-driven) alleviate prices. It also captures the cross-market linkage, where corn and wheat prices move together due to substitution in use (the regression finds corn is strongly dependent on wheat price). Overall, Zolotnytska *et al*. concluded that oil prices are a dominant driver, and that integrating energy, biofuel, and yield factors provides a robust explanation of corn price dynamics.

#### 1.5.1.3 Stocks-To-Use Price Model (Irwin & Good, 2016)

Industry analysts often use a simpler fundamental model relating price to ending stock levels relative to use. Irwin and Good (University of Illinois) updated this framework for the post-2005 ethanol era by regressing U.S. marketing-year average corn price on the reciprocal of the stocks-to-use ratio, with dummy variables to capture demand shifts after 2005.
This reciprocal form imposes the expected non-linear relationship: as stocks-to-use approach zero (a very tight supply), price must rise sharply to ration demand. Their model, segmented by demand regime, achieved an excellent fit (in-sample $R^2$ ~0.96–0.99) for 1990–2015 data. For example, using U.S. stocks, the model's standard error was only about USD0.18/bushel (~3% of price), indicating very high accuracy. A key finding was that a structural upward shift in the price function occurred after 2005 due to new demand from corn ethanol. Effectively, prices in the late 2000s were higher at a given stock level than in earlier decades.

This aligns with the fact that ~27% of the 2010–11 U.S. corn crop went to ethanol, up from 10% in 2005–06. In practice, this model implies that low stocks-to-use (tight supply) results in exponentially higher corn prices, and that incorporating global or regime factors (like biofuel demand) is necessary for accurate forecasts. While simple, the stocks-to-use approach is widely used and credible for medium-term price outlooks, reinforcing the importance of supply fundamentals.

#### 1.5.1.4 COINTEGRATION AND CAUSALITY ANALYSES.

Academic studies have also examined the evolving relationship between corn and external markets. For instance, Harri, Nalley, and Hudson (2009) found that from about 2006 onward, corn prices became cointegrated with crude oil prices, whereas in earlier years they were not. This econometric evidence confirmed a new long-run linkage formed in the mid-2000s, likely due to the boom in corn-based ethanol tying corn to energy prices. Harri *et al* also observed that exchange rates influence commodity price linkages over time where a depreciation of the U.S. dollar tends to support higher dollar-denominated corn prices (as importers can pay more in USD).
Research by agricultural economists (e.g. Abbott, Hurt, & Tyner, 2011) has qualitatively identified the major drivers behind the 2007–2011 grain price swings as: persistent demand shocks (especially U.S. corn use for biofuel and Chinese demand for soy), weather-related supply shortfalls, a weak U.S. dollar, and the generally inelastic supply/demand for crops that amplifies price movements. These studies corroborate the variables used in the above models highlighting that corn prices are driven by a mix of energy market shifts, policy-driven demand, supply tightness, and macroeconomic factors.

Across these models, there is strong consensus on key explanatory variables for corn futures including energy prices (crude oil), biofuel production/policy, supply fundamentals (yields, stocks-to-use), demand pressures, prices of substitute crops, and macro factors like currency. The models achieve high explanatory power (often 90%+ of variance) by combining these drivers. Notably, oil and supply/demand variables emerge as consistently significant with economically meaningful coefficients.

# Section 2: Key independent variables typically used in the main models and estimated coefficients

a) Based on the models reviewed in the comparative analysis of US Corn Futures forecasting, the following key independent variables are consistently identified across models as central to explaining and projecting corn price dynamics:
b) **Crude oil / energy prices (e.g. Brent Crude, WTI)** -Used to capture the biofuel-energy price transmission mechanism. Higher crude prices typically increase demand for ethanol, which in turn raises corn demand and prices;
c) **Ethanol prices / biofuel demand**- Reflects the direct link between corn (as a biofuel feedstock) and bioethanol markets. Often integrated via blending mandates or profitability margins in forecast models;
d) **Exchange rates** (especially USD/ZAR or USD/Major Currencies). Impacts competitiveness of US exports and price parity. A weaker dollar typically boosts US corn exports, supporting prices;
e) **Corn production levels** (US and Global). Driven by acreage, yield per acre, planting intentions, and technology adoption. Directly determines supply-side availability;
f) **Ending stocks / Stock-to-Use ratios**. Represents the buffer supply; lower ratios tighten markets and raise prices. Often a key determinant of volatility in futures markets;
g) **Corn export demand** (particularly from China, Mexico, Japan). Influences global balance sheets. Changes in major importer behaviour can lead to price swings;
h) **Weather / climatic conditions** (e.g. ENSO, drought indices). Affect planting and yield. Commonly integrated via NDVI indices, soil moisture data, or seasonal outlooks;
i) **Competing crop prices** (e.g. soybeans, wheat). Determine acreage allocation in planting decisions. Also relevant in substitution on the demand side;
j) **Interest rates and macro-economic indicators** (e.g. CPI, GDP growth). Less direct, but included in econometric models to account for broader market sentiment and inflationary pressures;
k) **Government policy** (e.g. subsidies, tariffs, blending mandates). Particularly important in OECD-FAO and USDA Baseline scenarios. Influences both production and consumption structures; and
l) **Speculative activity / market sentiment**. Integrated in some stochastic or Bayesian models to capture volatility or anticipate futures market movements.

Each model incorporates a different subset of these variables, depending on its scope (structural vs econometric vs market-based) and the forecast horizon. The following table provides a summary of the key independent variables and coefficient ranges.

**Table 2: Key independent variables in US Corn Futures forecasting models.**

| Variable | Model Inclusion | Rationale and Description | Estimated Coefficient Range (Elasticities) |
|---|---|---|---|
| **Brent Crude / Crude Oil Prices** | USDA, OECD-FAO, ABSA, WASDE (indirectly), BFAP | Represents the energy cost of production (e.g., fuel, fertiliser), and ethanol-blending profitability; oil prices influence demand for corn in biofuels. | +0.10 to +0.35 [6] |
| **Corn Yield per Acre** | USDA, WASDE, OECD-FAO, BFAP | A critical productivity measure; heavily weather dependent. | −0.35 to −0.65 (inverse relation to price under supply expansion) |
| **Ending Stocks / Stocks-to-Use Ratio** | WASDE, USDA, ABSA | Key indicator of supply tightness; lower stocks push futures higher. | −0.40 to −0.75 [7] |
| **Ethanol Prices / Ethanol-Corn Price Ratio** | USDA, ABSA, BFAP | Drives the incentive to convert corn into ethanol; higher ethanol prices stimulate corn demand. | +0.15 to +0.40[8] |
| **Global Corn Demand / Feed Demand Growth** | OECD-FAO, USDA | Higher feed and industrial demand lifts futures; emerging markets are critical. | +0.20 to +0.45 |
| **Input Costs (e.g., fertiliser, seed, diesel)** | BFAP, ABSA | Rising input costs reduce planted area or increase break-even prices. | +0.10 to +0.25 (lagged impact) |
| **Planted Corn Area (USDA)** | USDA, WASDE, OECD-FAO, BFAP | Indicates producer supply intent, influencing future output. | +0.25 to +0.60 depending on seasonal lag [9] |
| **Soybean-Corn Price Ratio** | USDA, BFAP, ABSA | Influences planting decisions (crop substitution); high soybean prices divert acreage. | −0.10 to −0.35[10] |
| **Speculative Activity (CFTC Commitments of Traders Reports)** | ABSA (private), USDA (indirectly via volatility proxies) | Large speculative positions amplify price volatility and trend shifts. | Varies significantly; contributes to short-run noise rather than fundamentals |
| **US Dollar Index / Exchange Rate** | ABSA, OECD-FAO, BFAP | Affects global competitiveness of US corn; stronger dollar suppresses export demand. | −0.20 to −0.40 [11] |
| **Weather Indicators (e.g., precipitation, temperature indices)** | USDA, WASDE, BFAP | Affects yield estimates and market expectations. Often proxied through NOAA drought monitor or satellite NDVI data. | Variable (model-specific); typically incorporated as dummy variables or interaction terms |

Sources: Various (2026)

[6] Nazlioglu & Soytas, 2012 ; Zhang et al., 2010
[7] Babcock & Fabiosa, 2010
[8] Irwin et al., 2011
[9] ERS, 2023
[10] Irwin & Good, 2016
[11] Zhang et al., 2008

## 2.1 Significance of key drivers and their quantitative influence

### 2.1.1 Crude Oil Prices[12]

Crude prices have a well-documented positive impact on corn prices. Oil affects corn through multiple channels: (1) Biofuel demand, where higher oil/gasoline prices stimulate ethanol production (since ethanol is a substitute for gasoline), increasing corn demand; and (2) Production costs, where oil drives fuel and fertiliser costs, raising the cost of producing and transporting corn. Empirical estimates consistently show oil as a significant driver of corn: for example, Baffes and Dennis (2013) report a long-run oil–corn elasticity of about +0.25 (i.e. 10% higher crude oil leads to 2.5% higher corn price). Zolotnytska et al. (2025) find that each USD1/barrel increase in Brent crude adds roughly USD0.43 per tonne to corn's price. Thus a USD10 rise in oil (e.g. from USD70 to USD80) would raise corn prices by about USD4.3/tonne. On a base corn price of USD150/tonne, that is almost a 3% increase indicating a moderate sensitivity.

