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Research article

Financial assets against inflation: Capturing the hedging properties of gold, housing prices, and equities

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Abstract: In this study, we employed a developed Fractional Cointegrating Vector Autoregressive (FCVAR) model to analyze the relationship between three different securities, i.e., housing prices, S&P500 stock prices and gold, and inflation rate, to determine the hedging properties of each type of asset against inflation shocks. Our analyses covered seven decades; ranging from January 1953 to January 2023. Our results suggested that housing prices and S&P500 performed partially against inflation and gold did not have hedging properties when attending to the full sample. Accounting for structural breaks, we discovered that these results changed. We found that housing prices and the S&P500 showed a superior hedging performance against inflation since the second regime. On the other hand, when we studied the behavior of gold, this security showed the inverse results, i.e., it showed no hedging performance in the second regime. Finally, these results were important for an optimal investment strategy, risk diversification, and monetarism.

Keywords: fractional cointegration; structural breaks; security; hedging; inflation

JEL Codes: C32, C58, E31, E44, E52

1. Introduction

By the end of 2021 and extending into 2022, developed nations (as well as nearly all global countries) encountered a surge in inflationary pressures as they emerged from the COVID-19 pandemic. This surge was primarily driven by a substantial escalation in the inflation of goods prices, complemented by the Ukraine-Russia conflict. Thus, popular perception insinuates that strong consumer demand experienced a significant rise against constraints on the supply of goods, rocketing inflation (Comin et al., 2023). In this respect, the European Central Bank, the Federal Reserve, and other monetary authorities of the industrialized economies try to respond to these inflation shocks with a rise in interest rates hoping inflation shocks could sustain or wane in the short run (Schnabel, 2023). Indeed, the inflation level is above the target scope of central banks in all advanced economies (World Bank, 2022). For example, following the Bureau of Labor Statistics (2022), in the United States, inflation reached 8.6 percent or the 8.1 percent in Europe, denoting the highest inflation level since the creation of the euro currency (Alderman, 2022).

In this context, investors may wonder which type of assets could be an efficient way to protect themselves from potential high-inflation shocks and provide the opportunity of maximizing returns and reducing risk. Therefore, it is well known that due to their distinct characteristics, assets display diverse responses to inflation. One prevalent attribute shared by many financial variables is their vulnerability to disruptions and their heightened sensitivity to structural shifts within the economy. Upon examining the recent history leading up to the current economic crisis, it becomes apparent that security prices were consistently rising. This led to the assumption that securities could effectively act as a hedge against inflation. However, when the bubble eventually burst, it became evident that assets were unable to effectively mitigate the impact of inflation and experienced substantial declines in their valuation (Salisu et al., 2020).

To the best of our knowledge, this is the first time that the FCVAR model is applied to capture the inflation hedging properties of housing prices and equities as well as gold. As it is well known in the literature concerning the FCVAR model, this model developed by Johansen (2008a, b) and further developed by Johansen and Nielsen (2012), faces with several studies in the literature that contemplate the relationship between different series, considering that they are integrated in order I(0)/I(1). However, using this methodology demonstrates that cointegration is not constrained to be integrated of order one or zero, being this premise too restrictive. The FCVAR model provides a more flexible and relaxed environment that allows us to reject the traditional cointegration assumptions that financial time series, such as securities, in this case, are unit-roots or I(1) but follow a fractional process I(d).

Our findings suggest that housing prices and gold hedge partially against inflation, while the S&P500 index seems to be a bad refuge against inflation. Nonetheless, when considering the existence of structural breaks, we find different breakpoints for each variable, when using the Bai-Perron (2003) test. For example, there are three structural breaks for housing prices, and one structural break for S&P500 and gold. Thus, we apply the FCVAR model to each regime and we find that housing prices and S&P500 show a superior hedging performance against inflation since the second regime. On the other hand, when we study the behavior of gold, this security shows the invers results, i.e., it shows no hedging performance in the second regime.

The rest of the paper is organized as follows. The following section covers the literature review of this topic. In section 3, we describe the methodology used for the work. In section 4, we discuss how different assets could display hedging properties against inflation and conclusions, from which we identify the policy implications given in section 5.

2. Literature review

Academics have studied the relationship between asset or securities returns and inflation rates to detect these products may protect investors from inflation. Usually, the popular perception ascribes an inflation-hedging capacity to equities/stocks, gold, or real estate. Nonetheless, does empirical evidence proof this vision? Can they give inflation protection?

