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Mexican white corn spot price replication with a U.S. agricultural futures portfolio for food security management

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Abstract

This paper demonstrates that a futures portfolio composed of 51.7% corn and 48.3% wheat solves the ineffective hedge of the CME corn contract for Mexican white corn. This portfolio, selected from over 1,013 combinations, achieves a hedging effectiveness of 0.6180. Its viability was confirmed through a backtest spanning from 2000 to 2025, which yielded a simulated profit of MXN 5.77 per kilo for a seller using this strategy. The results propose this portfolio as a novel financial tool for the government or financial institutions to offer guaranteed prices to producers, thereby strengthening Mexico's food security.

Keywords: White corn, Futures portfolio, Price replication.

Resumen

El presente trabajo demuestra que una cartera de futuros compuesta por 51.7% de maíz y 48.3% de trigo resuelve la ineficaz cobertura del contrato de maíz del CME para el maíz blanco mexicano. Dicho portafolio, seleccionado entre más de 1,013 combinaciones, alcanza una efectividad de cobertura de 0.6180. Su viabilidad fue confirmada mediante un backtest que abarcó desde el año 2000 hasta 2025, el cual arrojó una ganancia simulada de 5.77 MXN por kilo para un vendedor que utilizara esta estrategia. Los resultados proponen esta cartera como una herramienta financiera novedosa para que el gobierno o instituciones financieras puedan ofrecer precios de garantía a productores, fortaleciendo así la seguridad alimentaria de México.

Palabras clave: maíz blanco, portafolio de futuros, precio de replicación.

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Introduction

Agricultural production is an activity subject to several risks that impact the performance and livelihood of producers and some related intermediaries. This situation is particularly important for medium- and small-sized producers, who depend on favorable prices and weather conditions for their profitability. In this paper, the authors propose a method to hedge income risk for Mexican white corn (corn, henceforth) sellers (producers or intermediaries). Managing this type of risk is particularly relevant to enhancing the country's corn supply. Corn is the main staple of the Mexican diet, and its price could impact the consumption and welfare of all income levels. Consequently, the proper formation and stability of corn prices are essential goals.

Corn is a staple that depends on weather conditions and fluctuations in market prices. Low prices mean lower income and, consequently, a lower supply of corn. High prices affect the benefits of intermediaries as well as household consumption and overall inflation levels. Mexico is among the top ten corn-producing countries, according to the Food and Agriculture Organization's (FAO) 2023 figures (FAO, 2024).

Following the decline in white corn supply in the 1970s, Mexico faced a shortage of white corn that threatened general consumption, particularly among lower-income populations. To mitigate such an impact on general food security, the Mexican government implemented floor or minimum price (warranty or strike price) policies. It began purchasing white corn crops directly from producers. This corn was stored in public silos and sold to the low-income population at lower prices through Public (Government) stores. The difference (income loss) between the minimum or strike price paid (K) to the producer and the lower sale price was paid with tax contributions.

In 2016, after other successive food security programs, the Mexican Government implemented a new program known as SEGALMEX (Mexican Food Security Agency). A financial agency that is part of the Secretary of Agriculture (Martínez-Cuero, 2021). Its main goal was to implement, once again, a hedge or income insurance scheme by publishing an official ask (buy) price, estimated with the monthly mean strike price of the Chicago Mercantile Exchange (CME) 1-month yellow-3 corn futures and the mean close value of the Mexican peso/US dollar (MXNUSD) exchange rate in that period. This scheme was again funded with taxpayers' contributions and represents a fiscal burden to the Mexican Government.

