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Persistence in the MINT Stock Markets: Evidence from a Fractional Integration Model

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Abstract

This paper investigates persistence in the MINT (Mexico, Indonesia, Nigeria, Turkey) stock markets applying fractional integration methods to daily data from 1 January 2022 to 31 October 2025. Different model specifications are estimated for prices, log prices and log returns under the assumption of white noise and autocorrelated errors respectively. Mean reversion is found in most cases for prices with autocorrelated errors, which implies that shocks have only temporary effects in this case. Turkey displays the lowest degrees of integration, while Nigeria has the highest for both prices and log-prices. Structural breaks are found in the case of stock prices in all countries, with market inefficiencies appearing to be present in the most recent period characterized by geopolitical uncertainty resulting from the Russia-Ukraine conflict.

Keywords: Persistence; Fractional integration; MINT; Stock markets

JEL Classification: C22; G12

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1. Introduction

The MINT group of countries includes four emerging economies (namely Mexico, Indonesia, Nigeria, and Turkey) which share features such as a large and youthful population, a high degree of urbanization, abundant natural resources and strategic geographical locations, as a result of which they have been identified as having a high growth potential. However, these countries also face serious challenges in the form of corruption, instability and vulnerability to exogenous shocks such as commodity price fluctuations, global interest rate cycles, and geopolitical uncertainty.

The present study aims to assess the effects of such shocks on stock prices in those countries by estimating the degree of persistence of the series of interest. This is achieved by using a fractional integration framework that is ideally suited to capturing the slow mean reversion and long-range dependence that are often observed in financial series. The reason is that, in contrast to conventional time series models based on the $I(0)$ -stationary versus $I(1)$ -nonstationary dichotomy, the chosen approach allows the order of integration to take non-integer values and thus is more general and flexible and enables to distinguish between transitory and permanent effects of shocks. As a robustness check, in addition to the testing procedure developed by Robinson (1994), we also use various fractional integration methods such as the semiparametric log-periodogram approach developed by Geweke and Porter-Hudak (GPH, 1983) and extended by Robinson (1995), Velasco (2000) and others, as well as local Whittle methods as in Shimotsu and Phillips (2005). Finally, we test for structural breaks and re-estimate the models for the corresponding subsamples.

Applying fractional integration techniques in the case of the MINT countries is particularly important as long memory is most likely to be found in economies with structural rigidities and institutional frictions resulting in slow adjustment mechanisms. Surprisingly, there is only limited evidence concerning these countries which is based on fractional integration methods. Therefore

our contribution aims to fill this gap in the literature. The paper is structured as follows: Section 2 contains a brief review of the relevant literature; Section outlines the methodology; Section 4 describes the data and presents the empirical results; Section 5 offers some concluding remarks.

2. Literature Review

In the most recent literature stock markets have increasingly been analysed using fractional integration methods. For instance, Akpa (2023) investigated persistence in the Liner Shipping Connectivity Index (LSCI), a key indicator of trade efficiency, and found that shocks in trade connectivity exhibit stronger persistence in developing economies such as BRICS and MINT compared to advanced G7 nations. This implies slower recovery from disruptions and suggests that emerging markets remain structurally vulnerable to external shocks, which can further compound economic instability.

Some of the existing literature also focuses on the implications of long memory for the Efficient Market Hypothesis (EMH). Work by Anoruo and Gil-Alana (2011) showed pervasive long-memory characteristics in African stock markets, particularly in Nigeria and Egypt, where shocks exhibit lasting effects with little evidence of mean reversion unless structural breaks are incorporated. This undermines the assumption of informational efficiency. Similarly, Sadique and Silvapulle (2001), using a range of long-memory tests, found that several Asian-Pacific markets, including Korea, Malaysia, Singapore, and New Zealand, display long-term dependence, further challenging the EMH and highlighting the potential for technical trading strategies in environments where price movements retain predictability. Even studies on developed markets, such as Bentes and Cruz's (2011) analysis of G7 stock volatility, reveal persistent patterns, though with varying intensity across countries. Long-memory volatility appears strongest in Germany,

Italy, and France, whereas Japan shows weaker persistence, consistently with the view that mature markets may also exhibit inefficiencies during periods of heightened uncertainty.