To understand the effect of inflation on securities, we could appeal to the Fisher hypothesis (Fisher, 1930). Under this hypothesis, researchers try to evince securities prices or returns and inflation. In fact, according to Fama and Schwert (1977), nominal returns encompass the market's evaluations of anticipated inflation rates across various security types. This Fisher hypothesis also suggests that in an efficient market, investors should be completely compensated for the effects of increased price levels through an increase in nominal securities returns. As a result, real securities returns should primarily reflect expectations about real factors, independent of inflation. In other words, following Tiwari et al. (2018), securities returns are expected to act as a hedge against inflation. According to this hypothesis, there should exist a positive and one-to-one relationship between nominal securities returns and inflation rates if it holds true. Regarding this statement, one can find empirical evidence of the potential hedging properties of some securities of interest on inflation[1]. In this sense, we can highlight some recent studies such as Aye et al. (2017), Shahzad et al. (2018) or Valadkhani et al. (2022), for gold; Rushdi et al. (2012) or Spierdijk and Umar (2015), for stock markets; and Yeap and Lean (2017), Christou et al. (2018) or Taderera and Akinsomi (2020), for real estate prices.

Attending to gold hedging properties, to address the prevailing disagreement in existing research, Valadkhani et al. (2022) conducted an examination of the hedging efficacy of gold when inflation reaches a favorable threshold. The findings suggest that once annual inflation reaches around 6%, gold demonstrates its ability to effectively hedge against inflation. Furthermore, their findings also suggest the notion that gold possesses some degree of hedging capability, particularly during periods of abnormal stock market volatility. Thus, according to Hillier et al. (2006), financial portfolios that include precious metals outperform standard equity portfolios to a significant extent. There are several papers that examine the relationship between gold price returns and inflation. Initially proposed by Chua and Woodward (1982) and, more recently by Bampinas and Panagiotidis (2015) and Aye et al. (2017) have specified that the gold price return can be modeled as a function of inflation. Zaremba et al. (2019, 2021) demonstrate the inflation-hedging capability of 50 commodities (gold is included in this list) across 80 countries and seven centuries of data. Their findings affirm that commodities have historically served as a hedge against inflation, particularly over extended periods spanning multiple

[1] See Arnold and Auer (2015) for a survey.

years. However, the effectiveness of this hedging ability has shown significant variation, both temporally and across different geographic regions. On the other hand, papers such as Reboredo (2013), Erb and Harvey (2018), and Salisu et al. (2020) demonstrate that gold exhibits hedging properties primarily during periods of extreme adverse market movements. Additionally, some researchers have suggested that the hedging ability of gold might vary depending on the sample period or prevailing economic conditions. This viewpoint is supported by studies conducted by Beckmann and Czudaj (2013), Aye et al. (2016), Iqbal (2017), or Adekoya et al. (2021).

The significance of house prices in relation to inflation is acknowledged in various countries, where real estate plays a pivotal role in most private portfolios (Hong et al., 2013). As a result, corporate equities are becoming increasingly prevalent as investments within the household sector. Consequently, both homeowners and corporations recognize the importance of safeguarding investments against fluctuations in price levels, as it holds significant implications for personal wealth and the overall economy (Anari and Kolari, 2002).

Furthermore, the role of equity or stocks as hedging of inflation has been addressed by numerous research, showing mixed results. Following Lintner (1975), equities, as financial instruments, represent ownership stakes in tangible assets that are anticipated to maintain value relative to changes in purchasing power. On the other hand, on average, companies employ capital leverage and have a net debt position, implying they owe more in debt than their holdings in liquid assets. Thus, shareholders may take advantage from unexpected inflation as the company’s long-term obligations to fee fixed nominal sums decline in real value. Empirical evidence of this link, i.e., the equity-inflation nexus, has been treated by Lothian and McCarthy (2001), Anari and Kolari (2001), Engsted and Tanggaard (2002), Ahmed and Cardinale (2005), Valcarcel (2012), Rödel (2012, 2014), Antonakakis et al. (2017) or, more recently, Tiwari et al. (2018), among others.

In this paper, we applied the fractional cointegrated vector autoregressive (FCVAR, hereafter) model. This methodology, although limited, has been applied to this topic to identify the inflation hedging properties of different securities. Thus, we can highlight Aye et al. (2017) for the UK, where the hedging ability of gold is studied from 1257 to 2016. For its part, Oloko et al. (2021) also investigate the inflation hedging ability of gold, distinguishing between ten developed and ten developing countries and Usman and Akadiri (2021) test the inflation hedging capacity of gold, silver, platinum, and oil price (Brent).