The intended effort to hedge a non-commodity staple with a traded future is known as cross-hedging. As an example, it involves using the future of an agricultural commodity to hedge a non-commodity, such as white corn. US yellow corn is a commodity with high production and trading volumes globally, unlike varieties such as Mexican white corn, popcorn, or other staples like beans or avocados in Mexico. The problem with cross-hedging practices is the presence of basis or basis risk. The basis is the difference between the futures price change (ΔF_t) and the spot (non-commodity) price. The primary rationale for an appropriate hedging with derivatives is $\Delta P_t - \Delta F_{i,t} \approx 0$. The basis is when $|\Delta P_t - \Delta F_{i,t}| > 0$. Basis risk is defined as $\sigma^2(\Delta P_t - \Delta F_{i,t}) > 0$. The presence of basis risk is not suitable for hedging activities and affects the income risk for corn producers. Related to this issue in the white Mexican corn market cross-hedging with commodity futures, the work of Ortiz-Arango and Montiel-Guzman (2017) is the first to test the cointegration and hedging effectiveness of the CME yellow corn future in the Mexican white corn price of the leading corn producing states in Mexico (Sinaloa, Jalisco, Michoacan, the state of Mexico, Guanajuato, Chihuahua and Guerrero).

The authors found that only the State of Michoacan showed a significant relationship (in the short and long term) between its price and the corn futures price. They use the Engle-Granger (1987) cointegration test to determine the presence of a long-term (cointegrating) relationship and stochastic volatility models (like multivariate GARCH models) to estimate the significance of the time-varying and dynamic correlation (short-term relationship test). Building on this work and other studies reviewed in the following section, this paper extends the work of Ortiz-Arango and Montiel-Guzman, testing a potential solution to mitigate basis risk and enhance hedging effectiveness.

The primary motivation of the present test is to select an optimal futures portfolio $FP = \mathbf{w}*$ $= [\mathbf{w_f}]$ whose percentage variation $\Delta\%FP$ replicates or, at least, approaches that of the Mexican white corn spot price in Mexico. The working hypothesis tested herein is that "using an agricultural futures portfolio leads t, i.,t final subíndice casi igual a one and reduces basis risk significantly".

Once the primary motivation has been established, the paper's structure is as follows: The next section presents a literature review related to hedging effectiveness, hedge ratios, and, most importantly, those that have tested the hedging effectiveness of cross-hedging practices in agricultural products worldwide. In this section, the authors briefly describe the surplus-efficient frontier portfolio selection method. The third section outlines the data gathering and processing steps, along with the replication results for the white corn price. In this same section, the authors present a test of a quantitative hedging rule, demonstrating that using the optimal portfolio leads not only to proper price replication but also to a good hedge and reduced income risk. Finally, the last section presents the main conclusions and guidelines for further research.

Literature review

The primary objective of this paper is to demonstrate that it is feasible to replicate the Mexican white corn price using a portfolio of agricultural futures (henceforth referred to as a mimicking portfolio), illustrating the potential to hedge the corn price with a short position. The core idea is to translate the risk of the offered hedge from taxpayers to derivatives markets. Consequently, the Mexican

Government wouldn't be involved in subsidizing the potential loss by farmers, thereby releasing these resources for other economic policy matters.

For the Mexican case, two previous works tested the practice of cross-hedging in agricultural products. The first work is that of Ortiz-Arango and Montiel-Guzmán, which shows that there is no statistically significant short- or long-term relationship between the CME yellow corn futures price and the Mexican white corn spot price. The second is that of De la Torre-Torres et al. (2024) who conducted a test similar to the one presented herein. The authors tested the replication of the Mexican Hass avocado (a non-commodity staple in the Mexican diet) using a portfolio of Agricultural futures traded on the CME and NYMEX. The authors found that using a portfolio of 83.48% in sugar and 16.52% in coffee leads to a hedging effectiveness of 0.94 for avocado prices. This result suggests that it is feasible to use such a portfolio to offer a strike or minimum buy price for Hass avocados with a short position in the futures (sugar and coffee) portfolio. This paper aims to extend the results of these two papers to test whether it is feasible to have a proper hedging effectiveness and price replication of the white corn price in Mexico.