The World Bank model concluded that surging crude oil was the *single largest factor* behind the 2005–2012 food price boom, explaining more than half of the corn price increase in that period. This highlights oil's outsized role during major market swings. Academic studies reinforce this link: after 2006, corn and oil prices moved in tandem to the point of a cointegrated relationship (meaning they share a common long-run trend). This structural change coincided with the implementation of the U.S. Renewable Fuel Standard (RFS), which mandated ethanol blending and tied corn demand to fuel markets. Harri *et al* (2009) note that from 2006–07 onward, corn became strongly connected to crude, whereas pre-2005 such linkage was weak. An investor-focused interpretation is that corn has effectively become an energy-linked commodity, when crude oil rallies, corn futures tend to follow, and when oil plunges (as seen in 2014–2015), it puts downward pressure on corn.

### 2.1.2 BIOFUEL PRODUCTION AND POLICY VARIABLES

Biofuel production and policy variables provide the primary mechanism through which energy markets are transmitted into corn price formation. Corn is primarily impacted by ethanol (from corn starch) rather than biodiesel, but global biofuel trends matter. Zolotnytska *et al* included world biodiesel output per capita as a proxy for biofuel market strength; interestingly, they found higher biodiesel production correlates with higher corn prices (coefficient +0.82 USD/t per unit). This seemingly counter-intuitive result (biodiesel uses vegetable oils, not corn) likely captures the general effect of energy policies boosting demand for agricultural outputs: when biodiesel expands, it tightens vegetable oil markets, which can push more oilseeds toward fuel and more corn toward feed use, indirectly lifting corn's value. Additionally, biodiesel growth often parallels ethanol expansion as both stem from pro-renewable energy policy. Corn ethanol demand itself has been a game-changer – by 2010-11, ethanol consumed 27% of U.S. corn harvest (up from 10% in 2005). This new demand is highly inelastic (mandated volumes must be met regardless of price), so it effectively shifted the corn demand curve upward. Tyner *et al*. (2011) estimate that the U.S. Renewable Fuel Standard (RFS) and blend mandates raised corn

[12] Note: On Brent, this review shows that oil influences corn prices upstream (via ethanol economics and input costs) and that these effects are already embedded in corn futures prices, which is why Brent does not need to enter the downstream Yellow Maize or sorghum models directly and would risk double-counting if it did.

prices on the order of 20–30% in the late 2000s. One analysis cited by Zolotnytska *et al* noted that the RFS increase in ethanol output (an extra 5.5 billion gallons in the U.S. by 2021) required 1.3 billion bushels of corn and was estimated to raise corn prices by ~31% (and even wheat prices ~20% via land substitution). This underscores that energy policy can have a quantitatively large impact on corn markets.

In summary, Brent crude oil price is an indispensable variable in corn price models, and its coefficient is typically positive and significant (elasticity in the 0.2–0.3 range in long-run studies). Models that omitted oil often dramatically under-predicted the post-2005 corn price surge. For forecasting, having a view on oil prices (or scenarios thereof) is crucial, e.g. a sustained rise in crude oil will likely translate into higher corn futures, both through ethanol demand increases and cost-push effects. Conversely, if oil prices fall or policies limit biofuel expansion, that could cap corn price upside. *Energy markets thus form a key upstream driver for corn.*

### 2.1.3 Fundamental Supply and Demand Factors Remain Central to Corn Price Formation

Chief among these is the supply tightness, often measured by the stocks-to-use ratio (the ratio of ending inventories to annual usage). Low stocks-to-use indicate that carryover supplies are scarce relative to demand which is a classic recipe for price spikes as buyers bid aggressively to secure grain. Empirical models consistently show an inverse relationship: as stocks-to-use falls, prices rise non-linearly. Baffes & Dennis (2013) found a long-run elasticity of about –0.25 for stock-to-use, meaning a 10% reduction in the stock ratio tends to raise corn prices ~2.5%. Irwin and Good (2016) demonstrated that a reciprocal model (1/stock-to-use) fits corn prices extremely well, capturing the sharp price increases when stocks approach critically low levels. For example, when U.S. corn stocks dropped below 10% of usage in 2010–2012, corn prices topped USD7/bushel (far above long-run averages), the model would predict such a jump as necessary to ration demand. In their updated model, Irwin & Good had to allow a higher intercept after 2005 (due to ethanol demand) but the slope (sensitivity to stocks) remained consistent. This implies that while demand shifts elevated the overall price plateau (a new “era” of higher prices), the responsiveness to stock tightness is a fundamental trait.

### 2.1.4 Production and Yield Are Closely Related Drivers

A bumper crop (high yield) boosts supply and typically expands stocks, putting downward pressure on prices, whereas a poor harvest (drought-induced yield loss) can send prices soaring. Zolotnytska *et al.* quantified a negative coefficient for corn yield: –0.078 USD/tonne per 1 kg/ha, which means roughly for each 1% increase in global corn yield, corn prices drop around 0.5–1% (since yields in their data average on the order of thousands of kg/ha). In other words, higher productivity (whether from good weather or better technology) moderates prices. Conversely, if yields fall short (e.g. by 10%), the model would predict roughly a 7–8% price increase, all else being equal. The 2012 U.S. drought, which slashed corn yields by ~20%, caused Chicago corn futures to skyrocket by over 50% to record highs. This sensitivity underscores why climatic shocks to supply are so impactful (discussed more under climate). On the demand side, steady growth in feed, food, and industrial use provides a baseline pull on corn prices.

Rapid demand increases can tighten the balance if supply doesn’t keep up. For instance, the early 2010s saw China importing corn after years of self-sufficiency, contributing to higher world prices. However, demand growth for corn (aside from biofuels) is usually gradual (tied to population and income growth), so its effect is more in setting long-run trends than short-term spikes. Baffes & Dennis included income (GDP) as a driver but found its elasticity to be very small, implying that year-to-year corn price volatility is dominated by supply shocks and competing demand (biofuel, feed) rather than marginal increases in food/feed demand. Nonetheless, strong demand expansion in emerging markets does elevate a floor under prices over time.

### 2.1.5 Interaction with Substitute Commodities

Wheat and corn are to an extent interchangeable in diets and feed rations, so a shock in one will spill to the other. In 2007–08, for example, a poor wheat harvest sent wheat prices to record levels, which pulled corn upward as users switched some demand to relatively cheaper corn until that gap closed. In the 2025 regression, the coefficient on wheat price in the corn equation was +0.57, meaning a USD10/tonne increase in wheat would raise corn by about USD5.7/tonne on average. This cross-price effect is highly significant ($p < 0.01$) and reflects the high correlation ($r \approx 0.88$) between corn and wheat prices globally. Practically, this means a tight wheat market can buoy corn prices even if corn's own balance is comfortable, and vice versa. Similarly, corn and soybean prices have linkages through crop substitution (farmers switch acres based on relative profitability). While soy was not explicitly in the above models, analysts recognize an implicit relationship: for example, if soybean prices rise (perhaps due to Chinese import demand), corn may need to rise to prevent too many acres shifting away to soy, especially before planting season. Thus, a comprehensive corn price framework keeps an eye on other crop markets. In quantitative terms, elasticity between corn and wheat might be on the order of 0.5–0.8 as seen, and corn vs. soy a bit lower but still positive.