3. Methodology and data

3.1. Theoretical framework: The Fisher hypothesis

The Fisher hypothesis (Fisher, 1930), which is considered the initial attempt to link asset returns and inflation, forms the basis for establishing the inflation hedge of various security classes, such as gold, equity, or real estate. According to this hypothesis, the nominal interest rate is seen as the combination of the real return and inflation rate. Arnold and Auer (2015) further suggest that expected nominal returns reflect market evaluations of anticipated inflation rates and are applicable to all assets. Hence, by employing an appropriate measure of inflation, we can outline a comprehensive framework for the security-inflation hedge, as follows:

$$S_t = \alpha + \beta\pi_t + \varepsilon_t \tag{1}$$

where S_t is the security return computed as the first difference of the natural log of the asset price and is the inflation rate computed as log (cpi_t/cpi_{t-1}). As mentioned, we have selected three securities, gold, stocks, and housing prices, and the analyses are individually evaluated for these securities. The parameter β measures the inflation hedge of a particular security and there are three possible conclusions: (i) the partial hedge requires that $0 < \beta < 1$; (ii) if $\beta = 1$, this implies a full hedge; and (iii) it would be a superior performance if $\beta > 1$. In contrast, a given security has no inflation hedging properties if $\beta \leq 0$. Finally, following Hoang et al. (2016) or Taderera and Akinsomi (2020), the dynamics of hedging against inflation involve that the return on investments should be at least equal to the rate of inflation (Salisu et al., 2020).

3.2. The fractional cointegrated vector autoregressive model

The fractionally cointegrated vector autoregressive (FCVAR) model, developed by Johansen (2008a, b) and further developed by Johansen and Nielsen (2010, 2012) is a generalization of Johansen (1995)'s cointegrated vector autoregressive (CVAR) model to allow the fractional processes of order d that cointegrate to order d − b. To establish the FCVAR model, we start by raising to the CVAR model. Let Y_t, t = 1, …., T be a p-dimensional I(1) time series, the CVAR model is:

$$\Delta Y_t = \alpha\beta' L Y_t + \sum_{i=1}^{k} \Gamma_i \Delta L^i Y_t + \varepsilon_t. \tag{2}$$

To derive the FCVAR model, we must replace the difference and lag operators Δ^b and $L_b = (1 - \Delta^b)$, respectively, to achieve,

$$\Delta^b Y_t = \alpha\beta' L_b Y_t + \sum_{i=1}^{k} \Gamma_i \Delta^b L_b^i Y_t + \varepsilon_t. \tag{3}$$

And operating to $Y_t = \Delta^{d-b} X_t$, such that,

$$\Delta^d X_t = \alpha\beta' L_b \Delta^{d-b} X_t + \sum_{i=1}^{k} \Gamma_i \Delta^d L_b^i X_t + \varepsilon_t. \tag{4}$$

As always, ε_t is p-dimensional independent and identically distributed with mean zero and covariance matrix Ω. The parameters α and β are $p \, x \, r$ matrices, where $0 \leq r \leq p$. In matrix β the columns are the cointegrating relationships and $\beta' X_t$ are the stationary combinations, i.e., the long-run equilibrium. We follow the assumption derived from the seminal paper of Kasa (1992) about linearity in the relationship. However, on this linearity in our approach, once we are subject to this condition, seeks the study of changes in the behavior of the series through the analysis of structural breaks proposed by Bai-Perron (2003) as above mentioned, which allows us to measure possible non-linearity in the time horizon of the relationship. The coefficients in α correspond the speed of adjustment unto equilibrium. Therefore, $\alpha\beta'$ is the adjustment long-run and Γ_i represents the short-run behavior of the variables.

Considering $d = b$ as an assumption of a constant mean term for the cointegrating relations, we reach an intermediate step before the final model. That is:

$$\Delta^d X_t = \alpha(\beta' L_d X_t + \rho') + \sum_{i=1}^{k} \Gamma_i \Delta^d L_d^i X_t + \varepsilon_t \quad (5)$$

We consider the simple model as:

$$\Delta^d (X_t - \mu) = L_d \alpha\beta'(X_t - \mu) + \sum_{i=1}^{k} \Gamma_i \Delta^d L_d^i (X_t - \mu) + \varepsilon_t \quad (6)$$

where the variable μ is a level parameter that shifts each of the series by a constant in the way to avoid the bias related to the starting values in the sample (Johansen and Nielsen, 2016). $\beta'\mu = -\rho'$ defines the mean stationary cointegrating relations. Johansen and Nielsen (2012) show that the maximum likelihood estimators $(d, \alpha, \Gamma_i, \ldots, \Gamma_k)$ are asymptotically normal and the maximum likelihood estimator of (β, ρ) is asymptotically mixed normal.

The CVAR model is nested in the FCVAR model with the restriction d = b = 1; the error term is integrated of order (d – b), which is I(0) in this case. Conversely, in the FCVAR model, this is relaxed because, corresponding to Table 1 in Tkacz (2001), if d = 0, the error correction term follows a stationary process. For 0 < d < 0.5, there is a stationary process and, when 0.5 < d < 1, the error term follows a non-stationary process, but mean-reverting. Last, if d = 1, the error term follows a non-stationary unit root process.

