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Hedging Mexican Hass avocado price with exchange-traded agricultural futures

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Abstract

The present paper tests the use of an agricultural futures minimum tracking error portfolio to replicate the price of the Mexican Hass avocado (a non-commodity). By performing a backtest of a theoretical avocado producer from January 2000 to September 2023, the results show that the avocado producer could hedge the avocado price by 94% with the hedge offered by a theoretical financial or government institution. Also, this issuer could balance the risk of such a hedge by buying a coffee-sugar futures portfolio. This paper pretends to be one of the first in testing futures portfolios to offer a synthetic hedge of non-commodities.

Keywords: Hass avocado; non-commodity price hedging; minimum tracking error

Resumen

El presente artículo prueba el uso de un portafolio de futuros agrícolas de mínimo error de seguimiento (min tracking error) para replicar el precio del aguacate Hass mexicano (un no commodity). Al realizar un backtest de un productor de aguacate de enero de 2000 a septiembre de 2023, los resultados muestran que el productor de aguacate podría cubrir el precio del aguacate con una eficiencia de cobertura de 94%. Cobertura que puede ser ofrecida por una la cobertura emitida comprando un portafolio de futuros de café y azúcar. Este artículo pretende ser uno de los primeros en probar portafolios de futuros para ofrecer una cobertura sintética de no commodities.

Palabras clave: Aguacate Hass, cobertura de precio de no commoditties, minimum traking error

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Introduction

Income risk reduction is among the main issues that farmers face because of climatological, market, or even social factors. This task is a concern that could even affect the subsistence of a farm or producer, especially if its size (and related economies of scale) is medium or small. This risk could even have an essential impact on the farmers' country's economy due to the financial sustainability of their production. Food security and even sovereignty are among the main issues a given country wants to enhance. A proper (stable) income for their producers is essential to this goal.

This paper will not discuss food security and sovereignty because both terms and their implications still need to be debated. These concepts are mentioned because income risk affects these goals, not ensuring access to food for all the population in each country and economic growth and development in the local economies.

Countries like Mexico need to promote food security, which is understood as the capacity to produce the necessary food with local producers and with no or low dependence on agricultural imports. Food sovereignty is an extension of food security with a positive impact on the development of local production techniques (Glauber, 2013a, 2013b; Mishra & Goodwin, 2006; Roznik et al., 2019; Velandia et al., 2009). The Mexican government has made efforts to support small and mid-size producers' income. Among the most recent public programs, the Mexican Government created a government agency known as Mexican Food Security (SEGALMEX by its acronym in Spanish) that focuses on buying the small and mid-scale producers' output in vital products such as white corn, beans, wheat, and milk. For the specific case of corn and beans, the Mexican Government pays a floor or minimum price if the spot market price of these commodities is below the yearly yellow corn or wheat futures price in the Chicago Mercantile Exchange (CME). The payment of this floor price comes with resources from the Mexican Government (taxpayers) paid through SEGALMEX, and the latter has an unbalanced (contrary) position to cover the price risk of the offered hedge. Despite its practical usefulness, SEGALMEX still needs improvements to include the main agricultural products (Cruz Herrera et al., 2021; Garay et al., 2024; Martínez-Cuero, 2021; J. M. T. Silva et al., 2022; Zúñiga Espinoza, 2023) , and it could also be useful in extending its duties to other ones, such as avocados.

Among the main agricultural products in terms of exports, avocado has become one of the most notorious and fast-growing. Its exports to the US increased thanks to a border opening in 2000 (Ayala Silva & Ledesma, 2014; Canales et al., 2019; Cruz-López et al., 2022; Williams et al., 2017) , and it has become one of the leading export producers in the country. More specifically, the premium Hass avocado species is exported the most, and its production has increased mainly in Michoacán. This state has ideal geological and weather conditions due to the location of avocado crops in places with volcanic soil at more than 2,000.00 meters from sea level. According to the APEAM (the Mexican Avocado Producers and Exporters Association), a certification office and lobby group, Michoacán is the leading avocado producer in Mexico and worldwide. Consequently, this Economic activity is an important vehicle for Economic growth and development. Therefore, it is of interest to have proper price hedging to reduce income risk and to enhance Economic growth and development in Mexico and Michoacán.