In summary, agricultural fundamentals, supply, stocks, and demand, are also core determinants of corn futures. *The stocks-to-use ratio encapsulates these forces and often emerges as the single best predictor in equilibrium price models* (with a non-linear inverse relationship). Typical coefficient ranges show that a tightening of stocks (or a yield shortfall) can have a strong percentage impact on price (a few percent for each 1% change in stocks or yield, growing larger as stocks get very low). Importantly, these fundamental effects often interact with energy factors: e.g. a supply shock when stocks are already strained by ethanol demand leads to explosive price outcomes (as in 2008 and 2012). Therefore, any upstream model for corn should include a measure of supply tightness (stocks or yield) alongside energy variables. For sorghum forecasting, these supply-driven corn price swings are crucial: if global corn output is down or stocks are low, corn prices rise and *pull up sorghum prices* in tandem via substitution (since sorghum can substitute for corn in feed, buyers will bid up sorghum until its price aligns with corn import parity).

### 2.1.6 CLIMATE AND WEATHER CONDITIONS

Climate and weather conditions act as the dominant exogenous shocks to corn supply and, through yields and stocks, are among the most powerful drivers of price volatility. While many econometric models exclude weather variables explicitly (often due to lack of direct annual data or collinearity with yields), their influence is felt through yield and production outcomes. For example, temperature and precipitation anomalies strongly affect corn yields and droughts or excessive rains can drastically cut yields, whereas favourable weather boosts them. The impact on prices can be dramatic because crop demand is inelastic (people and livestock still need grains), so any supply shortfall triggers a sharp price increase. Historical analysis shows that extreme weather events explain a substantial share of price spikes. A recent study of the U.S. Midwest (Cornejo *et al*., 2026) found that hot, dry spells and extreme rainfall events in the growing season contributed significantly to contemporaneous corn price increases, in some cases causing price jumps on the order of 10% compared to normal conditions. Notably, the influence of excessively wet weather on prices has strengthened in later decades, possibly due to heavier downpours causing flooding or planting delays, which markets increasingly anticipate. Over 1971–2019, they observed that weather shocks could rival sizable demand or supply shifts in magnitude, reinforcing that climate volatility is a major risk factor for price volatility. Another study projected that near-term climate change may amplify corn price volatility four- to five-fold by mid-century under continued warming, as yield variability increases. *This indicates that the corn market's sensitivity to weather will persist or even grow.*

In terms of modelling, some approaches incorporate climate indicators such as the El Niño–Southern Oscillation (ENSO) phase, drought indices, or simple weather dummies (good vs bad year). However, because weather impact manifests through yield and stocks, many models instead use yield deviations or production shocks to capture it. For instance, if constructing a corn price model, a variable for deviation of yield from trend or production shortfall vs. expected could be included, which would effectively represent weather impacts. The magnitude of coefficients discussed here for yields/stocks gives a sense- a 10% global production shortfall (which could be caused by widespread drought) might boost corn prices by roughly 20–30%. The extreme drought in the U.S. in 2012 (which cut U.S. corn production by ~13% year-on-year) resulted in corn futures prices doubling from the previous year's level, a far greater than proportional response because stocks were already tight. This underscores a non-linear effect. Moderate weather impacts are partly buffered by stocks, but extreme events when inventories are low lead to outsized price reactions (a bull-whip effect[13] in supply chains).

In qualitative terms, weather is a key upstream uncertainty that drives corn price swings and thus sorghum prices. A favourable growing season (adequate rain, no heat stress) can lead to bumper crops, replenished stocks, and price declines benefiting buyers. Conversely, a major drought or flood in a top-producing region (U.S. Midwest, South America, Black Sea) can create global grain shortages and price spikes. Climatic factors often underlie year-to-year volatility that fundamental models must account for, usually via the yield or stocks inputs. In sum, climatic drivers are significant and their effects can be quantified indirectly, e.g. a one-standard-deviation adverse weather event might translate to a several percent change in yield, which then translates to a multi-percent (or larger) change in price, depending on initial conditions. This climate–yield–price linkage is particularly relevant for sorghum as well, since sorghum is often grown in marginal climates; any weather-driven corn price rally (due to, say, U.S. drought) is likely mirrored by sorghum (often also affected by similar drought conditions in sorghum regions).

### 2.1.7 ADDITIONAL DRIVERS

Beyond the core drivers above, some additional variables influence corn futures and are featured in some models. They include:

a) **Exchange rates**. Since corn is traded globally in U.S. dollars, the value of the USD can affect prices. A weaker dollar generally makes U.S. corn cheaper in local currency for importers, boosting

[13] The bullwhip effect describes how small changes in consumer demand at the retail level amplify into much larger fluctuations in orders as they move upstream through wholesalers, distributors, manufacturers, and raw material suppliers in a supply chain. This distortion leads to excess inventory, stockouts, and inefficiency.

international demand and lifting the USD price of corn. Baffes and Dennis (2013) quantified a relatively large elasticity of -1.25 for the U.S. dollar index. In practical terms, if the dollar depreciates 10% (vs. a basket of currencies), corn prices could rise by ~12.5% in USD terms, all else equal, because foreign buyers bid more aggressively. This was evident in the mid-2000s when a falling dollar coincided with rising commodity prices. Conversely, a strong dollar can cap corn prices by eroding import demand. While not all models explicitly include exchange rates, it is an important contextual factor. The Purdue economists in 2011 cited a weak and volatile U.S. dollar as one factor contributing to high food prices at the time. For an upstream model, considering USD trends (or treating them as given inputs from a macro forecast) can improve accuracy, especially for multi-commodity or longer-term outlooks. Notably, exchange rates might be less critical for very short-term corn futures movements (where weather or stocks dominate), but over multi-year periods currency shifts can impart a significant trend effect.

b) **Interest rates and investment.** Low interest rates reduce the cost of holding inventories and may encourage more speculative investment in commodities, both of which can influence prices. Some analysts argue that the 2000s commodity boom was exacerbated by loose monetary policy (cheap money flowing into commodity assets). However, econometric evidence for interest rate effects on corn is mixed. Baffes & Dennis included a real interest rate variable but found only a minor impact. Theoretically, higher interest rates raise carrying costs and could lead to lower commodity stockpiling, potentially softening prices (or vice versa). But in practice, interest rates often correlate with exchange rates and general economic conditions, making it hard to disentangle. Interest rates are a secondary factor, worth monitoring, (especially if there are major shifts, like the recent rise in global rates which might temper speculative longs in futures), but not as directly predictive as supply, demand, and oil.

c) **Speculation and investor flows**. Relatedly, the role of speculative money (index funds, etc.) has been debated. While a sudden influx of investors can cause short-run overshooting, fundamentals ultimately anchor prices. Studies by Abbott *et al.* and others have concluded that the 2007–2008 price spike was primarily driven by fundamentals (low stocks, biofuel demand, oil, etc.), with speculation perhaps amplifying volatility but not changing the long-run price level. Most models do not include a *speculation variable* per se, aside from possibly using lagged prices or volatility indicators to capture market sentiment. An expert consensus is that speculative activity can temporarily exaggerate moves (e.g. pushing corn above its equilibrium when bullish news hits), but unless fundamentals support it, prices will eventually mean-revert. For a forecasting model, it is more cautious to focus on fundamental drivers; speculative effects are indirectly present in market-based forecasts (futures prices themselves include them).

a) **Agricultural input costs**. Fertiliser prices (especially nitrogen fertilisers made from natural gas), and other input costs can influence corn production decisions and break-even prices. High input costs might curtail planting or application rates, reducing yields and supporting prices. These costs often track energy prices, so there is overlap with the oil variable. Indeed, oil price increases drive up fertiliser costs, so the oil–corn relationship partly reflects that cost-push. Some models implicitly account for input costs via the oil variable or via supply response functions. In the short run, input cost spikes can cause farmers to plant less or lower yield, tightening supply in future seasons. However, in most reduced-form price models, input costs are not included explicitly due to endogeneity (they rise with oil and with crop prices themselves in a feedback loop). It is sufficient to recognize that sustained high corn prices will eventually encourage more planting (unless inputs constrain it), while very low prices discourage production. This is the classical supply response and is usually a longer-term effect.

b) **Policy and trade factors**. Trade policies (export bans, import tariffs) and government interventions can jolt prices. For example, export restrictions by major producers (as Russia did for wheat in 2010) can cause global prices to spike. For corn, if a country like Argentina or Brazil imposed export taxes or bans, it could tighten global availability. Conversely, large importers releasing strategic reserves or cutting import duties might dampen price rises. These factors are episodic and difficult to predict, so they typically are not in forecasting equations but are considered in scenario analysis.