3.3. Model specification

The specification of the model is detailed in this subsection (following Dolatabadi et al., 2015, 2016, 2018). There are some steps to take to achieve the correct specification preparatory assessing the FCVAR model and the hypotheses of concern, attending to a few essential features in the model specification: The lag length (k), the deterministic components and the ranking of cointegration (r).

Initially, concerning the choice of the lag length, some information sources are employed, involving the Bayesian information criterion (BIC), the LR test statistics for the significance of Γ_k, and the tests for serial correlation in the residuals. The application of every case is based on the model that contains the whole of the deterministic elements studied and possess full rank $r = p$. Attending to the series selected, we initially utilize the BIC as an opening point for the lag length, and next, we observe the closest lag length that fulfils the criteria. After that, we evaluate if Γ_k is significantly based on the LR test, and finally, the tests for serial correlation in the residuals are examined, neglecting symptoms of misspecification.

Once the lag length is chosen, the deterministic components and the cointegrating rank (r) are selected. Regarding the first case, we consider that the restricted constant, $\rho\pi_t$, exists, ensuing the methodology background. The choice of deterministic components is focused on the lack or presence of the unrestricted constant[2]. That is the trend component. Since the limit distribution of the ranking of cointegration is governed by the actual cointegration rank and the presence or lack of the trend, we need jointly elect the cointegration rank and if the trend is incorporated (as Dolatabadi et al. (2016) declare). A deep analysis of both hypotheses is discussed in Johansen (1995).

[2] Our model is specified with and without the presence of the unrestricted constant. The reached estimates are reasonably the same heedlessly the presence or lack of the unrestricted constant. Results are available upon request.

3.4. Data

We use inflation rates and housing prices, stock prices (S&P500), and gold price data for seven decades; ranging from January 1953 to January 2023. This period, which generates 841 observations, covers periods of high and low inflation rates in the USA, and the period of positive and negative shocks on the securities selected. The data was gathered from the Federal Reserve Bank of St. Louis, for Consumer Price Index, and housing prices, stocks, and gold prices were obtained from the Shiller's Database for housing and stock prices and the World Bank for gold prices. Subsequently, for our analysis, we have expressed Inflation rate in percentage, while the securities are expressed in returns, as previously mentioned (see Table 1 for descriptive statistics).

In Figure 1, the trends of the prices of the securities selected and the Consumer Price Index are plotted. As we can see, some degree of co-movement among the variables can be observed, suggesting the presence of cointegration. Furthermore, the grey-vertical bands reflect the NBER business cycles.

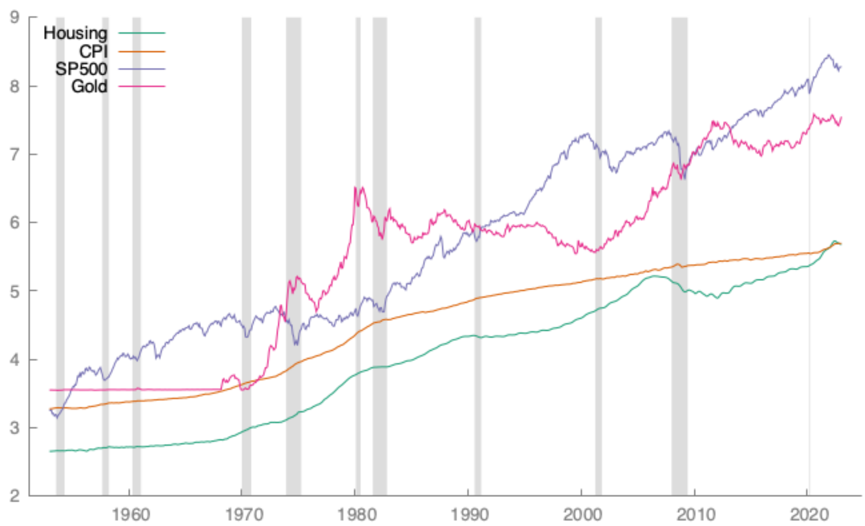

Figure 1. Trends in housing, stock and gold prices and the CPI. Notes: Own elaboration.

Table 1. Descriptive statistics.

	Mean	Median	Standard Deviation	Min	Max
CPI	0.288	0.284	0.357	1.790	−1.934
Housing	0.360	0.334	0.584	2.692	−2.285
S&P500	0.598	0.983	3.550	11.352	−22.804
Gold	0.476	0.028	4.150	37.493	−18.347

Notes: Own elaboration.