More recent studies argue that crises can increase persistence. Bhattacharjee et al. (2025), examining India's stock market across crisis periods including demonetization, the US-China trade conflict, and the COVID-19 pandemic, identified consistently high Hurst exponent values, especially during downturns. Their analysis demonstrates that crises increase persistence, reinforce herding behaviour, and reduce market efficiency, while also suggesting that time-varying persistence can serve as an early warning indicator for market stress. Likewise, Caporale et al. (2022) examined US stock prices and bond yields during the COVID-19 pandemic and found that equities largely kept their pre-pandemic persistence levels, whereas bond yields exhibited greater persistence, implying that fixed-income markets internalize prolonged uncertainty more strongly.

Interestingly, there is only a handful of studies concerning persistence in the stock markets of the MINT and other countries. Usman and Okoronkwo (2024) used a fractional integration approach for MINT stock prices during the COVID-19 pandemic and reported that the latter influenced persistence in those markets, with Nigeria and Indonesia exhibiting unstable differencing parameters and lower efficiency during that period. Imeri et al. (2024) showed that persistence in MENA and OIC markets increased at daily and weekly frequencies during both the pandemic and the Russia-Ukraine war, although changes in persistence appear to be only a short-run phenomenon. Karaomer (2022) obtained evidence supporting the Fractal Market Hypothesis (FMH) in the MINT economies by showing, through ARFIMA and ARFIMA-FIGARCH models, that both return and volatility series exhibit long memory, inconsistently with the Efficient Market Hypothesis (EMH). Logun (2023) examined return-volume interactions in the MINT markets during the COVID-19 period, and found asymmetric effects on returns in Turkey and Indonesia

that align with the mixture of distribution hypothesis, suggesting that trading volume carries substantial informational content. These results reinforce the view that emerging markets exhibit slower adjustment to shocks.

Finally, persistence is also evident in risk measures and asset pricing. Caporale et al. (2024) examined the persistence of realized betas in the CAPM framework and reported strong persistence at daily and weekly frequencies, with only weak mean reversion at monthly intervals. This suggests that beta values are heavily influenced by past movements, making short-term risk assessments sensitive to memory effects, a critical consideration for portfolio managers relying on beta stability for asset allocation and hedging. Extending the assessment to European equity markets, Caporale et al. (2024) found that stock returns and volatility display long-memory characteristics at higher frequencies, and their conclusion that many stock indices behave as $I(1)$ processes supports the idea that price changes follow a random walk, consistent with the EMH, although persistent volatility patterns suggest clustering behaviour.

3. Methodology

The analysis in this paper is based on the concept of long-range dependence (Beran, 1994). A covariance stationary process is said to display this property, also known as long memory, if its spectral density function, which is the Fourier transformation of the autocovariances, displays at least one singularity in the interval $[0, \pi)$. In many cases, this singularity occurs at the zero frequency, which implies very persistent cycles. A relatively simple model to capture this type of behaviour is the one based on fractional integration. Specifically, a process $[x(t), t = 0, \pm 1, \dots]$ is said to be fractionally integrated of order d , or $I(d)$ if it admits the following representation,

$$(1 - L)^d x(t) = u(t), \quad t = 1, 2, \dots, T, \quad (1)$$

where L is the lag-operator, i.e., $L^m x(t) = x(t-m)$, and $u(t)$ is $I(0)$ or integrated of order 0 and can be expressed as an uncorrelated white noise process or as a (weakly) autocorrelated one as in the AutoRegressive Moving-Average (ARMA) type of models. Note that under the specification given by (1), the spectral density function of $x(t)$ is given by:

$$f(\lambda) = \frac{\sigma^2}{2\pi} \left| \frac{1}{1 - e^{i\lambda}} \right|^{2d},$$

implying that $f(\lambda) \rightarrow \infty$ as $\lambda \rightarrow 0$.

In this paper we assume that $x(t)$ are the errors in a linear regression model that includes an intercept and a time trend, i.e.,

$$y(t) = \beta_0 + \beta_1 t + x(t), \quad (2)$$

where $y(t)$ stands for the observed data.