Subsidies or mandates (like the ethanol mandate) are more structural, and we have already incorporated those via the biofuel demand driver. Stocks management policies (e.g. China's stockpiling) also affect the effective stocks-to-use in markets. Abbott *et al.* (2011) noted that nearly 40% of the surge in Chinese soybean imports was due to stock building, not just consumption. Similar behaviour in corn (were China or others to build stocks) can tighten market availability and raise prices. These are essentially adjustments to demand or supply that an agile model might capture if the data show declining available stocks.

In conclusion, beyond the headline factors of oil and crop fundamentals, macroeconomic conditions (like currency values) and policy-driven shocks can play a significant role in corn pricing. However, the quantitative significance of these drivers is generally smaller or more context dependent. For instance, a 10% USD move (~1 standard deviation yearly) might cause a larger corn price change than a typical interest rate move. A policy shock can either be huge (if e.g. a sudden export ban) or non-existent. Thus, exchange rate in a corn price model could be included (especially for long-term forecasts) but speculation or ad-hoc policy changes could be treated qualitatively (using judgment or scenario adjustments rather than fixed coefficients).

## 2.2 Relative significance of key drivers

Relative significance as indicative percentage contributions are presented as a *normalised importance weighting* rather than a claim of exact causal decomposition.[14] Because these drivers are correlated and interact non-linearly, any percentage split *is necessarily an analytical construct (based on variance contribution, stability across regimes, and historical explanatory power)*, not a literal share of price formation. That said, decision-makers sometimes consider an intuitive weighting. Below is an evidence-based table based on these parameters.

### 2.2.1 METHODOLOGICAL NOTE

Percentages represent normalised importance weights derived from (i) typical elasticities reported across models, (ii) stability of effects across regimes (pre- and post-biofuel era), and (iii) observed contribution to major price dislocations (2007–2008, 2012 drought, 2021–2022 energy shock). They sum to 100 percent and reflect structural importance, not short-run noise.

[14] The percentages are a way of ranking drivers by structural importance and explanatory power in the real world, not a claim that price movements can be exactly broken down into fixed shares for each factor and are based on the weight of evidence across models and historical episodes.

**Table 3: Drivers indicative relevance for Corn Futures**

| Driver category | Typical elasticity range | Regime stability | Indicative relative significance (%) | Interpretation for price formation |
|---|---|---|---|---|
| Stocks-to-use (supply tightness) | −0.40 to −0.75 (non-linear at low stocks) | High | **30%** | Primary anchor of equilibrium price level and volatility; governs tail risk[15] |
| Energy prices (crude oil) | +0.10 to +0.35 (long-run 0.2–0.3) | Post-2005 structural | **22%** | Dominant regime shifter via biofuel demand and cost-push channels |
| Yields / production (weather-driven) | −0.35 to −0.65 | High | **18%** | Primary trigger of spikes; interacts with stocks to produce non-linear outcomes |
| Cross-commodity prices (wheat/soy) | +0.5–0.8 (wheat); soy via substitution | High | **10%** | Amplifies shocks and propagates tightness across grains |
| Biofuel policy / ethanol demand (regime effect) | Level shift (20–30% post-2005) | Regime-defining | **8%** | Raises baseline price level; increases sensitivity to tightness |
| Exchange rate (USD index) | −0.20 to −0.40 | Medium | **6%** | Shapes trend and parity over multi-year horizons |
| Input costs (fertiliser, diesel) | +0.10 to +0.25 (lagged) | Medium | **3%** | Second-order supply response; overlaps with energy |
| Global demand growth (feed/industrial) | +0.20 to +0.45 (trend) | High | **2%** | Sets long-run floor rather than driving spikes |
| Speculation / positioning | Unstable (short run) | Low | **1%** | Volatility amplifier; not a level determinant |
| Interest rates / macro sentiment | Small / unstable | Low | **0%–1%** | Contextual; indirect effects via FX and risk appetite |
| **Total** | | | **100%** | |

These weights reflect *structural contribution to price formation* rather than marginal elasticities in a single regression. Stocks-to-use and energy together account for approximately half of the explanatory structure because they (i) persist across regimes, (ii) dominate the tails of the price distribution during crises, and (iii) interact non-linearly to produce outsized price responses.

Yields account for a large share of episodic volatility and, when conditioned on tight stocks, drive the largest spikes. Cross-commodity linkages materially amplify shocks. Biofuel policy is treated as a regime-level contributor to the price level rather than month-to-month variance. Exchange rates shape multi-year trends and parity transmission. The remaining factors are secondary or primarily affect volatility rather than equilibrium price levels.

[15] Risk of rare but extreme price movements that sit at the far ends (the “tails”) of the probability distribution of outcomes, rather than in the normal middle range of outcomes.

For downstream transmission to sorghum, these weights can be combined with estimated corn-to-sorghum elasticity ($\beta_1$) to provide indicative attribution of sorghum price movements to upstream drivers. For example, if $\beta_1$ is approximately 0.54 under import parity, then the upstream contribution of stocks-to-use to sorghum variance is approximately 0.54 × 30% ≈ 16% of total sorghum price formation, before FX and local parity effects.

# Section 3: Suggested Corn Futures Pricing Model Structure Options

## 3.1 Primary option. OECD–FAO AGLINK-COSIMO baseline framework

From a modelling science and policy credibility perspective, the OECD–FAO AGLINK-COSIMO partial equilibrium framework represents the closest available approximation to a gold standard for anchoring upstream grain price formation. Its strength lies not in short-run trading signals, but in its structural coherence, multi-country coverage, and disciplined treatment of global supply–demand balances across grains, energy inputs, and policy regimes. For a sorghum pricing application that must stand up to investor scrutiny and policy use, AGLINK-COSIMO offers three important advantages.

First*, it embeds corn price formation within a fully articulated global market-clearing system*. Prices emerge from endogenous interactions between acreage allocation, yields, stocks, trade flows, biofuel demand, input costs and macro assumptions across all major producing and consuming regions. This structure materially reduces the risk of spurious correlation and omitted-variable bias that often afflicts reduced-form regressions, particularly when regimes shift due to policy changes or climate shocks. As a result, the model remains robust across structural breaks such as the post-2005 biofuel regime and recent energy price shocks.

Second, AGLINK-COSIMO is *maintained through a formal institutional process with continuous updating, peer review, and back-testing across multiple commodity cycles*. This governance confers a level of methodological durability and reputational credibility that is difficult to replicate in project-based bespoke modelling. For external stakeholders, the provenance of the model matters. An upstream anchor that is already accepted by multilateral institutions materially strengthens the legitimacy of downstream price forecasts for sorghum.

Third, *the framework is scenario driven*. This is critical for decision support. It allows systematic exploration of oil price shocks, climate yield impacts, policy changes in biofuels or trade, and macro assumptions, with internally consistent propagation through global grain markets. This aligns directly with the stated objective of using upstream corn dynamics as a driver for sorghum scenario analysis, rather than as a narrow point forecast.

### 3.1.1 LIMITATIONS AND MITIGATION

AGLINK-COSIMO is not designed for *high-frequency* futures price forecasting. It produces baseline price paths grounded in fundamentals rather than short-run market sentiment. This is a limitation for near-term trading signals, but not for strategic sorghum pricing, which depends more on medium-term equilibrium trajectories and scenario sensitivity than on daily volatility. *This limitation can be mitigated by calibrating short-run basis adjustments using futures curves or spreads without undermining the structural integrity of the baseline.*

### 3.1.2 CONCLUSION

For policy-facing, investor-grade sorghum price modelling, AGLINK-COSIMO provides the most defensible upstream anchor because it combines structural completeness, institutional credibility and scenario coherence. It is therefore the recommended option.

## 3.2 Secondary option- USDA ERS Baseline + WASDE supply–demand framework

The USDA ERS Baseline, supported by the WASDE supply–demand accounting system, constitutes a highly credible alternative where access to AGLINK-COSIMO is constrained or where a more US-centric anchor is acceptable. Its principal strengths lie in granular empirical calibration, transparency of assumptions, and high-frequency updating of core market fundamentals. For corn futures anchoring, this framework benefits from unparalleled depth in acreage, yield, stocks, ethanol demand, exports and policy parameters, all of which are central drivers of global price formation.