Table 1 exhibits the descriptive statistics for the securities prices and CPI. This table displays that the average CPI and standard deviation is 0.288 and 0.357, respectively. Attending to the securities selected, housing prices shows a mean of 0.360 and a standard deviation of 0.584; for S&P500, 0.598 and 3.550, respectively; and for gold, 0.476 and 4.150, respectively. This suggests that the gold is more volatile compared to the rest of variables. It should be noted that the volatility of housing prices is similar to CPI.

4. Results

In this section, we show the results of applying a FCVAR model to simultaneously assess the hedging properties of different securities against inflation and the persistence of a shock in the relationship between both variables. The application of the FCVAR model, which is a novelty to accomplish this goal, is summarized in Table 2. We start our econometric exercise by studying the possibility that the fractional cointegration would be more appropriate than the standard one. Once this step is done, we study the hedging properties of each security attending to the value of *β.* Finally, we test the degree of persistence of a given shock in the relationship.

Table 2. Strategy of empirical research.

	Procedure	Hypotheses
Step 1	Standard Cointegration vs. Fractional Cointegration	H_1^d: Is the fractional cointegration more appropriate than traditional cointegration?
Step 2	Hedging properties	H_1^β: What type of hedging properties does each security show?
Step 3	Degree of security persistence, i.e., order of integration (d)	d: How long is the duration of the shock (short-lived or long-lived)?

Furthermore, our methodology allows us to connect both principles covered in the Introduction section, i.e., the degree of integration of each variable (the parameter *d*), and the value of *β.* This idea is represented in Table 3, where are introduced some new scenarios of hedging performance.

Remember that, when attending to β, we can measure the inflation hedge of a particular security. In this regard, we can achieve three possible conclusions: (i) the partial hedge requires that $0 < \beta < 1$; (ii) if $\beta = 1$, this implies a full hedge; and (iii) it would be a superior performance if $\beta > 1$. In contrast, a given security has no inflation hedging properties if $\beta \leq 0$. Additionally, following Oloko et al. (2021), *d* is a is a non-integer value, which measures the degree of persistence due to change in inflation rate. The higher the value of is, the higher the level of dependence between a given security return and inflation rate, implying higher persistence in the impact of shocks. If $d = 0$, the cointegrating process is stationary and has short memory with no cointegrating persistence. This implies that a change in the persistence due to a shock will vanish almost instantaneously. In other words, the effect of the shock on the relationship persistence does not persist. There is however fractional cointegration and possible security – inflation rate persistence if $d > 0$. For example, if *d* is positive but less than 0.5 ($0 \leq d < 0.5$), the cointegrating process is also covariance stationary, but rather exhibits long memory with low cointegrating persistence. This suggests that the effect of a shock on the security persistence would persist for a short while. In other words, the shock will die out within a short period. However, the cointegrating process is said to exhibit long memory or high persistence if $d \geq 0.5$, such that a high persistent cointegrating process could either be mean reverting and covariance stationary if is less than 1 ($0.5 \leq d < 1$).

Table 3. Degree of hedging performance of the securities by applying the FCVAR.

Order of integration	Hedging performance (β)			
	$\beta \leq 0$	$0 < \beta < 1$	$\beta = 1$	$\beta > 1$
I(d) = I(0)	No hedging performance.	Partial hedge and the shock duration is short-lived.	Full hedge and the shock duration is short-lived.	Superior performance
I(0) < I(d) < I(0.5)		Partial hedge and the shock duration is long-lived.	Full hedge and the shock duration is long-lived.	
I(0.5) < I(d) < I(1)		Partial hedge and the series follow a nonstationary process, although mean-reverting and the shock duration is long-lived.	Full hedge and the series follow a nonstationary process, although mean-reverting and the shock duration is long-lived.	

4.1. Univariate analysis

Before testing the possible long-run relationship between inflation and each security and aiming to decide if the FCVAR model is suitable to the main purpose, each of the series is examined singly before driving the multivariate analysis[3]. Broadly, if both stationary tests and unit root tests of a time series are rejected, which suggests that the time series is likely a fractional time series, even though there are considerable procedures for estimating the fractional differencing parameter in a semiparametric context. Though the semiparametric log-periodogram regression recommended by Geweke and Porter-Hudak (1983) (GPH, hereafter) is the most used, this method was varied and deeper developed by Robinson (1995) and has been analyzed by Velasco (1999) and Shimotsu and Phillips (2002), among others. Then, the estimation of the fractional parameter d is determined for each univariate series, with the results presented in Table 4. The GPH[4] test is computed with the bandwidths $m = T^{0.4}$, $m = T^{0.5}$, and $m = T^{0.6}$, respectively and, when conducting the univariate analysis, the GPH estimates support the idea that the fractional cointegration could be appropriate for this issue.