To determine if a futures position is appropriate for hedging the price of a staple (commodity or not), there are two measures to judge such a hedge. One is hedging effectiveness $HE_{i,t}$ and the other closely related concept is the hedge ratio, or the number of future contracts that the hedger must hold to mitigate basis risk. For this purpose, several hedge ratios have been proposed as summarized by Myers (1989). From all these, the authors of this paper used Ederington's (1979) functional form using the percentage price variation of the spot and futures position:

$$\Delta\%P_t = \alpha + \beta\Delta\%F_t + \varepsilon_t \quad (1)$$

The other functional forms, which are more complete in terms of the information set that models the future-spot position relationships (such as the generalized autoregressive one of Myers), are set aside because the percentage price variation takes a uniform scale or unit. To give a general idea, the corn future is quoted in dollar cents per bushel, as is the case with the soybean or wheat. Despite this, the difference between these bushels is that the corn bushel equals 25.4 Kg and the soybean bushel 27.2 Kg. Similarly, the coffee and sugar futures are quoted in pounds. Complementary to this issue, the number of units to which each futures contract is standardized differs, leading to the use of the percentage price or future variation to mitigate the impact of these different quotations. Also, using percentage price variations reduces the effect of scale in the price variation, mayúscula delta mayúscula P subíndice t,mayúscula delta mayúscula F subíndice t, proper of high price levels, leading to a reduction in the presence of heteroskedasticity in (2).

One of the reasons for adopting cross-hedging with a future or a portfolio of futures is that not all staples that qualify for a commodity classification possess the necessary trading qualities.

Sanders and Manfredo (2002) showed that the lack of a proper contract design, the lack of industry buy-in, and the education of final users were critical factors that led to the failure of the Minneapolis Grain Exchange white shrimp future contract. To avoid such a complication, a futures portfolio used to replicate the price of the staple of interest could be a potential solution.

To replicate the performance of a given benchmark, a portfolio selection method known as minimum tracking error portfolio selection is employed. This method was proposed by Grinold (1998). To appreciate the difference between conventional (no benchmark restricted) portfolio selection, the following expression is the optimal portfolio selection problem solved in the geometric locus of expected returns of the set of assets involved in the portfolio selection $E(r_i)^* \in [\min E(r_i), \max \mathrm{E}(r_i)]$ with $r_i = \Delta\% P_{i,t}$ for all the assets or securities in the portfolio or investment set (Markowitz, 1959):

$$\mathbf{w}^* = \arg\min \mathbf{w} \ \mathbf{w}'\boldsymbol{\Sigma}\mathbf{w} \tag{2}$$

Subject to:

$\mathbf{w}'\mathbf{1} = 1$

$\mathbf{w} \geq 0$

In the previous expression, $\boldsymbol{\Sigma}$ is the variance-covariance matrix, a key parameter to incorporate the benefits of diversification to portfolio variance ($\sigma_p^2 = \mathbf{w}'\boldsymbol{\Sigma}\mathbf{w}$) or risk exposure reduction.

The goal of the portfolio selection method in this paper is not to create alpha from a theoretical benchmark that replicates the Mexican white corn price. The idea is to create a proper portfolio that replicates such a price. Consequently, the selection problem (6) is not helpful for the intended purposes herein.

The minimum variance portfolio selection method, or its univariate benchmark-related version (surplus efficient frontier), has been tested primarily in equity markets or applications of asset-liability management; however, little has been written on its intended cross-hedging purposes. Only the work of Goswami et al. (2023) takes a similar approach, testing the hedging effectiveness of corn, soybeans, and wheat by incorporating the impact of convergence and non-convergence between the spot and futures prices. The authors found a prolonged period of non-convergence between 2005 and 2011 and demonstrate that the lack of carryover results in low hedging effectiveness due to increased price volatility.

In the case of Chilean cattle prices, the work of Troncoso-Sepúlveda and Caba-Monje (2019) tested the use of CME cattle futures. Using the Johnson (1960) and Stein (1961) hedging method (a future-spot portfolio selection problem like the one tested herein), the authors found that the hedging effectiveness is appropriate in this case. They also suggest extending the test to other staples, such as grains, milk, or pork.

In the Colombian case, Barrera, Cañon, and Sanchez (2020) tested the hedging effectiveness of several agricultural prices using Colombian electricity futures. In only nine of the 93 agricultural products tested, the authors found a significant hedging effectiveness of no more than 0.32. For this purpose, the authors employed VAR, VEC, and GARCH models to estimate the short- and long-term relationships, with the GARCH models yielding the best fit, a result expected due to the lack of cointegration between agricultural prices and electrical futures.