The ERS Baseline is empirically grounded in US production and export dominance in maize markets, making it particularly powerful for modelling global price benchmarks that transmit into import-parity pricing in downstream markets. WASDE's monthly updates provide near-real-time adjustments to supply–demand expectations, improving responsiveness to weather shocks and export dynamics relative to purely annual structural baselines.

### 3.2.1 LIMITATIONS AND MITIGATION

The principal limitation of the USDA framework is its partial geographic scope and more limited treatment of non-US structural drivers relative to a fully global equilibrium model. It is therefore more vulnerable to external shocks originating outside the US production system, such as South American weather extremes or policy shifts in major importing regions. This limitation can be mitigated by augmenting the baseline with global macro and energy scenario overlays, but the model remains less globally integrated than AGLINK-COSIMO.

### 3.2.2 CONCLUSION

Where the objective prioritises empirical transparency, frequent updating and strong representation of the dominant exporting benchmark, the USDA ERS Baseline & WASDE framework is a credible and defensible second choice. It is particularly appropriate for operational forecasting where near-term responsiveness is valued alongside medium-term structural grounding.

## 3.3 Final methodological position

The suggested upstream anchor is OECD–FAO AGLINK-COSIMO, due to its global equilibrium structure, institutional governance and scenario coherence. The recommended second-best option is USDA ERS Baseline & WASDE, due to its empirical depth, update frequency and centrality to global corn price discovery. Both options materially outperform bespoke reduced-form hybrids on criteria of robustness, external validation and long-term governance, and either would provide a fully defensible upstream foundation for South African sorghum price modelling.

# Section 4: Detailed Profiles of Models & Alignment

## 4.1 OECD–FAO AGLINK-COSIMO connection to the Blueprint sorghum model

AGLINK-COSIMO produces a structural, global equilibrium corn price path under a coherent set of assumptions (macros, policies, yields, stocks, trade, energy linkages). To use it operationally in the sorghum model the steps would be:

a) Map AGLINK corn output to the corn benchmark used in the sorghum equation
If the sorghum model is parameterised on CBOT corn futures, a translation layer is needed.

**Equation 1- Translation layer**

$$\ln\ P_t^{CornFut} = \ln\ P_{AG,t}^{Corn} + \ln\ B_t$$

where $B_t$ is a basis term capturing the systematic difference between the AGLINK price concept and the futures benchmark (risk premia, timing, and contract convention). $B_t$ can be estimated historically and held constant or made scenario-dependent if desired.

b) Feed the translated corn series into the existing sorghum equation
The sorghum model remains unchanged structurally. Only the input $P^{Corn}$ becomes model driven.

**Equation 2- Model driven input**

$$\Delta\ln\ P_t^{Sorg} = \beta_0 + \beta_1 \Delta\ln\ P_{AG,t}^{CornFut} + \beta_2 \Delta\ln\ FX_t + \cdots$$

The benefits of this are i) driver completeness and scenario coherence**.** AGLINK internalises the main fundamentals that the report identifies as persistent corn drivers, particularly energy-agriculture linkage, global stocks tightness, yield and trade balance effects, and policy regime shifts. It produces a corn path that is structurally interpretable for policy and investment decisions, which strengthens the credibility of downstream sorghum scenarios; and ii) better treatment of non-US shocks. Because AGLINK is global, it is more likely to transmit shocks originating outside the US (South America weather, global trade disruptions, import demand surges), which improves the sorghum model's relevance for import parity risk.

Timing and frequency mismatch need attention as possible challenges**.** AGLINK baselines are typically annual (or low frequency). If the sorghum model is monthly, interpolation is needed or a stepwise annual-to-monthly path can be adopted. This almost always reduces short-run variance of the corn input. Statistically, if the corn input becomes smoother than the historical futures series, two things happen as follows:

a) The sorghum forecast becomes smoother, with fewer short-term swings

b) On re-estimation, $\beta_1$ may drift upward to compensate for the lower variance in $\Delta\ln\ P^{Corn}$ (a standard scaling effect), but the model may still understate tail risk during rapid shock episodes

Similarly, futures expectation and risk premium are not native**.** AGLINK is fundamentals-led. Futures embed expectations, risk premia and positioning. If relying solely on AGLINK without an explicit basis and timing layer, the sorghum model may lag market turns, particularly around fast-moving weather or energy shocks.

### 4.1.1 IMPACT ON SORGHUM SENSITIVITIES

AGLINK shifts the sorghum model from being driven by market-price corn to being driven by fundamentals-consistent corn. That changes the path and decomposition of sorghum forecasts. Using the chain rule, the implied sensitivity of sorghum to an upstream driver $X$ that operates through corn is-

**Equation 3- Implied sensitivity**

$$\frac{\partial \ln\ P^{Sorg}}{\partial \ln\ X} = \beta_1 \cdot \frac{\partial \ln\ P^{Corn}}{\partial \ln\ X}$$

Typical corn elasticities include oil around 0.2 to 0.3, stocks-to-use around negative 0.25 (often more negative under tight-stock non-linear forms), and strong cross-grain effects. So, illustratively, if AGLINK implies-

**Equation 4- AGLINK implications**

$$\frac{\partial \ln\ P^{Corn}}{\partial \ln\ Oil} \approx 0.25$$

then under the import-parity sorghum elasticity $\beta_1 \approx 0.54$, the implied sorghum oil sensitivity through corn is $0.54 \times 0.25 \approx 0.135$, meaning a 10% oil shock implies approximately a 1.35% sorghum effect through the corn channel, before FX and local maize effects. *This is the core AGLINK advantage,* essentially it provides driver-to-outcome traceability for policy scenarios, even if near-term volatility is damped.

## 4.2 USDA ERS Baseline & WASDE connection to the Blueprint sorghum model

The USDA ERS Baseline is a structural, partial-equilibrium projection system for US agriculture that generates medium-term corn price paths under explicit assumptions (macros, policy, acreage, yields, stocks, domestic use, exports). WASDE is not a formal econometric model, but an operational forecasting system that provides high-frequency, authoritative supply–demand updates (area, yields, production, consumption categories, ending stocks, global trade flows) that the market uses to update expectations. In combination, ERS Baseline supplies the longer-horizon structural anchor, while WASDE supplies the rolling information set that shifts the market's view of stocks-to-use, yield risk, export demand, and the balance sheet. For downstream sorghum application, the key point is that this option is not just an alternative price series. It is a different information architecture in that it updates corn drivers in a way that more closely resembles how futures markets re-price when new balance sheet information arrives.

The steps taken to use this as upstream are i) define the corn price concept needed as the upstream driver.  The Blueprint downstream sorghum model is calibrated on a corn benchmark that behaves like a market price (typically CBOT futures or a close proxy). USDA systems often provide (a) marketing-year average farm price concepts, and (b) monthly balance-sheet updates that shift expectations. To operationalise it for the Blueprint Sorghum model as the upstream driver, in the first step a translation layer is needed that turns USDA information into a corn futures-consistent input as follows.

**Equation 5- USDA into Corn input**

$$\ln\ P_t^{CornFut} = \theta_0 + \theta_1 \ln\ P_t^{USDA} + \theta_2 \ln\ STU_t + \theta_3 \ln\ Oil_t + \theta_4 \ln\ P_t^{Wheat} + \theta_5 D_t^{policy} + \nu_t$$

Where

a) $P_t^{USDA}$ is the USDA price concept you have access to (ERS Baseline path or a WASDE-derived implied price measure, depending on availability).
b) $STU_t$ is stocks-to-use (WASDE provides the components).
c) $Oil_t$ and $P_t^{Wheat}$ capture the energy and cross-grain channels that the report highlights as central to corn price formation.
d) $D_t^{policy}$ captures the structural post-biofuel regime shift discussed in the draft (the *higher intercept* era).

This translation step prevents conceptual mismatch (farmgate vs futures) and isolates basis/risk premia effects in $\nu_t$ rather than contaminating the sorghum coefficients.

The second step requires that the translated corn futures series is plugged into the sorghum model unchanged. Once $P_t^{CornFut}$ has been established, the downstream structure stays stable.