[3] As previously mentioned, we have transformed the securities prices into returns by the first difference of the natural log of each asset price and for the inflation rate, we have computed as log (cpi_t/cpi_{t-1}).

[4] For testing the presence of unit roots, the estimates were obtained using first-differenced data because the original series may be above 0.5. This test expects that the results are limited to the interval $-0.5 < d < 0.5$, and then, 1 is added to obtain the appropriate estimates of d.

Table 4. Univariate analysis. GPH estimates.

	$m = T^{0.4}$ d	$m = T^{0.5}$ d	$m = T^{0.6}$ d
Housing	0.602	0.595	0.831
	(0.228)	(0.092)	(0.110)
Inflation	0.849	0.939	0.635
	(0.216)	(0.147)	(0.098)
S&P500	0.314	0.105	0.150
	(0.277)	(0.151)	(0.104)
Gold	0.431	0.258	0.374
	(0.342)	(0.160)	(0.102)

Notes: GPH denotes the Geweke and Porter-Hudak semiparametric log-periodogram regression estimator. Standard errors are given in parenthesis beneath estimates of d. The sample size is 841.

4.2. Multivariate analysis: The FCVAR model

Once we have concluded that the fractional prism is suitable for our purpose, we show the procedure (see the model specification above) that we will perform for a battery of results shown below in Table 5. First, to select the FCVAR lag length, we apply the Bayesian information criteria (BIC), and the optimal lag length that is selected is five, one, and two for housing, S&P500 and gold, respectively. Then, once the lag length is selected, we determine if there is a long-run relationship between the variables that are chosen. For this reason, we test the cointegration rank before testing the hypothesis of the fractional parameter and evidence that the number of cointegrating vectors is one in all cases. Once the rank cointegration test is established, we test the hypothesis H_1^d, which tests whether the fractional cointegration is more appropriate than standard cointegration is. In our case, this hypothesis is rejected with a 0.000 *p-value* for each security so, therefore, fractional cointegration is appropriate for this study. Later, attending to the fractional parameter *d*, we can see that, for each security, it possesses a value between o and 0.5, determining that the cointegrating process is covariance stationary, and exhibits long memory with low cointegrating persistence (Aye et al., 2017). In other words, the common order of integration of each pair is 0.392, 0.250 and 0.408 for housing, S&P500 and gold, respectively, showing that the stochastic trend is fractionally nature and possess stationarity with a long memory and the shock duration is long-lived (Tkacz, 2001) and this is evidence of inefficient markets (see Salisu et al., 2019; or Vides, 2022). Finally, at the bottom of Table 5, we can see the different values of β. Thus, it can be observed that both housing and gold provide a partial hedging property against inflation. Conversely, S&P500 show a negative value of β, indicating a no hedging performance against inflation of the US stock market.

Table 5. Rank test, Fractional Cointegration test and Hedging performance.

Optimal lag length	Housing	S&P500	Gold
	5	1	2
Rank test			
0	27.637	19.289	18.682
	(0.000)	(0.001)	(0.001)
1	2.607	0.004	0.073
	(0.106)	(0.949)	(0.787)
H_1^d	142.523	167.627	153.144
	(0.000)	(0.000)	(0.000)
$\hat{d}$	0.392	0.250	0.408
	(0.021)	(0.098)	(0.038)
β	0.898	−0.035	0.912

Notes: In this table is shown the estimations for each database in different columns. It also shows the values of LR Statistics, and the p-values are in brackets. For the parameter d we show its value, and the standard deviation value is in parenthesis. The significance level is set to 10% for exclusion following Jones et al. (2014). The sample size is 841 monthly observations.

4.3. The FCVAR model under the existence of structural breaks

However, recall that we are using a sample that covers the period 1953–2023. In this period, different and many economic events occurred with effects on our variables of interest. Thus, we consider the possibility that the existence of structural breaks would provide a better empirical description of the security-inflation relationship. For this purpose, we apply the test for structural breaks proposed by Bai and Perron (2003) with a 15% trimming, which limits the maximum number of breaks allowed under the alternative hypothesis to 3. Among the breaks identified for housing prices, the first breakpoint is placed in May 1968, which corresponds to the Fair Housing Act. The second breakpoint corresponds to July 1989, just the peak of prices before the recession of 1990. Finally, the third breakpoint is identified in February 2012, when the subprime crisis and its effects were diminished. Regarding the S&P500, the Bai-Perron test identifies one breakpoint (August 2008), which matches to the beginning of the subprime crisis. Finally, concerning the structural breaks in gold prices, it is dated January 1980. This can be explained because gold hits a record high of $850 an ounce, as investors pile into bullion prompted by high inflation due to strong oil prices. So, once we have identified the possible structural breaks, we proceed to follow the same empirical strategy within each regime for each security in Tables 6, 7, and 8, respectively.