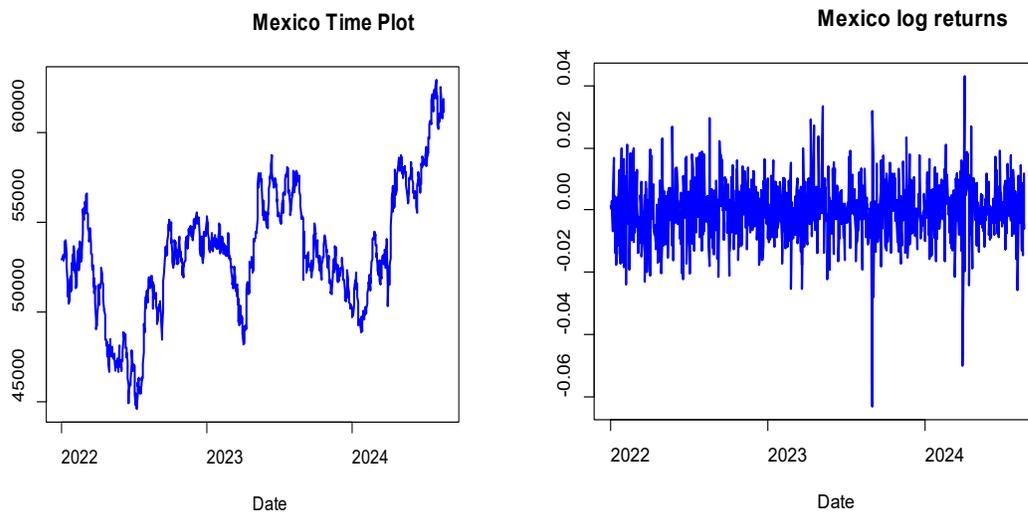
Using (1) and (2), we test the null hypothesis:

$$H_0: d = d_0, \quad (3)$$

for a set of values of d_0 from -2 to 2 with 0.01 increments, using a very simple version of a testing procedure developed in Robinson (1994) and whose specific functional form can be found in Gil-Alana and Robinson (1997). The reason for using this method is its advantages with respect to other approaches. In particular, it is the most efficient one in the Pitman sense against local departures from the null. Moreover, it has a null limit distribution which is standard normal, and this behaviour holds independently of the inclusion of deterministic terms as in (2); finally, the fact that d_0 may be any real value implies that this method is valid even in nonstationary contexts, without the need to take differences of nonstationary data.

4. Data Description and Empirical Results

The four series analysed are the Mexican MXX, Indonesian JKSE, Nigerian NGE, and Turkish MSCI stock indices. The frequency is daily, and the sample goes from 1 January 2022 to 31 October 2025. The data were retrieved from Yahoo finance. The original series and their log returns are displayed in Figure 1 below, whilst Table 1 reports some descriptive statistics for both. There are sizeable differences between maximum and minimum values, especially in the case of Mexico. The standard deviation implies that stock prices are most volatile in Mexico, followed by Indonesia, Nigeria and Turkey in that order.