One of the main limitations of hedging the price of the avocado is the absence of a commodity derivative (such as a traded future or option). Therefore, using a synthetic hedge through a portfolio of the most traded Agricultural futures is a potential answer. This paper tests the use of a minimum tracking error portfolio that seeks to replicate the performance of the Mexican spot avocado price. A tracking error portfolio is optimal for replicating the performance of a benchmark or statistical (economic) reference. Usually, this benchmark is a well-known security price index or multi-asset one. The main aim of this minimum tracking portfolio is to reduce the difference or distance between its percentage price variation and one of the benchmarks. In general terms, the tracking error of the return of a given portfolio $TE_{p,t}$ is the standard deviation of the difference between that portfolio's return ($r_{p,t}$) and the benchmark's ($r_{bm,t}$):

$$TE_{p,t} = \sigma\left(r_{p,t} - r_{bm,t}\right) = \sigma\left(\sum w_i \cdot r_{i,t} - r_{bm,t}\right) \quad (1)$$

The tracking error is used to select a portfolio with optimal weights (w_i^*) that minimize $TE_{p,t}$. This is a practice common in asset-liability management (AL) or passive portfolio management investing [16,17,17–20] in which the benchmark is either an Economic factor or Statistical index replicating the liability's performance to hedge or a market portfolio (index). This paper uses the historical Mexican avocado price's return (national average price a t) as the benchmark return ($r_{bm,t}$) to select the optimal (minimum tracking error w_i^*) portfolio of Agricultural futures to hedge (replicate) the avocado price.

The core idea is that if it is possible to select a minimum tracking error portfolio of agricultural futures that replicates the avocado price at t, a financial or Government institution (such as SEGALMEX) could use it to hedge the Mexican producers' avocado price and, as a consequence, to hedge the producers' income without any market distortion, such as subsidies or the payment of an insurance primer risk.

If this result is feasible, Mexican financial institutions or the Government could use this synthetic hedge (minimum tracking error futures portfolio) to sell avocado price hedges with the opposite (balanced) hedging position. SEGALMEX could buy the futures portfolio to transfer the cost of hedging the avocado price to the Mexican producer. The main question to address is whether the difference between the performance of the futures portfolio and the avocado producer (basis risk) is as low (near zero) as possible.

Following this motivation, this paper simulated the performance of 127 agricultural futures combinations to select a minimum tracking error portfolio. This portfolio performance was compared against the Hass premium quality avocado's price. It also simulated the theoretical income a theoretical avocado producer would have had had their bought the avocado price hedge in a $t + 1$, $t + 4$, $t + 12$ weeks hedging horizon. The main goal of this second motivation is to enhance the hedging effectiveness ($HE_{p,t}$) to values near 1, suggesting that this synthetic hedge or minimum tracking error portfolio is appropriate for income risk hedging purposes.

The author's theoretical position or working hypothesis is that using agricultural futures minimum tracking error optimal portfolios will create a synthetic hedge of the avocado price, leading to a significant income risk reduction for an avocado producer. This implies that an agricultural futures portfolio could replicate the Mexican Hass avocado price properly.

Previous literature review

The previous literature testing the use of hedging spot commodity prices with futures is vast, but the most related to this paper deals with hedging agricultural spot prices with futures. Hedging strategies exist in countries where several exchanges or delivery spot markets exist. Cases such as India, Vietnam, and even the US are interesting (Mansabdar & Yaganti, 2020; A. M. McKenzie & Holt, 2002; A. McKenzie & Singh, 2011; Nhung et al., 2020; Rout et al., 2021). In these works, the main findings suggest that heterogeneity in the delivery spots (or markets) or the presence of several futures markets could lead to basis risk (difference in value between the spot hedged position in the hedging futures one).