By incorporating prudence and temperance in the hedging decision process, Kamdem and Moumoni (2020) used lower moments and ordinary least squares (OLS) and GARCH models in the time series to estimate the hedge ratio. Their dynamic model led to better hedging effectiveness in storable commodities (the carryover effect).

Penone et al. (2021) tested the hedging effectiveness of soybeans, corn, and wheat using Euronext or CME futures. By employing a naïve hedging strategy (a 1-to-1 spot minus future position), the authors found that the OLS or GARCH hedge ratio method yields better hedging results with Euronext futures. The authors concluded that, using the previous hedging method, the European futures market is more suitable for hedging purposes in Italy.

For the specific case of the Mexican price market, Barrios-Puente et al. (2022) Applied the binomial tree theory to estimate the spot price over several hedging periods (ranging from one to four months) and utilized the NYMEX coffee futures. Their results suggest that hedging the Mexican price of coffee with futures and their statistical method leads to higher income, especially if the hedging horizon is longer.

Finally, the work of Erasmus and Geyser (2024) tested the use of the CME soybean futures contract, denominated in South African rand and traded on the Johannesburg Stock Exchange (JSE), to hedge the soybean spot price in the same exchange. By testing the OLS, VEC, and VEC-GARCH models (after conducting the necessary cointegration tests), the authors found that the future contract outperforms the spot price when the prices are close to or below the export soybean price.

As noted in the literature review, cross-hedging practices lead to better income results for commodity and non-commodity sellers (both producers and intermediaries). Additionally, it has been noted that the CME yellow corn future and the Mexican white corn spot prices exhibit no significant relationship, and the former serves as a poor hedge for the latter when used as the sole hedging security. Finally, previous works have shown the benefits of using a minimum tracking error futures portfolio (selected within a surplus-efficient frontier context) to replicate or cross-hedge spot positions.

Consequently, these previous works and results motivate this paper because the authors extended some of these to prove that using not a single CME corn future position, but a mimicking portfolio, leads to better hedging effectiveness (corn price replication). Based on this literature review and the related motivations, the following section outlines the data gathering and processing method, as well as the main results and findings of the backtests.

Methodology

Data gathering and processing

To test the working hypothesis, the authors obtained the weekly white corn price for the traded kilograms in the main public markets across the 32 States of Mexico (Secretary of Economy, 2025). With these 32 trade prices, the authors estimated a weekly mean value to obtain the mean price value of white corn in Mexico (P_t). This price will be used herein as the spot price to be hedged. It is noted that the price difference is low, even with the presence of outliers. This result, and following the findings of Ortiz-Arango and Montiel-Guzman [6], who also found similar price behavior and cointegration in almost all the origin prices, suggests that the assumption of a homogeneous and single (mean) white corn price in Mexico can be upheld. The test of this assumption and the impact of market frictions is left for further research.

With the historical corn prices P_t, the authors estimated the continuous-time returns (log differences or r_{P_t}) for both the surplus-efficient frontier portfolio selection and the hedging effectiveness test.

Similarly, the authors retrieved the weekly historical closing prices of the ten most traded agricultural futures from Refinitiv databases (Commodity Futures Trading Commission, 2025) for CME and NYMEX. To account for the impact of the Mexican peso-US dollar (USDMXN) FX rate, the authors converted the original price in the futures units' specifications to the Mexican peso per kilogram equivalent. For example, the yellow corn contract in the CME specifications is quoted in US dollars per bushel, and the contract units are 5,000 bushels. For this purpose, the authors divided the price by 100 (the quote is in US cents per dollar) to convert the price to US dollars and then divided this value by 25.4 (a CME corn bushel, equivalent to 25.4 Kg). With this US dollar per kilogram price equivalent, the authors multiplied this price by the current USDMXN rate at t to arrive at the Mexican peso per kilogram equivalent price of the future contract. Table 1 summarizes the futures contracts used in the backtests, the ticker used to identify it in this paper, the Refinitiv identifier code (RIC), the contract trade unit, the conversion operation used to convert the price to US dollars, the conversion operation used to express such price in US dollars per kilogram, the standard number of units traded per contract (contract size) and the exchange where the future trades.