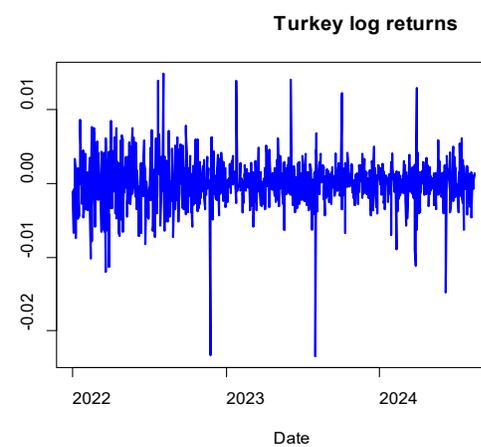
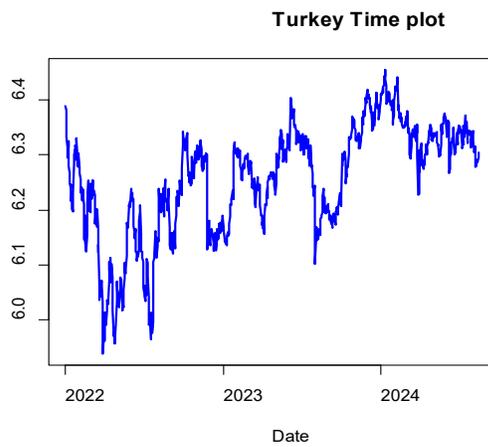
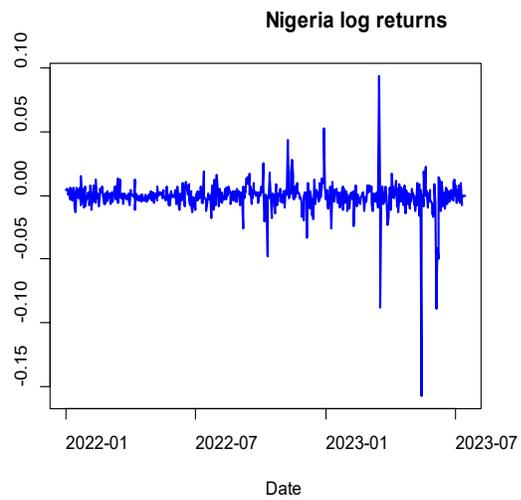
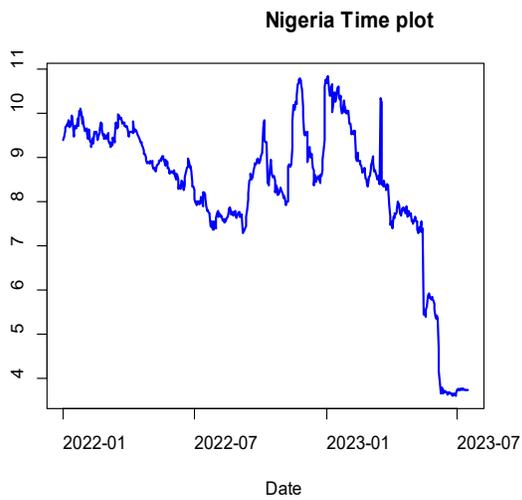
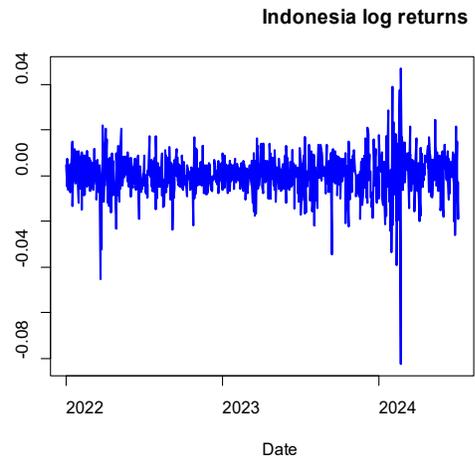
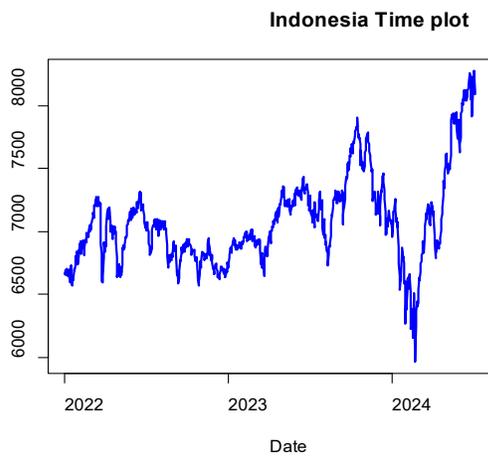


Figure 1: Plots of series and their log-returns

Table 1: Descriptive Statistics

	Original series				Log returns series			
	Min	Max	Mean	Std. dev.	Min	Max	Mean	Std. dev.
Mexico	44627	62916	53265	3477	-0.0631	0.0430	0.0002	0.0098
Indonesia	5968	8274	7078	367	-0.0823	0.0468	0.0002	-
Nigeria	3.63	10.83	8.344	1.66	-0.1573	0.0937	-0.0009	0.0129
Turkey	5.938	6.455	6.254	0.10	-0.0234	0.0148	-0.00001	0.0032

Tables 2 and 3 report the estimates for d with the corresponding confidence intervals for three model specifications (namely without regressors, with an intercept only, and with an intercept as well as a linear time trend) for the original stock indices, their logs, and their log-returns under the assumption of white noise and autocorrelated errors respectively. The values in bold are those for the specification selected on the basis of the statistical significance of the regressors.