For the Mexican case, the one of interest herein, the efforts to support farmers' income started in the decade of the 1930s. These efforts had little impact on creating economies of scale among small and mid-size farmers. Despite this and following a local industry protective trade policy (a fiscal policy more oriented to oil exports), Mexico saw an acceptable development of agricultural activity with an acceptable level of food sovereignty. That is, an agricultural activity with low dependence on food imports (J. Silva, 1950; J. M. T. Silva et al., 2022; Zúñiga Espinoza, 2023). On the decade of the 1970s, Mexico experienced an abrupt shift due to fiscal deficits and high inflation levels. This led to income destruction among small and mid-size farmers, creating a food output crisis. To support food security and sovereignty, the Mexican government allowed more food imports and established a minimum price policy for agricultural products such as white corn, beans, and milk. With this minimum price policy, the Mexican government bought these products, stored them, and sold them to the Mexican population through government-sponsored stores at lower prices. The core idea of this policy was to incentivize small and mid-size agricultural production with more stable and appropriate minimum prices and to secure food distribution with lower prices among citizens (Cruz Herrera et al., 2021). This model was later evolved with other policies in which Mexican agricultural producers had market protection. Despite this taxpayers' effort, food imports increased in the main agricultural products, leading to higher food dependence from producers abroad and a concentration of the main agricultural products in some states. The ones with the biggest economies of scale and the most appropriate natural conditions. As a result, the Mexican Government evolved its food security program to one oriented to paying a minimum price for corn, beans, and milk. Nowadays, a public agency named Mexican Food Security (SEGALMEX) buys some agricultural products with a minimum price hedging (like white corn or beans). For the specific case of corn, the minimum price to hedge is estimated as the monthly average 1-month yellow corn future settle price in the Chicago mercantile exchange (CME), valued in Mexican pesos with the monthly average rate of the US dollar-Mexican peso foreign exchange rate. The difference between the minimum price and the spot market one (if it is lower) comes from Mexican government fiscal proceedings. That is, it is paid by tax contributors.

No previous works deal with alternative public hedging methods for Mexican or non-commodity methods that reduce the burden on taxpayers. This paper tests a potential solution to this issue: An agricultural futures portfolio optimally selected to balance or transfer the cost (basis risk) of offering a hedge in the price of non-commodities like the premium Hass avocado. For this purpose, the present paper shows the results of Hass avocado price replication with this futures portfolio. The hypothesis tested herein is:

H0: "Using a portfolio of agricultural futures traded in the CME or the NYMEX, optimally selected with the minimum tracking error method, leads to a proper replication of the premium Hass avocado mean price in Mexico."

Once this paper's main theoretical and practical motivations are discussed, the next section depicts the data gathering and processing method, along with a brief discussion of the minimum tracking error optimal selection simulated weekly. The hedging methods tested are also briefly explained.

Materials and Methods

Given this paper's theoretical motivations, it is interesting to mention how the authors gathered the data and made the simulations for avocado price hedging. To such simulations, it is of interest to establish the following assumptions:

1. The hedged avocado production was sold over a one-week ($t + 1$), four-week ($t + 4$) and three months ($t + 12$) period.
2. A public or private agent (or financial intermediaries) is interested in offering an ask-settle price for avocado production (offering a price hedge).
3. This agent balances the offered hedge by buying an optimal (minimum tracking error) portfolio of the following agricultural futures traded in the CME and NYMEX:
    a. The 1-month expiration cocoa future traded in CME.
    b. The 1-month expiration coffee future traded in NYMEX.
    c. The 1-month expiration yellow corn future traded in CME.
    d. The 1-month expiration wheat future traded in CME.
    e. The 1-month expiration rough rice future traded in CME.
    f. The 1-month expiration soybean future traded in CME.
    g. The 1-month expiration sugar future traded in NYMEX.

The previous futures contracts were selected due to their agricultural (cultivated) nature end because these seven agricultural future contracts are among the most traded in the US futures markets (Commodity Futures Trading Commission, 2024).

To estimate the optimal portfolio with the lowest tracking error. The tracking error was estimated as in (1), using the weekly percentage return of the average price of the Mexican Supreme quality Hass avocado (Hass avocado or avocado henceforth). This average weekly price was estimated from all the recorded prices in the main spot markets in Mexico. These prices come from the National Markets Information System (SNIIM for its acronym in Spanish) of the Mexican Economics Secretary. These prices are recorded directly from the main public markets of the main cities in Mexico at t. The Mexican average Hass avocado price ($P_{avo,t}$) was estimated at t with the arithmetic mean of all these recorded prices. With this average price, the historical continuous price return was estimated as follows:

$$r_{bm,t} = ln\ ln\left(P_{avo,t}\right) - ln\ ln\left(P_{avo,t-1}\right) \quad (2)$$

A similar method was used to estimate the weekly continuous time price return of the seven agricultural futures of interest:

$$r_{i,t} = ln\ ln\left(P_{i,t}\right) - ln\ ln\left(P_{i,t-1}\right) \quad (3)$$

The historical price data of the seven futures is the close settle price at t from the CME and NYMEX databases through the Refinitiv platform.