4.3.1. FCVAR model and Hedging performance for housing prices

Thus, Table 6 shows the four regimes resulting the application of the Bai-Perron test, which returns a value of three structural breaks (and therefore 4 regimes). Attending to the first, third, and fourth regimes, we can highlight the existence of one cointegrating relationship in each of them. Furthermore, the H_1^d indicates that the use of the FCVAR model is more appropriate than the CVAR.

However, for regime 2, there is no cointegrating relationship. Attending to the fractional parameter (*d*), it increases along time, going from having a value of 0.371 in the first regime to 0.526 in the fourth regime, indicating greater persistence of a possible shock in housing prices, but an inefficient market. To this we must add that the β also increases over time, indicating partial hedging in the first regime to showing superior performance in regimes 2 and 3. If we consider both parameters jointly, i.e., *d* and β, we could assume that housing prices could be a good refuge for investors from the second regime onwards, because any inflation shock would spend more time to be absorbed by the housing market.

Table 6. Rank test and Fractional Cointegration test and Hedging performance for housing prices.

Optimal lag length	Regime 1	Regime 2	Regime 3	Regime 4
	1	1	2	1
Rank test				
0	35.620	4.796	31.834	8.824
	(0.000)	(0.309)	(0.000)	(0.093)
1	2.283	0.552	0.854	0.499
	(0.131)	(0.458)	(0.207)	(0.970)
H_1^d	53.634	-	63.958	31.492
	(0.000)		(0.000)	(0.000)
$\hat{d}$	0.371	-	0.519	0.526
	(0.072)		(0.030)	(0.048)
β	0.503	-	12.476	8.979

Notes: In table shows the estimations for each database in different columns. It also shows the values of LR Statistics, and the p-values are in brackets. For the parameter d we show its value, and the standard deviation value is in parenthesis. The significance level is set to 10% for exclusion following Jones et al. (2014).

4.3.2. FCVAR model and Hedging performance for S&P 500

Table 7 shows Rank test, Fractional Cointegration test and Hedging performance for S&P500. By applying the Bai-Perron test to this variable, we have identified two regimes. As can be observed, there are one cointegrating relationship in each regime and, furthermore, the use of fractional cointegration is more appropriate than de traditional one (H_1^d). As occurred previously when examining the behavior of housing prices in each regime, S&P500 also sees how its fractional parameter increases from regime 1 to regime 2, affecting to the duration of inflationary shock on the US stock market and again, regarding β, it also increases over time, indicating partial hedging in the first regime to showing superior performance in the second regime. Indeed, if we analyze these results together, the more persistence, the more hedging properties of S&P500 (Aye et al., 2017). Thus, we can conclude that S&P500 became a good refuge for investors after the subprime crisis.

Table 7. Rank test and Fractional Cointegration test and Hedging performance for S&P500.

Optimal lag length	Regime 1	Regime 2
	1	1
Rank test		
0	27.284	34.775
	(0.000)	(0.000)
1	8.147	26.955
	(0.005)	(0.000)
H_1^d	141.594	18.071
	(0.000)	(0.000)
$\hat{d}$	0.386	0.534
	(0.050)	(0.118)
β	−0.287	6.758

Notes: This table shows the estimations for each database in different columns. It also shows the values of LR Statistics, and the p-values are in brackets. For the parameter d we show its value, and the standard deviation value is in parenthesis. The significance level is set to 10% for exclusion following Jones et al. (2014).

4.3.3. FCVAR model and Hedging performance for gold

Finally, Table 8 shows mixed results or the inverse when compared to the previous cases. Although the rank test and the H_1^d provide proofs in favor of the use of fractional cointegration, the parameters d and β follow an inverse sense than the previously shown. In fact, the fractional parameter decreases from regime 1 to regime 2 (0.635 to 0.440), and β follows the same behavior, from 4.344 to −5.981. These results surprisingly contrast with those obtained for housing prices and S&P500 and imply that gold is not a good refuge for investors in hedging strategies against inflation after the breakpoint. This diverges from the behavior of the investors that explain the breakpoint.

Table 8. Rank test and Fractional Cointegration test and Hedging performance for gold.

Optimal lag length	Regime 1	Regime 2
	1	1
Rank test		
0	42.078	58.251
	(0.000)	(0.000)
1	6.368	33.709
	(0.104)	(0.000)
H_1^d	47.415	76.128
	(0.000)	(0.000)
$\hat{d}$	0.635	0.440
	(0.043)	(0.063)
β	4.344	−5.981

Notes: This table shows the estimations for each database in different columns. It also shows the values of LR Statistics, and the p-values are in brackets. For the parameter d we show its value, and the standard deviation value is in parenthesis. The significance level is set to 10% for exclusion following Jones et al. (2014).