Table 2: Fractional integration results on Stock Prices. White noise errors

i) Original data			
Original	No terms	With an intercept	With time trend
Mexico	1.001 (0.968, 1.054)	0.982 (0.943, 1.033)	0.982 (0.941, 1.028)
Turkey	0.967 (0.920, 1.019)	0.957 (0.918, 1.006)	0.957 (0.919, 1.008)
Nigeria	1.007 (0.951, 1.064)	1.004 (0.952, 1.077)	1.004 (0.951, 1.075)
Indonesia	0.989 (0.953, 1.035)	0.969 (0.923, 1.013)	0.969 (0.924, 1.014)
i) Logged data			
Log	No terms	With an intercept	With time trend
Mexico	0.996 (0.957, 1.042)	0.985 (0.943, 1.033)	0.985 (0.942, 1.033)
Turkey	0.991 (0.951, 1.038)	0.966 (0.920, 1.017)	0.965 (0.920, 1.017)
Nigeria	1.003 (0.952, 1.066)	1.055 (1.002, 1.121)	1.055 (1.002, 1.122)
Indonesia	0.995 (0.955, 1.041)	0.962 (0.921, 1.011)	0.961 (0.920, 1.011)
iii) Log returns			

Log	No terms	With an intercept	With time trend
Mexico	-0.015 (-0.063, 0.032)	-0.016 (-0.066, 0.033)	-0.018 (-0.065, 0.034)
Turkey	-0.035 (-0.083, 0.011)	-0.035 (-0.084, 0.012)	-0.035 (-0.085, 0.011)
Nigeria	0.055 (0.003, 0.122)	0.055 (0.003, 0.123)	0.045 (0.002, 0.111)
Indonesia	-0.037 (-0.072, 0.010)	-0.037 (-0.073, 0.011)	-0.038 (-0.073, 0.008)

The values in parenthesis are the 95% confidence bands of the non-rejection values of d . Those in bold indicate the selected specification for each series on the basis of the statistical significance of the deterministic terms.

Table 2 shows that, with white noise errors, the estimates of the differencing parameter d are close to 1 in virtually all cases for the stock indices. In the case of the logged values the estimate of d is significantly higher than 1 only for Nigeria. Finally, for the log returns, the estimates are close to 0 for Mexico, Turkey and Indonesia and significantly above 0 for Nigeria, thus indicating long memory behaviour in the latter. This evidence is consistent with the estimate above 1 for the log prices in this country.

Table 3: Fractional integration results on Stock Prices. Autocorrelated errors

i) Original data			
Original	No terms	With an intercept	With time trend
Mexico	0.986 (0.938, 1.064)	0.962 (0.880, 1.035)	0.962 (0.882, 1.036)
Turkey	0.907 (0.840, 0.987)	0.892 (0.815, 0.958)	0.892 (0.815, 0.958)
Nigeria	0.984 (0.891, 1.094)	0.911 (0.845, 0.997)	0.911 (0.839, 0.997)
Indonesia	0.977 (0.923, 1.045)	0.944 (0.873, 1.035)	0.944 (0.874, 1.034)
i) Logged data			
Log	No terms	With an intercept	With time trend
Mexico	0.987 (0.937, 1.077)	0.956 (0.893, 1.044)	0.956 (0.893, 1.044)
Turkey	0.974 (0.915, 1.058)	0.892 (0.830, 0.982)	0.892 (0.830, 0.982)
Nigeria	0.994 (0.914, 1.090)	0.977 (0.902, 1.054)	0.977 (0.902, 1.054)
Indonesia	0.988 (0.925, 1.063)	0.930 (0.861, 1.012)	0.930 (0.861, 1.012)
iii) Log returns			