Table 1

The futures used in the back tests, their general contract specifics, and the steps followed to express the traded price in US dollars per kilogram.

Future	**Ticker in this paper**	**Refinitiv RIC**	**contract unit**	**US dollar quote conversion in the paper**	**Kilogram transformation in this paper**	**Future contract standard units**	**Future's exchange**
1-month corn	cornFuture	Cc1	Bushel	Price/100	Price/25.4	5000	CME
1-month wheat	wheatFuture	Wc1	Bushel	Price/100	Price/27.21	5000	CME
1-month rough rice	roughRiceFuture	RRc1	Hundred weight (cental)	None	Price/45.36	2000	CME
1-month soybean	soyBeanFuture	Sc1	Bushel	Price/100	Price/27.21	5000	CME
1-month oats	oatsFuture	Oc1	Bushel	Price/100	Price/27.21	5000	CME
1-month cocoa	cocoaFuture	CCc1	Metric ton	None	Price/1000	10	NYMEX
1-month coffee	coffeeFuture	KCc1	Pounds	None	Price*0.453592	37500	NYMEX
1-month no.11 sugar	sugar11Future	SBc1	Pounds	None	Price*0.453592	112000	NYMEX
1-month cotton	cottonfuture	OJc1	Pounds	None	Price*0.453592	50000	NYMEX

Source: Own elaboration with data from CME (2025).

With these future price data $F_{i,t}$, the authors also estimated the continuous-time return $r_{F_{i,t}}$. As a first test, the authors examined the hedging effectiveness, OLS hedge ratio, and the Engle-Granger (1987) cointegration tests of each future's return $r_{F_{i,t}}$ with the Mexican spot rice price. The core idea is to prove that not all futures are cointegrated with the corn price and, following Ortiz-Arango and Montiel-Guzmán, to demonstrate that the hedging effectiveness of a single future position is not appropriate.

The historical data for both white corn and futures are weekly data from January 1998 to February 2025.

Using the historical returns data, the authors estimated the optimal futures' investment weights $\mathbf{w}^*$ of the surplus-efficient frontier in (7). Given $\mathbf{w}^*$ at t, the authors estimated the percentage price variation of the simulated portfolio as follows:

$$r_{port,t} = \mathbf{w}^{*\prime}\boldsymbol{r}, \boldsymbol{r} = [r_{i,t}] \tag{8}$$

The rationale of the backtests and the working hypothesis is that the ideal futures portfolio must have a percentage price variation equal to that one of the Mexican white corn:

$$H_0: r_{port,t} = r_{P,t} \tag{9}$$

To test this equality, the authors estimated the optimal portfolio from January 1st, 2000 to February 23, 2025 and used the weekly historical returns data from January, 2nd 1998 to the date of the simulation.

To determine which agricultural futures portfolio is the best performing in terms of price replication, the authors simulated 1,013 combinations (portfolios) of the ten futures. The best hedging portfolio will be the one with the highest hedging effectiveness, estimated as in (1). To strengthen these results, the authors performed the cointegration test of the simulated portfolio with the avocado price.

Finally, to demonstrate the practical application of these replicating portfolios, the authors backtested the top five best-performing portfolios. The backtest involves taking a short position in the simulated portfolio if a down price trend is expected $t + 1$. To identify such a downtrend, the authors employed a technical analysis indicator widely accepted among investors: the moving average convergence-divergence (MACD) (Achelis, 2001). This indicator (a lag indicator) suggests that, if its value is positive (negative), an upward (downward) price trend is expected. The MACD is calculated as the difference between the 26-day moving average of the Mexican white corn price and the 12-day moving average.

The authors' selection of the quantitative trading rule is arbitrary and was chosen because this indicator is easy to estimate and is widely used in the financial industry. The use of other technical indicators, machine learning, or quantitative methods for the hedging decision rule is left for further research. The authors used this technical indicator to conduct an initial test and approach to the practical benefits of the corn price replication method proposed herein.