The historical data of the mean avocado price $P_{avo,t}$ and each future of interest $P_{i,t}$, started at January 9, 1998 (t_0) to September 29, 2023.

To perform the simulations of interest, the weekly historical return data was used from t_0 to the simulated week (t) in a time range from January 1st, 2000, to September 29, 2023. The historical data used to perform the optimal portfolio selection was an updated vector variable from t_0 to the simulated date t:

$$X = \left[TE_{i,t}\right] \tag{4}$$

The previous vector variable (matrix), $TE_{i,t}$ is the tracking error or price return of the ith future concerning the price return of the avocado price:

$$TE_{i,t} = \left[r_{i,t} - r_{bm,t}\right] \tag{5}$$

With this vector variable in (4) an expected tracking error vector (e) was estimated with the arithmetic mean values of the returns of each futures tracking error:

$$e = \left[\underline{TE_{i,t}}\right] \tag{6}$$

Also, a time-fixed tracking error variance-covariance matrix was estimated with X:

$$\Sigma = \left[X^{'}X\right]^{n-1} \tag{7}$$

With the expected tracking error vector and the covariance matrix in (6) and (7), the following quadratic programming problem was solved to select the optimal futures position (weights) w^{*}:

$$W'\Sigma W \tag{8}$$

Subject to:

1) $W'1 = 1$
2) $W \geq 0$

This optimal weight vector ($W = [w_i^{*}]$)gives the investment level that each future must have in the balancing position of the avocado price replication portfolio, leading to estimate the simulated portfolio's return at t.

$$r_{p,t} = \sum w_i^{*} \cdot r_{i,t} \tag{9}$$

To test the working hypothesis in this paper, 127 combinations of futures were used to select the optimal portfolio at t with (8). These combinations range from sets of one to seven of the futures of interest. The core idea is to test the benefit of using different futures combinations to determine the most appropriate for avocado price replication.

To test such replication benefits, it is expected to select the futures combinations and their optimal investment levels that lead to the most significant reduction of the tracking error in (1). This means to reach values of $TE_{p,t} \approx 0$. To determine such effectiveness, the best replicating portfolio must have the highest hedging effectiveness estimated as follows:

$$HE_{p,t} = 1 - \frac{\sigma(r_{avo,t} - r_{p,t})^2}{\sigma(r_{avo,t})^2} \quad (10)$$

The simulated futures portfolio with the $HE_{p,t}$ value closest to one is the one that replicates the avocado price the best. That is, it is the most suitable combination to use as the balancing position of the avocado price hedge $(r_{avo,t} - r_{p,t})$. The hedging effectiveness in (10) assumes a "naïve" hedging strategy. That is, it assumes a 1 to 1 short futures position as spot one. Following Ederington (Ederington, 1979), Ederington and Lee (Ederington & Lee, 1993), Myers and Thompson (Myers & Thompson, 1989), and Martinez and Zering, there is an "optimal" hedging position that does not necessarily use the 1 to 1 short futures position. There is an optimal hedging ratio that leads to better hedges and better hedging effectiveness. This hedge ratio β could be estimated with a least square regression model, with the futures return as a regressor and the spot position (avocado in the case of this paper):

$$r_{avo,t} = \alpha + \beta \cdot r_{p,t} + \varepsilon_t \quad (12)$$

Given the optimal hedge ratio in (12), the optimal hedging strategy could be simulated as $(r_{avo,t} - \beta r_{p,t})$. This strategy assumes that a 1 to 1 hedging position is not necessary. A 1 to β could lead to better hedging and basis risk reduction.

Using either 1 to 1 or a 1 to β hedging position assumes that the same position or weight in the futures portfolio is time-fixed. This implies a passive hedging strategy that assumes that an avocado producer will hedge each time she or he wants to sell avocados.

To relax this assumption, the authors used a simple active hedging strategy with Markov-Switching (MS) models (Hamilton, 1989, 1990, 2005). For this specific case, the avocado's return could be modeled in a Gaussian two-regime context:

$$r_{avo,t} \sim \Phi\left(\underline{r}_{avo,s,t}, \sigma^2_{avo,s,t}\right) \quad (13)$$

The first regime ($s = 1$) corresponds to a "calm" or "normal" time periods with low volatility returns and, the second ($s = 2$), to "distress" periods with high volatility. This implies $\sigma^2_{avo,s=1,t} < \sigma^2_{avo,s=1,t}$ and $\underline{r}_{avo,s=1,t} > \underline{r}_{avo,s=2,t}$.