Log	No terms	With an intercept	With time trend
Mexico	-0.048 (-0.103, 0.031)	-0.048 (-0.104, 0.031)	-0.051 (-0.111, 0.033)
Turkey	-0.107 (-0.163, 0.012)	-0.107 (-0.164, 0.014)	-0.107 (-0.165, 0.013)
Nigeria	0.023 (0.093, 0.055)	0.023 (0.093, 0.060)	-0.049 (-0.124, 0.037)
Indonesia	-0.068 (-0.122, 0.012)	-0.069 (-0.122, 0.013)	-0.070 (-0.122, 0.008)

The values in parenthesis are the 95% confidence intervals of the non-rejection values of d . Those in bold indicate the selected specification for each series on the basis of the statistical significance of the deterministic terms.

Table 3 shows that, with autocorrelated errors, the results change slightly. Specifically, the estimates of d are now slightly lower than before, and evidence of mean reversion is found in the cases of Turkey ($d = 0.892$) and Nigeria (0.911) with the original data, and again for Turkey ($d = 0.892$ with the logged values). As for the log-returns, the estimates of d support the $I(0)$ hypothesis.

To check robustness, we also use alternative fractional integration methods such as the semiparametric log-periodogram regression proposed by Geweke and Porter-Hudak (GPH, 1983) and extended by Robinson (1995), Velasco (2000) and others, as well as local Whittle methods as in Shimotsu and Phillips (2005). The results (not reported for reasons of space), despite being somewhat sensitive to the bandwidth parameters, are broadly consistent with those obtained before.

Next, we test for the possible presence of breaks in the series. This is an important issue as several studies have pointed out that ignoring the presence of non-linearities and/or breaks in the data may cause long memory as a spurious phenomenon (Diebold and Inoue, 2001; Granger and Hyung, 2004; Bisaglia and Gerolimetto, 2009). Table 4 reports the results of the Bai and Perron (2003) tests for multiple endogenous breaks in the stock indices. Four breaks are detected in both Nigeria and Turkey, and three and five in Indonesia and Mexico respectively. These breaks appear to correspond to well-known policy changes in the case of Nigeria as well as to the period of

uncertainty caused by the Russia-Ukraine conflict, especially in the case of Turkey. In Mexico they might also be related to trade policy shifts. Supply chain disruptions resulting from the Russia-Ukraine war are also significant factors explaining the breaks in Nigeria, Mexico and Indonesia, the latter being a major exporter of coal.

Table 4: Results of the Bai and Perron’s (2003) test for structural breaks in the stock indices

Series	Number of breaks	Break dates
Mexico	5	6/06/2022; 11/01/2022; 12/07/2023; 6/03/2024; 4/23/2025
Indonesia	3	12/06/2022; 11/30/2023; 12/17/2024
Nigeria	4	6/14/2022; 10/13/2022; 3/31/2023; 11/28/2023
Turkey	4	1/11/2023; 11/15/2023; 8/06/2024; 3/04/2025

Finally, we re-estimate the models for the subsamples based on the detected breaks.

Table 5 reports the results under the assumption of autocorrelated errors.

Table 5: Fractional integration results for the stock indices by subsample

i) Mexico			
Subsamples	d ((95% band)	Intercept (tv)	Time trend (tv)
1 st subsample	0.964 (0.756, 1.289)	10.876 (1024.95)	---
2 nd subsample	0.902 (0.707, 1.155)	10.788 (1045.11)	---
3 rd subsample	1.004 (0.882, 1.157)	10.830 (1191.193)	---
4 th subsample	0.868 (0.692, 1.084)	10.954 (1091.32)	---
5 th subsample	0.942 (0.811, 1.112)	10.867 (1078.63)	---
6 th subsample	0.793 (0.606, 1.073)	10.965 (1467.77)	0.0007 (2.15)
ii) Indonesia			