**Equation 6- Downstream structure unchanged**

$$\Delta\ln\ P_t^{Sorg} = \beta_0 + \beta_1 \Delta\ln\ P_t^{CornFut} + \beta_2 \Delta\ln\ FX_t + \beta_3 \Delta\ln\ P_{t-k}^{YM} + \varepsilon_t$$

The main mechanical effect of choosing USDA/WASDE is that $\Delta\ln\ P_t^{CornFut}$ becomes more information-responsive (because WASDE updates stocks, yields, exports, and use), and therefore the sorghum forecast inherits that responsiveness through $\beta_1$.

There is a third optional step, where WASDE can be treated as an *event updater* inside the corn driver. WASDE behaves like a sequence of information shocks. A practical way to use it is as follows:

**Equation 7- WASDE event updater**

$$\ln\ P_t^{CornFut} = \ln\ P_{t-1}^{CornFut} + \lambda(\ln\ P_t^{Corn*} - \ln\ P_{t-1}^{CornFut}) + \sum_j \phi_j\ \Delta Z_{j,t}$$

Where $P_t^{Corn*}$ is the equilibrium price implied by the balance sheet (stocks, yield, use, exports, oil), and $\Delta Z_{j,t}$ are WASDE surprises (revisions relative to market expectations, or revisions relative to prior WASDE). This structure mirrors how futures re-price, partial adjustment toward a new equilibrium plus reaction to surprises.

### 4.2.1 IMPACT ON SORGHUM SENSITIVITIES

The USDA ERS Baseline and WASDE framework sharpens the stocks-to-use and yield channels. Stocks-to-use and yield fundamentals are central to corn price formation, with strong inverse and non-linear behaviour. USDA/WASDE is, practically, the most authoritative public pipeline for keeping those variables current. That has a direct downstream benefit: the sorghum model's corn input will reflect supply tightness sooner and more credibly than a purely annual structural baseline. The sorghum forecast would show more pronounced and earlier moves in drought/shortfall conditions (when WASDE revises yields down and STU tightens), and less risk of under-reacting in the early phase of a shock and it improves near-term realism without turning the sorghum model into a high-frequency trading model.

Unlike a purely annual global equilibrium baseline, WASDE introduces intra-year information updates that move market expectations. This tends to produce a corn input with the kind of step changes and turning points that procurement and risk teams recognise. It impacts the corn coefficients because the corn input retains more futures-like variance and timing, re-estimation typically leaves $\beta_1$ closer to its current magnitude (less likely to see $\beta_1$ artificially inflate to compensate for a smoothed corn series). In other words, the sorghum model remains statistically well-scaled. It also aligns well with how South African prices transmit through import parity and FX. WASDE-driven shifts are strongly reflected in global maize benchmark expectations, which then feed through to import parity calculations. Because your sorghum models already treat FX as a principal pass-through channel, the USDA option tends to generate coherent co-movement between the corn leg and the FX leg, rather than introducing slow-moving corn shifts that are out of sync with currency-driven parity dynamics. This tends to reduce residual error in periods where the domestic market is import-parity sensitive, because the corn benchmark used in the model updates in ways the parity mechanism actually sees.

Challenges for attention include a concept mismatch risk (farm price vs futures) which can bias the downstream $\beta_1$ if translation is skipped. If a USDA season-average farm price is fed directly into the sorghum equation as if it were futures, the sorghum model may compensate by shifting $\beta_1$ and/or $\beta_0$, and timing may be misattributed. A smoothed upstream price causes the downstream model to under-represent tail dynamics and can induce serial correlation.

This can be dealt with by implementing the translation layer, *which is not optional if defensible econometrics are required*. Similarly, non-US shocks may be underrepresented unless explicitly added. USDA is strongest on the US balance sheet. Global shocks (Brazil/Argentina, Black Sea disruptions, non-US demand surges) can still filter into WASDE, but not with the same endogenous global closure as a fully global equilibrium model. If the world shock is non-US and does not immediately shift the US balance sheet, the USDA-derived corn futures proxy may react less structurally (or react via market sentiment rather than balance-sheet variables). This could impact on the sorghum forecast and result in understatement of some scenarios where global non-US supply risk is the dominant driver, unless a global tightening proxy (global STU rather than US-only, or a global export availability indicator) is added.

Finally, WASDE updates can introduce sudden revisions. This is realistic, but it changes the distribution of forecast errors in that more step changes and potentially more short-run volatility can occur. More frequent short-run forecast updates and larger month-to-month moves can be noticed. For decision-making, this is often a benefit (early warning), but it requires governance- stakeholders must accept that the model is dynamic and responsive.

The downstream sensitivity of sorghum to any upstream driver $X$ that operates through corn remains

**Equation 8- Downstream sensitivity**

$$\frac{\partial \ln P^{Sorg}}{\partial \ln X} = \beta_1 \cdot \frac{\partial \ln P^{CornFut}}{\partial \ln X}$$

This option affects the right-hand term because USDA/WASDE puts more weight on specific drivers, particularly the balance-sheet drivers that can change materially with new information (yield, stocks, exports, use). The practical implication is that under USDA/WASDE anchoring, $\frac{\partial \ln P^{CornFut}}{\partial \ln STU}$ and $\frac{\partial \ln P^{CornFut}}{\partial \ln Yield}$ become more state-dependent and event-driven, because revisions can shift perceived tightness quickly. As a result, Sorghum inherits a more realistic jump risk [16] profile through $\beta_1$, especially in drought onset phases or export surprise phases.

If the sorghum model variant has $\beta_1$around 0.54 (import-parity case), then the sorghum response to a corn driver shock is half-strength relative to corn. But the important change under this option is not the multiplier; it is that the corn driver shocks arrive sooner and less smoothed, particularly for stocks/yield.

*This is where Option 2 differs from Option 1*. Option 1 tends to make $\frac{\partial \ln P^{Corn}}{\partial \ln X}$structurally interpretable but smoother while Option 2 tends to make it operationally responsive and revision sensitive.

If this option is adopted, two safeguards will be useful and are recommended. First, re-estimate $\beta_1$under the translated futures proxy, not under a raw USDA price concept. This avoids coefficient distortion and preserves interpretability; second use regime testing or rolling estimation (at minimum) to check whether $\beta_1$remains stable when WASDE revision behaviour changes across periods (for example, the volatility regime during major droughts vs normal years). This is critical because the upstream information process changes the variance structure of $\Delta \ln P^{CornFut}$, and untested stability can produce fragile sorghum forecasts.

[16] The risk that prices change suddenly and discontinuously, rather than moving gradually over time.

**Figure 1: Options comparison.**

**What changes in the sorghum forecast depending on the upstream corn model selected?**

The choice of upstream corn price model changes the behaviour of the sorghum forecast.

*If a global structural baseline such as OECD–FAO AGLINK-COSIMO is used as the upstream anchor,* the sorghum price path becomes more stable, smoother and more structurally interpretable over the medium term. Global drivers such as energy prices, stocks tightness, yield shocks and policy regimes are coherently embedded, which strengthens scenario credibility and policy narrative. However, near-term sorghum forecasts tend to adjust more gradually to emerging shocks, because the upstream corn signal is driven by fundamentals rather than by fast-moving market expectations. This produces sorghum scenarios that are well-suited to strategic planning and policy analysis, but less responsive to short-run turning points.

*If a USDA ERS Baseline & WASDE framework is used as the upstream anchor*, the sorghum forecast becomes more responsive, more market-adjacent and more revision-sensitive. Because the corn input updates as new balance-sheet information on yields, stocks and exports is released, sorghum prices react earlier and more sharply to emerging supply shocks and demand surprises. This improves early-warning capability for procurement and risk management, but results in more frequent short-run forecast revisions and higher apparent volatility. The trade-off is that global non-US shocks are less endogenously captured unless explicitly augmented.

In practical terms, the AGLINK option produces smoother, scenario-coherent sorghum paths anchored in global fundamentals, while the USDA/WASDE option produces faster-moving, information-responsive sorghum paths aligned to market re-pricing dynamics. The appropriate choice therefore depends on whether the primary decision need is medium-term strategic planning or near-term operational risk management.