Following the previous methodology, the hedging effectiveness $HE_{p,t}$ will be the key parameter to determine if one of the 127 combinations of futures portfolios is the best option to replicate the performance of the avocado price and, consequently, to use it as a potential balancing position of a hedge issuance for avocado producers. This parameter will be tested in the four previous scenarios summarized as follows:

1. A naïve hedge of the avocado price return ($r_{avo,t}$) with a 1 to 1 short position in the simulated futures portfolio.

2. A hedging position given by the optimal hedging ratio (β) in a single regime scenario.

3. A naïve hedge of the avocado price return if $\xi_{s=1,t+1} > 50\%$.

4. A dynamic hedging position with a regime-specific hedging ratio ($\beta_{s=2}$). if $\xi_{s=1,t+1} > 50\%$.

The authors expected a more diversified futures portfolio (preferent with the seven futures of interest) would be the one with the highest (closest to one) $HE_{p,t}$. Therefore, the selection criterion of the best combination for hedging purposes will be the one with the highest $HE_{p,t}$.

The authors programed the weekly simulations of estimating the optimal minimum tracking error portfolio in R scripts, using SQLite databases to store the results and the fPortfolio (*Package «fPortfolio» Title Rmetrics -Portfolio Selection and Optimization*, 2017), Quantmod (Ryan et al., 2018), and MSwM (Josep Sanchez-Espigares & Lopez-Moreno, 2018) libraries for optimal (min tracking error) portfolio selection and Gaussian time fixed variance MS models estimation with the EM algorithm.

In this first review for non-commodity agricultural price hedging, it will be of interest to use the seminal Gaussian two-regime MS model in the high volatility regime ($s = 2$) forecast at $t + 1$ with the following estimation method, given θ_t in (14) at t:

$$\left[\xi_{s=1,t+1}\ \xi_{s=2,t+1}\right] = \Pi\left[\xi_{s=1,t+1}\ \xi_{s=2,t+1}\right] \qquad (15)$$

Once the simulation method and data gathering and processing were detailed, the next section discusses the main results and findings.

Results

Basis risk is among the main drawbacks of using agricultural commodity futures to hedge non-commodities.

This general behavior makes the avocado price less cointegrated with these futures, showing price increases in periods such as 2008 or 2020. A price increase that reverts to lower (perhaps equilibrium) levels in posterior periods. Consequently, using one of these futures to hedge the avocado price is useless.

Following this result, it was interesting to perform 127 combinations, starting with 7 single future portfolios to a set of a portfolio with seven futures (the ones of interest herein). Appendix A shows the results of the simulations. Table 1 summarizes these results by showing the portfolios with the best hedging effectiveness (10) in each of the four scenarios of interest (single or two-regime).

Table 1.

The simulated portfolios with the best hedging effectiveness in the four scenarios and three hedging horizons of interest

Hedging strategy	Hedging horizon	Simulated portfolio	Hedging effectiveness	Optimal hedging ratio (β)
Single regime Naïve	t+1	Sugar-Coffee	0.9387	1.0000
Single regime Naïve	t+4	Sugar	-0.3517	1.0000
Single regime Naïve	t+12	Wheat-Rough rice-Sugar-Coffee-Cocoa	-1.0960	1.0000
Single regime optimal hedging ratio	t+1	Sugar-Coffee	0.9434	1.0762
Single regime optimal hedging ratio	t+4	Wheat-Rough rice-Sugar-Coffee-Cocoa	0.0000	0.9067
Single regime optimal hedging ratio	t+12	Wheat-Rough rice-Sugar-Coffee-Cocoa	0.0000	1.1058
Two-regime Naïve	t+1	Corn-Rough rice	0.4888	1
Two-regime Naïve	t+4	Corn-Rough rice	0.4888	1
Two-regime Naïve	t+12	Corn-Rough rice	0.4888	1
Two-regime optimal hedging ratio	t+1	Wheat-Cocoa	0.4445	1.1329
Two-regime optimal hedging ratio	t+4	Wheat-Cocoa	0.4434	1.0959
Two-regime optimal hedging ratio	t+12	Wheat-Cocoa	0.4445	1.1096

Source: Own elaboration with data from Refinitiv and Secretaría de Economía (2023).