Subsamples	d ((95% band)	Intercept (tv)	Time trend (tv)
1 st subsample	1.084 (0.903, 1.312)	8.804 (1085.69)	---
2 nd subsample	0.932 (0.804, 1.137)	8.830 (1461.79)	---
3 rd subsample	0.978 (0.844, 1.152)	8.889 (933.90)	---
4 th subsample	0.601 (0.354, 0.862) ^{MR}	10.954 (765.66)	0.0016 (6.02)
iii) Nigeria			
Subsamples	d ((95% band)	Intercept (tv)	Time trend (tv)
1 st subsample	0.767 (0.506, 1.109)	2.245 (205.03)	---
2 nd subsample	0.755 (0.422, 1.228)	2.187 (207.74)	-0.0015 (-3.40)
3 rd subsample	0.880 (0.673, 1.132)	2.036 (98.68)	0.0022 (1.97)
4 th subsample	0.674 (0.531, 0.865) ^{MR}	2.346 (92.52)	-0.0019 (-4.08)
5 th subsample	0.920 (0.606, 1.367)	2.012 (46.07)	-0.0105 (-2.62)
iv) Turkey			
Subsamples	d ((95% band)	Intercept (tv)	Time trend (tv)
1 st subsample	0.923 (0.771, 1.112)	6.383 (261.84)	---
2 nd subsample	0.832 (0.709, 0.981) ^{MR}	6.249 (357.04)	---
3 rd subsample	0.911 (0.790, 1.078)	6.231 (304.80)	---
4 th subsample	0.738 (0.594, 0.930) ^{MR}	6.332 (434.96)	---
5 th subsample	0.587 (0.392, 0.887) ^{MR}	6.294 (552.92)	---

It can be seen that mean reversion (i.e., statistical evidence of $d < 1$) occurs in a number of cases, specifically in Indonesia (5th subsample), Nigeria (4th subsample) and Turkey (2nd, 4th and 5th subsamples). In the other cases, the unit root null hypothesis cannot be rejected. These results suggest more inefficiencies during the most recent period characterised by geopolitical instability. Very similar results (not reported to save space) were obtained when using the log prices, the number of breaks and the break dates being almost the same as those for prices themselves.

Table 6 shows the break test results for the log-return series. In this case only a single break is detected in Nigeria in September 2023, with the order of integration being close to 0 in both subsamples, and negative in the second one.

Table 6: Results of the Bai and Perron’s (2003) test for structural breaks on Log returns

Series	Number of breaks	Break dates
Mexico	0	-
Indonesia	0	-
Nigeria	1	14/09/2023
Turkey	0	-

Table 7: Fractional integration results for the log-returns by subsample

Nigeria			
Subsamples	d ((95% band)	Intercept (tv)	Time trend (tv)
1 st subsample	0.023 (-0.124, 0.211)	---	---
2 nd subsample	-0.052 (-0.238, 0.264)	-0.0083 (-2.93)	---

5. Conclusions

This paper applies fractional integration methods to investigate persistence in the stock markets of the MINTS countries over the period from 1 January 2022 to 31 October 2025. This approach is more general than standard ones based on the dichotomy between stationary and nonstationary series and sheds light on the long-memory and persistence properties of the series of interest, the possible occurrence of mean reversion, the speed of the adjustment towards the long-run equilibrium, and the permanent or transitory nature of the effects of shocks. It is particularly appropriate for countries such as those examined where structural rigidities are likely to result in log memory. The analysis is carried out using different model specification, estimation methods,

and assumption about the errors, for the stock indices themselves, their logs and their log returns. Tests for structural breaks are then performed and estimates are obtained also for the corresponding subsamples.

Evidence of mean reversion is found for most of the series with autocorrelated errors; this implies that the effects of shocks are temporary, with the series of interest reverting to their long-run equilibrium over time. The structural break tests and the subsample analysis point to greater inefficiencies in the most recent period characterised by geopolitical instability, mainly caused by the Russia-Ukraine conflict, especially in the case of Mexican stock market.

Future work should also consider nonlinear specifications, still in a long-memory context, allowing for a more gradual evolution of the relevant parameters such as those based on Chebyshev polynomials in time or Fourier functions as in Cuestas and Gil-Alana (2016) and Gil-Alana and Yaya (2021). Stochastic non-linear long-memory models are currently being developed and could also be used in future work.

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