The preferred upstream anchor is therefore OECD–FAO AGLINK-COSIMO, due to its global equilibrium structure, institutional governance, and scenario coherence. The recommended second-best option is USDA ERS Baseline & WASDE, due to its empirical depth, update frequency, and centrality to global corn price discovery. Both options materially outperform bespoke reduced-form hybrids on criteria of robustness, external validation, and long-term governance, and either would provide a fully defensible upstream foundation for South African sorghum price modelling.

### 4.2.2 CONNECTION TO THE SORGHUM PRICE FORECASTING MODEL.

Given this recommended model, how would movements in upstream variables translate into sorghum price dynamics. The connection works through two-stage modelling. First, changes in drivers lead to corn futures price change (as per model coefficients); then corn futures lead to Sorghum price change.

Concretely, if crude oil surges, the corn model might predict a noticeable corn price increase (e.g. +5% for a 20% oil rise, based on elasticity ~0.25). That higher corn price, when fed into the sorghum model, will tend to raise South African sorghum prices. Sorghum often trades at a discount to corn, but global corn sets a benchmark: if corn becomes more expensive (whether due to ethanol pulling more corn or higher feed demand globally), sorghum, as an alternative feed grain, will see increased demand and its price will climb until the price gap closes. Similarly, consider a supply shock: a drought reduces corn yields by 5%.

Within the recommended corn framework, a negative yield shock reduces production and, all else equal, tightens the supply–demand balance, resulting in a lower stocks-to-use ratio. For example, the model might predict a 10–15% corn price increase depending on initial stocks (small change if stocks were ample, large if stocks were already tight). That corn price jump would transmit to sorghum. Domestically, South African feed buyers might shift to sorghum if corn imports are expensive, bidding up sorghum until its price reflects the import parity of corn (plus quality adjustments). The timing may have lags (it might take a few weeks or months for sorghum prices to fully adjust as inventories deplete or contracts reset), but ultimately sorghum follows corn's direction. Our framework explicitly captures this in that corn futures is an exogenous input to the sorghum pricing model, so any upstream movement in corn (driven by oil, stocks, etc.) will filter into the sorghum price forecast.

For example, one key upstream variable is Brent crude. If energy analysts forecast Brent to decline from USD80 to USD60 (a 25% drop), this corn model would likely forecast corn prices easing (oil elasticity ~0.25, so roughly a 6% drop in corn price, other factors constant). This would feed through to a somewhat lower sorghum price outlook than before. Conversely, if oil is expected to spike on geopolitical tensions, the corn forecast should be adjusted upward, and sorghum's projected prices would rise. Additionally, empirical estimates of this relationship vary from +0.20 to +0.40 elasticity of corn futures to Brent Crude in recent studies (Carter *et al.,* 2020; Zhang & Adkins, 2021).

Essentially, the South African sorghum price is anchored by import parity to corn, so global corn's drivers become sorghum's drivers by extension. The benefit of the recommended model is that it allows these linkages to be quantified e.g., we can say how much sorghum might move given a certain shock to oil or a poor harvest scenario, because the corn model's coefficient and the sorghum vs. corn relationship (which might be a fixed differential or elasticity), are available. This end-to-end understanding is what makes the forecast expert and defensible. It can be explained that *"if X happens (Brent up USD10, or U.S. yields –5%), then corn will likely do Y%, and thus sorghum (with lag Z) will do something proportional*."

In summary, the recommended model structure incorporates the qualitative and quantitative relationships identified in credible research. It blends energy market linkages (oil price, biofuel demand), agricultural fundamentals (production, stocks, yields), and relevant macro factors (exchange rates, policy shifts). By using proven coefficients as a starting point, the model is grounded in real-world behaviour. Each driver's relative significance is evidenced by both its coefficient magnitude and its historical contribution to price variance (oil and stocks being most significant, as multiple studies show). The model's outputs will thus reflect the combined impact of these forces. Adopting this framework upstream ensures that changes in energy markets, global grain supply, or other key factors will flow logically through corn futures to the local sorghum outlook. This approach is consistent with both academic findings and investor-focused analysis, and it should yield robust, transparent forecasts that can withstand scrutiny. By quantitatively linking upstream drivers to corn and then to sorghum, we can confidently explain our price projections and account for risks, achieving the goal of a comprehensive, contradiction-proof analysis of sorghum price dynamics via corn futures.

Taken together, the literature clarifies how upstream structural factors including energy prices, biofuel policy, supply shocks, and inventory dynamics shape US corn price formation. These effects are reflected in observed corn futures prices, which act as a market-based aggregation of both fundamental conditions and expectations. As such, downstream models linking South African Yellow Maize and sorghum prices to corn futures operate consistently with the broader literature, without requiring these upstream drivers to be re-estimated at each stage.

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# Annexures

## Annexure 1- Available Models

*Public sector models* that are freely available are generally not for sale but are publicly accessible and widely used as benchmarks.

a) USDA Baseline Model / WASDE – Freely available via USDA's Economic Research Service and World Agricultural Outlook Board.
b) OECD–FAO Agricultural Outlook Model – Published annually and accessible online, although raw model internals (coefficients, equations) are not always fully disclosed.
c) BFAP Baseline Model (South Africa) – Available through collaboration or partnership, not directly purchasable. Access may be granted via subscription or institutional engagement.
d) ABSA 5-Year Forecast – Outputs may be published in strategic insights reports or via client relationships. The underlying model is proprietary.

*Proprietary/commercial models* are available for purchase or under licence. The following models are either explicitly for sale or integrated into commercial platforms

**Table 4: Models that can be procured**

| Model / Organisation | Availability |
|---|---|
| Refinitiv Agriculture Models | Yes – offered as part of their Eikon platform. Licensing required. |
| Bloomberg Commodity Forecasting Suite | Yes – integrated into Bloomberg Terminal services. Subscription-based. |
| S&P Global Commodity Insights (Platts) | Yes – access to forecasting and analytics tools available through licensing. |
| CRU Group | Yes – offers agricultural forecasting models for a fee, including time-series data tools. |
| Macquarie Agricultural Commodities Modelling | Yes – proprietary but reports and modelling access can be purchased. |

S&P Global is also widely trusted by institutional investors and offers data integration features, back-testing environments, and strong customer support.

# Annexure 2- Constructing a bespoke hybrid corn futures model

Bringing together the insights from reputable studies and the comparative analysis, an integrated model structure for U.S. corn futures could serve as a foundation for sorghum price forecasting. The model would be a multi-factor regression or equilibrium equation specified approximately as:

Equation 9- Model specification

$$\text{Corn Price}_t = \alpha + \beta_1 \ln\left(\text{Crude Oil}_t\right) + \beta_2 \ln\left(\text{Stocks-to-Use}_t\right) + \beta_3 \ln\left(\text{Exchange Rate}_t\right) + \beta_4 \ln\left(\text{Wheat Price}_t\right) + \beta_5 D_{policy} + \varepsilon_t,$$

(where this is in log terms for elasticity interpretation, and $D_{policy}$ could be a dummy or trend capturing the biofuel policy era post-2005).

The key components would therefore be *energy prices* where Brent crude oil is included as a driver. Based on literature, the expectation is that $\beta_1 > 0$. For instance, $\beta_1$ might correspond to an elasticity ~0.2–0.3 (as found by Baffes & Dennis, and others). This captures both ethanol-driven demand (more oil → more ethanol use of corn) and cost inflation in production. Given the strong statistical significance of oil in models (often $p < 0.01$), this variable could be a major contributor to explained variance. If oil prices are forecast to rise, such a model will duly forecast higher corn prices. Brent futures or analyst projections could be used as input for oil.

*Supply tightness* would be another key component. Using global (or U.S.) stocks-to-use ratio, or alternatively global corn production relative to trend, to represent supply-demand balance. The coefficient $\beta_2$ is expected to be negative. In log-log form, it measures elasticity and would expect roughly $\beta_2 \approx -0.25$ in long-run magnitude (consistent with World Bank findings). However, to capture non-linearity (price skyrockets as stocks approach critically low levels), we might use an inverse specification (like 1/(stocks-use)) or allow $\beta_2$ to change at low stock levels. For simplicity, a piecewise linear or quadratic term could be added. This part of the model ensures that corn price responds to global crop supply conditions. For example, if a poor harvest slashes stocks, the price will rise steeply. It grounds the model in fundamental reality and anchors long-term equilibrium. For forecasting, expected stocks or production numbers from USDA could be used.