As noted, the single regime hedging strategies are the ones that show an important income risk reduction in the avocado price in the $t + 1$ hedging horizon. Using longer time horizons does not lead to a significant income risk reduction. In some cases, it is worst to use the hedging strategy, as is the case of a naïve strategy in a single regime for $t + 4$ and $t + 12$ hedging horizons.

The last column of Table 1 shows the optimal hedging ratio used in each scenario. The naïve strategies rows show the 1 beta value assumed in this strategy and the optimal hedging ratio, the beta values either in the single regime context or the high volatility beta value used for hedging.

From all the 127 futures combinations (portfolios) tested herein, a portfolio with sugar and coffee futures is the best option to hedge the avocado price in a single regime context. This conclusion is due to the 0.94 hedging effectiveness that this portfolio shows. That is, the hedging effectiveness, is close to the ideal value of one, suggesting a proper income risk reduction.

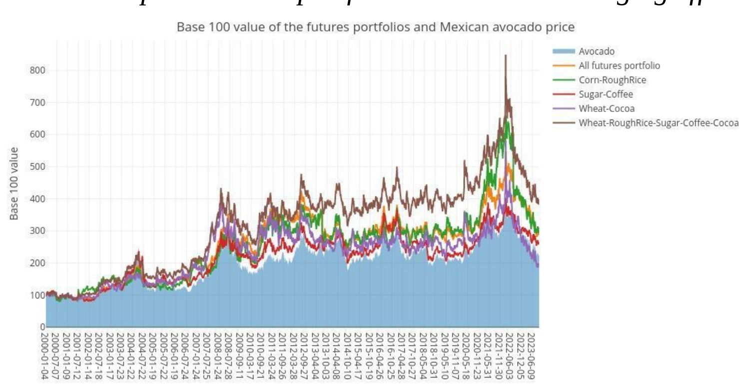
In the two-regime context, the best performing (best hedging) portfolios are those with corn and rough rice futures in a two-regime naïve strategy and the wheat-cocoa portfolio in the optimal hedging ratio one. Despite this, using a futures portfolio to hedge (to replicate) the avocado price in a two-regime only reduces the income risk by 44%-48%, leading to the conclusion that the naïve strategy in a single regime hedging context is preferable by using a sugar-coffee futures portfolio to replicate the Hass avocado price in a $t + 1$ hedging horizon.

It is important to highlight that using a sugar-coffee portfolio leads to similar hedging effectiveness results. It is preferable to use the naïve strategy because the optimal hedging ratio of the same portfolio is close to 1. Consequently, the avocado price could be replicated (and hedged) with this naïve hedging strategy to reduce the price or income risk.

To show the causes of this hedging effectiveness in the sugar-coffee futures portfolio, figure 2 shows the historical performance of the simulated portfolios, depicted in Table 1, against the base 100 value of the avocado price at t.

Figure 2.

Historical values of the avocado price v.s. the portfolios with the best hedging effectiveness



As noted in Figure 2, the sugar-coffee and wheat-cocoa portfolios have a simulated value close to the avocado price. The main difference comes in the 2008-2021 period, in which the sugar-coffee portfolio (as in the whole time series) has the closest fit to the non-commodity of interest. This result comes from the mean investment level in sugar and coffee futures (83.48% and 16.52%, respectively), depicted in Table 2.

Table 2.

The mean future investment level in the simulated portfolios with the best hedging effectiveness in the four scenarios and three hedging horizons of interest

	Mean investment level (%) in each future						
Simulated portfolio	**Cocoa**	**Coffee**	**Corn**	**Rough rice**	**Soy bean**	**Sugar**	**Wheat**
Sugar-Coffee		16.5166				83.4834	
Corn-RoughRice			59.7291	40.2709			
Wheat-Cocoa	19.2849						80.7151
Wheat-Rough rice-Sugar-Coffee-Cocoa	3.4962	3.5369		14.0753		38.7131	40.1785
All futures	7.1427	7.0626	41.601	5.7315	9.3856	17.1066	11.9699

Source: Own elaboration with data from Refinitiv and Secretaría de Economía (2023).

From Table 2 and Figure 2 results, it is interesting to highlight that even if Table 1 shows that a single future portfolio leads to poor hedging results in a non-commodity such as avocados, a linear combination or portfolio of sugar and coffee futures enhances avocado price replication. Also, for the specific case of the mean national Hass avocado price in Mexico, the futures of the NYMEX (coffee and sugar) are the most suitable for hedging this non-commodity.