The first reason for using only the ten most traded US agricultural futures is the dimensional feasibility of the quadratic programming problem in (7) when the number of futures increases. Due to this limitation, some portfolios or combinations were excluded from the simulations due to feasibility issues. The second reason for using such a limited futures set is that these backtests serve as a first approach to test the benefits of using the portfolio replication of interest. The authors kept the agricultural nature of the futures, setting aside the use of non-agricultural and even non-US futures for further research.

Results discussion

Individual futures' cointegration and hedging effectiveness tests

Before examining the results of the 1,013 combinations of futures or portfolios, it is essential to review the hedging effectiveness and cointegration tests of the individual future-specific tests with the Mexican white corn price. Figure 2 shows the historical Mexican peso per kilogram price of both the spot and CME futures prices. The upper panel displays the price of the Mexican peso per kilogram, and the lower one shows the continuous-time return. At first glance, the historical data suggest that the prices may be cointegrated based on the close historical performance of both time series. To test this potential long-term relationship, Table 2 summarizes three cointegration tests: the Augmented Dickey-Fuller (1979) with one lag in the residuals of the auxiliary test's regression, the Phillips-Perron (1988), and the Kwiatkowski et al. (1992) (KPSS) tests.

The first two tests' p-values correspond to a unit root test null hypothesis, and the third to a stationary trend vs. non-stationary time series. As noted in Table 2, the Mexican white corn price has a unit root, and the corn and wheat futures have it at a 10% significance level (practically no unit root). These results align with those of Ortiz-Arango and Montiel-Guzman (2017), who found weak cointegration and a non-significant relationship between the CME corn futures and the origin-specific white corn prices. The other futures of interest have no unit root except for rough rice, soybeans, oats, and sugar, which have it at a 5% significance level. Due to the lack of unit roots between some futures (starting with the one of primary interest in this paper: corn), it is not possible to determine if the Mexican white corn and these futures are cointegrated. Consequently, using other hedging methods such as the one suggested by Alexander and Dimitriu (2005) is not feasible. Consequently, the use of a surplus efficient frontier portfolio selection (7) with two or more futures in the replicating portfolio is a potential solution.

Table 2

Unit root tests' p-values for the price (level) time series of the Mexican white corn and the futures of interest.

Time series	Augmented Dickey-Fuller test	Phillips-Perron test	KPSS test
Mexican white corn price	0.5835	0.7995	0.0100

cornFuture	0.0981	0.0747	0.0100
wheatFuture	0.0868	0.0100	0.0100
roughRiceFuture	0.0100	0.0100	0.0100
soyBeanFuture	0.0311	0.0539	0.0100
oatsFuture	0.0422	0.0242	0.0100
cocoaFuture	0.9900	0.9900	0.0100
coffeeFuture	0.9900	0.9900	0.0100
sugar11Future	0.0452	0.0124	0.0100
cottonFuture	0.3246	0.5565	0.0100
orangeJuiceFuture	0.3246	0.5565	0.0100

Source: Own elaboration with data from Refinitiv (2025).

Mexican white corn price replication with the futures portfolios

To review the result of the simulations of the 1,013 portfolios, it is essential to mention that the name of the futures in it identifies each simulated portfolio. For example, the portfolio "cornFuture,oatsFuture" is a simulated portfolio that includes only the corn and oats futures. It is also important to mention that 256 portfolios (25.2771% of the 1,013 simulated) were not feasible to test due to dimension issues in the optimal selection problem in (7). Of the 757 remaining, they were backtested. From these, the authors selected the five portfolios with the highest mean hedging effectiveness estimated as in (1). As a methodological note, it is important to mention that the five-portfolio selection is arbitrary, and using a wider set, such as the ten best-performing, leads to similar conclusions.

Table 3 summarizes the results. As noted in the exhibit, the portfolios with either corn and oats or corn and wheat futures are those with the highest mean observed hedging effectiveness. Even if this hedging effectiveness is good to replicate, there are some issues to address to achieve more accurate price replication. Consequently, the use of other types of futures, such as energy, metals, financial, or even weather, could be a potential solution to test in future works.