4.4. Discussion

In sum, our results can be represented in Table 9, which is a modification of Table 3. As we can see, it seems that when there exists a greater persistence ($0.5 < d < 1$), as justified by Aye et al. (2017) or Oloko et al. (2021), the hedging properties of a given security show a superior performance.

Table 9. Degree of hedging performance of the securities by applying the FCVAR.

Order of integration	Hedging performance (β)			
	β ≤ 0	0 < β < 1	β = 1	β > 1
I(d) = I(0)				
I(0) < I(d) < I(0.5)	S&P500 S&P500 (Regime 1) Gold (Regime 2)	Housing prices Gold Housing Prices (Regime 1)		
I(0.5) < I(d) < I(1)				Housing prices (Regime 3) Housing prices (Regime 4) S&P500 (Regime 2) Gold (Regime 1)

Notes: Own elaboration.

Indeed, investors should be focused to the fluctuations appreciated in the behavior of these securities in terms of pattern and trend. Additionally, diversifying their portfolio could prevent capital loss and minimize their exposition to future inflationary shocks. Industrialized countries are mired in an energy crisis due to the Russia-Ukraine war, causing much volatility in energy markets. Thus, as Jain and Ghosh (2013) stated, investment in other securities, such as precious metals, becomes beneficial in terms of high returns to investors in the long run, could be beneficial for an efficient portfolio since it could diversify risk (Arif et al., 2019). In fact, Zaremba et al. (2019, 2021) recommend including commodities in the portfolio to minimize risks. Geopolitical factors such as the Russia-Ukraine war could trigger risk spillovers. In this context, Qian (2023) and Yaya (2024) assert that global shocks or developments in foreign markets can influence other international markets, such as the US market. This highlights how the rapid economic development in China may impact international markets, underscoring the significance of risk spillovers across countries.

Furthermore, from a policy standpoint, authorities and investors should analyze the relationship between each security and inflation rates before adopting any monetary policy or investment strategy. For example, attending to the persistence and the duration of a shock, investors should take into consideration that their investment strategies would depend on their investment horizons and, on the other hand, monetary authorities should expect that policies might cover different effects on the short-run and the long-run. Finally, monetary policy authorities can mobilize capital resources by introducing more investment channels into the economy. Although it is demonstrated that investing in gold is not a good instrument to protect investors against inflation, monetary authorities should discourage large hoarding of gold as this can lead to a loss of confidence in fiat money and limit the opportunity to invest in other assets such as stock markets or real estate (Aye et al., 2017), thereby reducing the volume of financial resources that would contribute to economic growth and development.

5. Conclusions

In this paper, we studied the hedging properties against inflation of different securities (housing prices, S&P500 prices and gold), using a fractionally cointegrated vector autoregressive (FCVAR) model for the USA. Following Salisu et al. (2020), we also assumed that stock, gold, and real estate have different market features; thus, should react differently to inflation shocks. Despite controversy in the existing literature regarding treatment of this issue, the fractional cointegration model avoids most of the problems raised in the literature. Additionally, this model allows us to identify persistence and hedging properties in our monthly time series, jointly.

Therefore, our analysis was performed considering the full sample, which covers the period January 1953–January 2023. Our findings suggest that housing prices and gold hedge partially against inflation, while the S&P500 index seems to be a bad refuge against inflation. Nonetheless, when considering the existence of structural breaks, we find different breakpoints for each variable, when using the Bai-Perron (2003) test. For example, there are three structural breaks for housing prices, and one structural break for S&P500 and gold. Thus, we apply the FCVAR model to each regime and we find that housing prices and S&P500 show a superior hedging performance against inflation since the second regime. On the other hand, when we study the behavior of gold, this security shows the inverse result, i.e., it shows no hedging performance in the second regime.

This paper makes additional contribution among academics in better understanding the inflation hedging ability of different securities based on new application of the fractional integration approach. Our findings have important implications in terms of investment policy implication, portfolio selection and risk management strategies. The results obtained, when assuming the existence of structural breaks, suggest that investors would have a good hedge against inflation by holding stock assets and real estate, and not by holding gold.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Author contributions

All authors have contributed significantly to the development of this article. While Antonio Golpe and José Carlos Vides have provided valuable insights, particularly in the quantitative analysis, Julia Feria has enriched the study through her comprehensive review of the literature. Alejandro Almeida has added depth to the interpretation of the results. Nonetheless, all authors have been involved in every stage of the research process, from conceptualization to final revisions, ensuring a collaborative and well-rounded approach to the study. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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