The results from Tables 1 to 3 show that, as theoretically expected, using single agricultural commodity futures is not useful to hedge non-commodities like the Hass avocado. The main result is that using an agricultural futures portfolio leads to a proper avocado price replication for hedging purposes. From all the combinations of portfolios with the seven futures of interest herein (coffee, corn, rough rice, soybean, sugar, and wheat), a portfolio made of a mean investment level of 83.48% in sugar futures and 16.52% in coffee leads to a very close price replication. Replication with hedging effectiveness of 94% of the avocado's price fluctuations.

Despite this interesting result, to hedge the avocado price with the sugar-coffee futures portfolio leads to poorer hedging effectiveness in $t + 4$ and $t + 12$ weeks hedging horizons.

As a corollary of the results discussed herein, using a synthetic hedge with an agricultural futures portfolio of the avocado price is feasible. It could help cover avocado producers' income risk.

Conclusions

Hedging the price of non-commodities with commodities futures is an activity that needs further review to translate or share the risk of commodity price changes. The main issue with this practice is the presence of basic risk. That is, the future difference that the non-commodity's spot price and the futures position will have. This result could reduce or even increase the price risk in the best-case scenario.

Departing from this need, this paper tests a first method to hedge the price and, consequently, the income of premium-quality Hass avocado producers. This non-commodity is an agricultural sector that is raising demand around the world. Its popularity as healthy food and fruit used in "haute cuisine" or as the fundamental ingredient of dips and appetizers has motivated an important price and volatility.

This fruit is among the main agricultural exports in countries like Mexico, Chile, Colombia, Perú, and Israel (among others). Departing from this fact, it is interesting to test avocado price hedging methods, especially in the Mexican market, which is the main producer of this fruit worldwide and creates Economic value through its related activities.

To hedge such prices, this paper tested using the seven main agricultural futures traded in the Chicago Mercantile Exchange (CME) and the New York Mercantile Exchange (NYMEX): corn, cocoa, coffee, rough rice, soybean, sugar, and wheat. Because these futures prices and the avocado aren't cointegrated and show a high level of basis risk in a hedging strategy, the authors tested the use of a futures portfolio, optimally selected through the minimum tracking error method. A method in which the hedging position w^* is optimally selected by minimizing the difference between the portfolio's percentage change and the benchmark's (the avocado price in this tests).

The core idea is to find such optimal investment levels w^* that will reduce the basis risk to Cero. The hedging effectiveness $HE_{p,t}$ is a metric used to measure how effective is a hedging (futures or options) position to reduce basis risk. A value of $HE_{p,t} \approx 1$ suggest a perfect fit (zero basis risk) between the hedging position and the spot one. A value $HE_{p,t} \approx 0$ suggest a poor hedge and a value of $HE_{p,t} < 0$ shows that the basis risk increases. The hedging position adds more price fluctuation than the single or unhedged spot one.

This paper tested the optimal selection of the futures portfolio to replicate the avocado price in a $t+1$, $t+4$ and $t+12$ week's hedging horizon is from January 1st, 2000, to September 29th, 2023. The optimal portfolio selection was tested in 127 different portfolios, each combining the seven futures of interest. The core idea was to find the best-fitting optimal futures combination to replicate the avocado's price.

The goal of replicating properly the avocado price to reach $HE_{p,t}$ values near to one will show an important avocado price hedging method that could help a Mexican public or financial institution (like SEGALMEX that is a Mexican public company that hedges agricultural products and seeks Mexican food security) to offer an avocado price hedging for avocado producers. Offering such a hedge could translate the price risk to this institution, a risk that could be balanced by buying the futures optimally selected portfolio tested herein.

The results of the simulations show that using an optimal portfolio with a mean investment level of 16.52% in coffee and 83.48% in sugar futures will lead to a hedging effectiveness of 0.94. Consequently, a Mexican public or financial institution could buy this simulated portfolio to balance the price hedge offered to Mexican avocado producers.

It is important to highlight that this result hold in a $t + 1$ hedging scenario and the $t + 4$ and $t + 12$ ones need further review or testing of other optimal selection methods.

This work pretends to be one of the first to test the use of quantitative optimal futures portfolio selection to hedge the price of non-commodities with futures portfolios, being the case of the Mexican avocado, which could be extended to other agricultural products in Mexico and abroad.

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