Table 3

*Hedging effectiveness and hedge ratio summary of the five best hedging portfolios***.**

Simulated portfolio (futures included)	Mean hedging effectiveness	Last observed hedge ratio	Last observed hedge ratios' p-value	Mean observed hegde ratio	Mean observed hegde ratio's p-value
cornFuture, oatsFuture	0.6202	1.0580	0.0000	1.2476	0.0000
cornFuture, wheatFuture	0.6180	1.0771	0.0000	1.3083	0.0000
cornFuture, orangeJuiceFuture	0.5687	0.8927	0.0000	1.1292	0.0000
cornFuture, sugar11Future	0.5639	0.9431	0.0000	1.0734	0.0000
cornFuture, cottonfuture	0.5559	0.9466	0.0000	1.1237	0.0000

Source: Own elaboration with data from Refinitiv (2025).

Although the two best-performing portfolios demonstrated a hedging effectiveness of 0.62 at most (leaving 0.38 as potential basis risk), it is necessary to determine whether these five future portfolios have a long-term relationship and whether their use remains appropriate for hedging purposes. Table 4 shows the results of the three-unit root tests of Table 3, applied to the five best hedging portfolios. The last column shows the p-value of the Phillips-Ouliaris (1990) cointegration test, an extension of Dickey-Fuller's with a non-parametric Phillips-Perron unit root test in the residuals of the cointegrating equation.

Table 4

Unit root and cointegration tests of the five best hedging portfolios.

Simulated portfolio (futures included)	Augmented Dickey-Fuller test	Phillips-Perron test	KPSS test	Phillips-Oularis test (naïve strategy)
cornFuture, oatsFuture	0.5677	0.6331	0.0100	0.0100
cornFuture, wheatFuture	0.5622	0.4074	0.0100	0.0100
cornFuture, orangeJuiceFuture	0.5919	0.3650	0.0100	0.0100
cornFuture, sugar11Future	0.5842	0.4972	0.0100	0.0100
cornFuture, cottonfuture	0.5835	0.5232	0.0100	0.0100

Source: Own elaboration with data from Refinitiv (2025).

As shown in Table 4, the prices of these five simulated portfolios are non-stationary and cointegrated. This result extends the previous tests by demonstrating that including more futures in the corn future position reduces noise and leads to a cointegrated time series with the Mexican white corn price. This first result suggests that it is feasible to replicate the corn price and use such a portfolio for hedging purposes. The only drawback to be tested is that the mean hedging effectiveness of this replicating (hedging) portfolio is around 0.62.

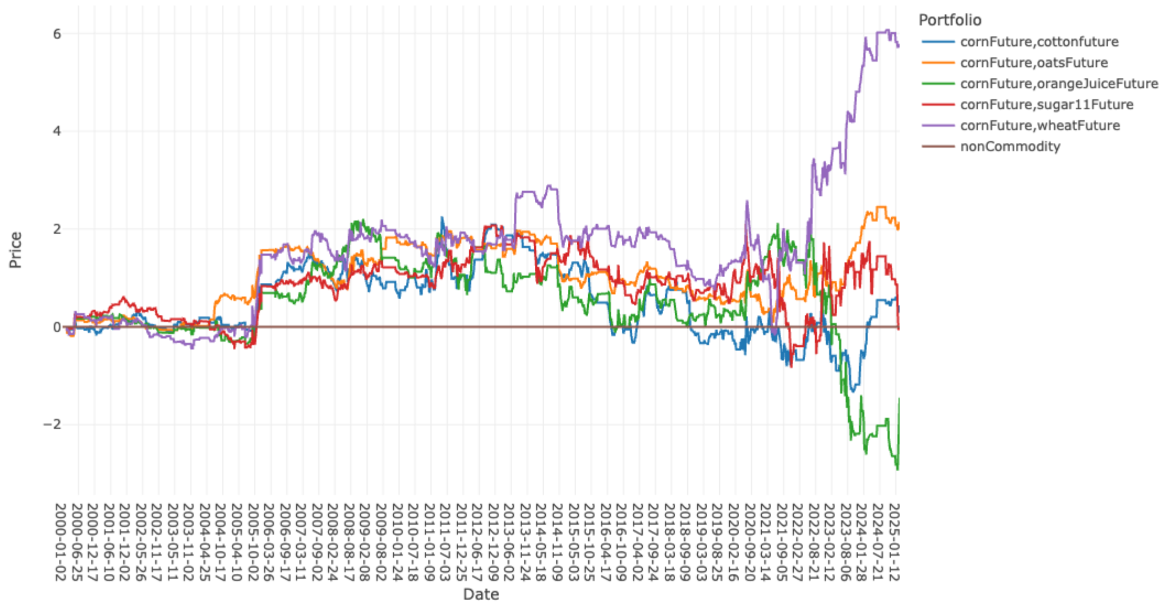
To test if these five best hedging portfolios are a proper option to hedge the Mexican white corn price, the authors performed the backtest detailed in the previous section by using 4 hedging rules or strategies:

1. A naïve hedging method in which each week the theoretical agent (seller) of corn buys a short position in the replicating portfolio to hedge against price fluctuations at $t+1$.
2. A $MACD$ strategy in which the agent hedges at t+1 only if the $MACD < 0$.
3. A $MACD$ strategy in which the agent buys the short position in the portfolio if the $MACD$ indicator shows a higher value than its signal line (the 9-day moving average value of the $MACD$).
4. A hedging strategy that combines the two previous ones.

To test the benefit of such a strategy, the backtest recorded the weekly profit or loss (P/L) of the simulated agent of the portfolio's position (from $t-1$ to t). E.g., if the white corn price falls (grows) from $t-1$ to t, and the hedging portfolio does the same, the short position will pay a positive (negative) P/L that is added to the income of the price of each Kg of white corn sold in the spot market. To illustrate the results of the extra revenue generated by the hedging strategy (P/L), Figure 1 display the historical accumulated income corresponding to the observed extra P/L values of the best-performing of these strategies: to sell when the MACD is negative and lower than the signal line.

Figure 1

*The historical accumulated income with the MACD<signal hedging strategy***.**



Source: Own elaboration with data from the Secretary of Economy (2025), CME (2025), and Refinitiv (2025).

These results suggest that using these two portfolios in conjunction with this hedging strategy creates value and hedges a white corn seller (producer or intermediary) against negative market changes.

Concluding remarks

After backtesting the performance of 1,013 portfolios or combinations of the nine most traded agricultural futures of the CME and the New York Mercantile Exchange (NYMEX), the results suggest that using a portfolio invested in corn and wheat futures (with a 51.6741% and a 48.3259% mean investment level respectively), leads to a hedging effectiveness of 0.6180. Even if this value is not as close to 1 as it is preferred (a hedging effectiveness value close to 1 suggests an almost perfect income risk reduction), the improvements in terms of hedging are appropriate.

To test the practical use of this mimicking portfolio for hedging purposes, the authors backtested a trading decision. The results suggest that making hedging decisions when the MACD is below its signal line (its nine-day moving average) leads to a significant added value of MXN 5.7664 per kilo sold during the simulation (MXN 5,766.400 per traded ton).

What this result implies for food security in practical terms is that the Mexican Government or a financial institution could offer a buy strike price *K* at t+1 to a given white corn seller (producer or intermediary) and balance or hedge the price risk with a short position of the simulated futures portfolio. With this hedging of the offered hedge, the Mexican Government wouldn't need to use public resources to pay or absorb the loss incurred, due to the income generated with the short position in the mimicking portfolio. Consequently, this paper demonstrates the benefits of cross-hedging a non-commodity staple, such as Mexican white corn (or a similar product), with a portfolio of corn and wheat futures.

Among the extension of this papers, it is essential to highlight the need of repeating the backtest in a context that incorporates trading costs, and most of all, the impact of the difference not in the portfolio and white corn price, but between the nominal or face value (due the futures contract specifications) of such portfolio with a Mexican peso equivalent face value. This test is of practical need because, as is the case in the fixed income or foreign exchange markets, the Mexican Government or a financial institution that offers the hedge must pool the hedge prices of several corn sellers to balance them with the short futures position.

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