*Cross-commodity price* is a third key component. The world wheat price (or an index of substitute grain prices) can be included as an independent variable. $\beta_4$ should be positive, given corn and wheat move together (there was a +0.54 to +0.57 USD/USD tonne cross-effect in Zolotnytska's model). The inclusion of wheat accounts for any external shocks specific to wheat (or rice, etc., if we use a broader index) that would spill into corn. For example, a wheat crop failure in another country could boost wheat price and indirectly lift corn via demand substitution – our model will catch that via this term. If one prefers to avoid using wheat futures (to keep the model independent), an alternative is to include a constant long-run price spread and rely on stocks and oil to handle co-movement. But evidence suggests that adding wheat price improves fit, making a corn model more robust to cross-market influences.

*Biofuel policy/structural shift* could be a dummy variable $D_{policy}$ (value 1 from 2006 onward, 0 before) or a smoother function to account for the ethanol era demand shift. This would adjust the intercept $\alpha$ upward in the post-2005 period, reflecting that corn now trades at a higher baseline price for a given stock level (Irwin & Good found a higher intercept for 2006+ data). If calibrating the model only on recent data (e.g. last 15–20 years), a dummy might not be needed, but it can be useful if combining earlier history for statistical power. This term essentially encodes the effect of mandates that are not explained purely by oil price (since even at moderate oil, corn is more valuable due to the guaranteed ethanol demand).

*Exchange Rate (optional):* If focusing on an international perspective, the USD index (broad or relevant currency basket) could be included. $\beta_3$ would be negative (a higher index means stronger dollar resulting in lower corn USD price). The magnitude could be approximately –1 to –1.3 as per Baffes (2013), though it could be calibrated specifically for corn. This factor is more relevant if we want to capture macroeconomic scenarios (e.g. a sharp dollar depreciation could push corn higher than fundamentals alone suggest). Given South Africa's context (where rand-dollar affects local prices), it is conceptually useful to consider currency. If included, then forecasts from macro sources for USD should be used.

*Error correction/dynamics*. The above is a static equilibrium relationship. In practice, futures prices can deviate in the short run and then revert. The model could be implemented in a dynamic form (e.g. a Vector Error-Correction Model linking corn with drivers) to capture short-term lags. For instance, corn prices might not instantly adjust to a new oil price or stock level, especially if using high-frequency (monthly/quarterly) data. An Error Correction Mechanism (ECM) would include a term for last period's price vs. equilibrium and allow partial adjustment. This could improve near-term forecast accuracy. However, for annual forecasts (which might suffice for strategic work), a static model is typically acceptable.

*Statistical validation*. This model could be validated on historical data (e.g. last 20–30 years). A high fit can be expected (possibly $R^2$ ~ 0.8–0.9) if specified well, consistent with published studies. Each coefficient should have the expected sign and be statistically significant. For example, oil price with t-stat perhaps >5 (very significant) as prior studies show, stocks/use with strong significance, etc. Notably, oil and stocks-to-use can be somewhat correlated (high oil can spur production affecting stocks), but since one acts on demand and the other on supply, including both is in order. Zolotnytska et al. had to drop direct climate variables due to collinearity with yields, but oil and yield remained distinct. Collinearity might be encountered between oil and a time trend (as both rose in 2000s), but using detrended data or including the dummy helps alleviate that. Ensuring robust estimation is key so that model coefficients can be trusted for out-of-sample prediction.

# Annexure 3- Question and Answer

**Q1. Is it possible to compare the results of the different models?"**

Yes. It is possible to compare the results of the different models, but the comparison should be interpreted carefully because the models differ in structure, forecast horizon, and price definitions. Some models forecast international benchmark prices such as futures or export-parity prices, while others generate producer or domestic market prices, and several models incorporate different combinations of structural drivers, econometric relationships, or scenario assumptions. As a result, the outputs are not directly identical but are broadly comparable in terms of direction, magnitude and sensitivity to key drivers. In practice, comparison is typically undertaken through convergence analysis across model outputs. When the major models reviewed (for example USDA baseline projections, OECD-FAO outlooks, BFAP projections, and private-sector econometric models) are examined together, they generally produce similar directional responses to key drivers such as oil prices, stocks-to-use ratios, yield shocks and global demand growth. The absolute price levels may differ due to methodological differences, but the models consistently indicate the same fundamental relationships: tighter global stocks raise corn prices, higher energy prices support corn via ethanol demand, and favourable production conditions moderate prices.

**Q2. Is it possible to demonstrate the implementation of these recommendations based on the current published forecasts from the two institutions? Eg for OECD-FAO the starting point would be to indicate current input assumptions for the relevant input parameters as explained earlier. Then show the P(corn,AG,t) and Bt and subsequently the result of equation 1 in section 5.1.**

Yes, it is possible, and it is a good way to make the recommendations concrete. The cleanest way to do it is as a worked example using the latest publicly available OECD-FAO Outlook series for (i) the corn price path and (ii) the key driver assumptions that underpin that path (for example crude oil and exchange rate assumptions where available, and supply-demand balance variables such as production, consumption, and stocks). You extract the OECD-FAO baseline corn price series for the forecast horizon and define that as the upstream price path:

$$P(\text{corn}, AG, t)$$

where $AG$indicates the chosen upstream agricultural benchmark (OECD-FAO is one valid benchmark source).

Define the basis term $B_t$(the translation from the upstream benchmark to the domestic sorghum pricing space). $B_t$is not "given by OECD-FAO"; it is your decided bridging term which can be implemented as either:

- a fixed or rolling historical average basis (simple implementation), or
- a basis model driven by explicit covariates such as freight, exchange rate, tariffs, and domestic handling/marketing margins (more rigorous implementation).

Compute Equation 1 (Section 5.1) year-by-year:

- typically this is

$$P(\text{sorghum}, t) = \alpha + \beta \cdot P(\text{corn}, AG, t) + B_t$$

(or the exact form specified in 5.1, applied consistently).

This would show implementability using real published forecasts, clarify what is taken from OECD-FAO (the upstream price path and scenario assumptions), and what is locally constructed (the basis and the translation equation).

**Q3. How should the inputs to the Excel file be made**

Excel needs a clear separation between (A) upstream forecast inputs and (B) local translation inputs, with explicit cell locations and units. The simplest implementation is:

*A. Upstream inputs sheet* (from chosen source)

- A column for year $t$
- A column for $P(\text{corn}, AG, t)$(the source corn price series)
- Optional columns for upstream assumptions *if you are using them explicitly* (oil price, USD index, stocks-to-use, production, etc.)

*B. Basis / translation sheet*

- A column for year $t$
- A column for the chosen basis method's inputs (depending on approach)
- A column for $B_t$(computed)
- A column that calculates the sorghum forecast from Equation 1

*C. Output sheet*

- Final sorghum price forecast path
- Sensitivity toggles (scenario switches)

What must be explicit in the Excel is

- *Units* (USD/tonne, ZAR/tonne, real vs nominal)
- *Price definition* (futures, export parity, domestic benchmark)
- *Time alignment* (marketing year vs calendar year)
- The Excel should also include short inputs required box at the top of each input sheet, listing exactly what must be pasted in and where.

**Q.4 How to choose between the different approaches (5.1 and 5.2)**

This is a model governance decision. Both approaches can be valid, but they serve different purposes. A clear decision rule is to use both or:-

*Choose Approach 5.1* (direct translation from upstream corn forecast via a stable relationship and basis) when:

- you need a transparent, auditable, low-complexity forecasting tool,
- the primary objective is planning-grade forecasting rather than causal inference,
- data availability for local covariates is limited or unreliable,
- you want robustness and ease of updating (paste in new OECD-FAO/BFAP corn path, update basis, output updates immediately).

*Choose Approach 5.2* (driver-based or more structural implementation) when:

- you want sorghum forecasts to respond explicitly to key drivers (exchange rate, freight, domestic supply shocks, etc.),
- you have reliable time-series data for those drivers,
- you need scenario capability beyond the upstream corn price path (for example shocks to logistics or domestic drought),
- you accept higher complexity in exchange for richer sensitivity behaviour.

Consider treating 5.1 as the baseline production model, and 5.2 as the scenario/sensitivity module used when conditions depart materially from history (for example severe logistics disruption, major FX shock, domestic production collapse). If this is done, they are complementary rather than competing.

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