sciendo

UDC: 336.748.12:339(100)
DOI: 10.2478/jcbtp-2025-0002

Journal of Central Banking Theory and Practice, 2025, 1, pp. 21-42
Received: 14 December 2023; accepted: 7 June 2024

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Reassessment of Structural Changes in Financial Markets: The Direct Impact of Central Banks[1]

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Abstract: The evidence of financial globalization and the rapid and uniform contagion that it entails among the different international financial markets, have been exposed after the 2008 crisis outbreak, as well as the different chapters of financial stress that have been experienced since then, such as the sovereign debt crisis, the Brexit event, the COVID-19 pandemic, and the war in Ukraine. Despite these specific episodes, volatility in the post-subprime crisis period has been low in historical terms due, among many other factors, to the monetary policies of central banks which, with their increases in the money supply and low interest rates, have led to a change of substance and form in the financial markets, not only at a national level but also at a supranational level. However, after the COVID-19 pandemic and the outbreak of the war in Ukraine, inflation appeared abruptly putting central banks in an uncomfortable situation, which have been forced to raise interest rates quickly and forcefully. In this paper, an estimation and quantification of the pre-pandemic and post-pandemic volatility thresholds is carried out for each of the main stock market indices to estimate the changes in these borders that affect and determine different degrees of financial contagion. Additionally, this study may determine the potential causal relationship between the change in the balance sheets of the main central banks and market volatility. If such relationships exist, it could un-

[1] The authors would like to thank David Álvaro Berlanga and Adrián Pérez Cosculluela, members of the GVC Institute, for their collaboration.

doubtedly mark a before and after in the implementation of monetary policies by these banking entities.

Keywords: Central bank balance sheet, systemic risk, financial contagion, stock market volatility, VAR analysis, financial crisis.

JEL Classification: C22, C58, E52, E58, G01

1. Introduction

Since the turn of the century, financial markets have undergone a profound transformation. Events such as the 2008 crisis have highlighted the impact of financial globalization on the spread of faster and more uniform financial contagion across economies (Beck, Demirgüç-Kunt & Levine , 2009). Environmental factors, deregulation, financial disintermediation, and the evolution of information and communication technologies have favoured greater interconnection between agents. One more factor to consider is that after the COVID-19 pandemic and the deep digitalization in investments, it is evident that social networks act as a catalyst in the behaviour of investors, adding signs of instability in the financial system, which has undoubtedly influenced the current banking events of 2023.

The result of this new framework, mainly due to financial deregulation, has generated a significant increase in the international mobility of capital, facilitating a more efficient allocation of resources worldwide, a greater diversification of risks, and a stimulus to the growth of emerging market economies (Mishkin, 2009). Consequently, the elimination of frontiers between different intermediaries and markets has led to an increasingly versatile offer of both financial products and services.

On the other hand, greater deregulation has also led to greater market complexity and, consequently, greater instability, interpreted as a consistent increase in financial market volatility. In this sense and during the post-subprime crisis period, volatility has been low by historical standards but it has nevertheless revealed that this transformation of capital markets has also provoked chapters of high volatility at specific moments such as the sovereign debt crisis, the Brexit, the pandemic and, more recently, the war between Russia and Ukraine. All these events are global and very relevant episodes, which have reflected uniform and very notable increases in volatility, neutralized only in part by the unconventional monetary policy adopted by different central banks.

Volatility is a concept that implies variability or instability in prices. It does not necessarily imply changes in the average, but rather a greater dispersion around that average and, therefore, volatility is sensitive to the flow of data that impacts and determines the formation of prices. Thus, if positive or negative changes are observed in stock prices, volatility will increase or decrease depending on the relative magnitude of those variations concerning the average. If we look at the history of the main stock market indexes of the different financial markets, we can see that those with a higher degree of development tend to have lower volatility than less developed markets, something that has already been mentioned in previous research (Piffaut and Rey Miró, 2019).

Against this background, this paper attempts to contrast two objectives; the first one is to study how the volatility threshold of the main pre- and post-pandemic indices has changed after central bank intervention, and the second, is to detect a plausible causal relationship between central bank balance sheet changes and increased volatility in financial markets.

2. The transformation of financial markets

Financial globalization understood as the mutual and growing financial dependence between countries, has allowed any change occurring in one latitude to be quickly reflected on the other side of the world. Similarly, the monetary policy applied by major central banks during the post-crisis periods, such as increases in money supply and low interest rates, have transformed financial markets worldwide, reflecting not only a change of substance and form in the markets themselves but also in the behaviour of investors.

The first substantial change has been the size of the market, which was brought about by the new instruments developed by the central banks themselves, which are active participants in many of the underlying assets. Undoubtedly, globalization, defined as the growing integration and interconnection of various domestic markets into a single international financial market, has considerably changed the economic environment, as well as modified the financial system, and has also been a catalytic agent in this process. In this sense, the monetary policies of the different central banks have caused monetary base increases to homologate different assets in markets in other latitudes.

Whereas in the past most stock exchanges around the world were limited by national borders and their specific industries (for example, the Spanish stock exchange was a market made up mainly of banks and electricity generating companies), nowadays we can observe an international expansion of financial markets and an increasingly strong consolidation of global financial exchanges, which has led to monetary policies having a supranational scope and impact. In addition, there is a growing trend towards the creation of broader, global indexes such as the MSCI World or the FTSE Global All Cap, indexes that cover a wider range of stocks from different regions.

A clear sign of this sensitivity is the stock market indexes of different financial centers, where a higher degree of correlation between these different assets is observed, evidence that they are increasingly interrelated. Therefore, the risks of financial globalization together with monetary policies have conditioned a change in the contagion effect, and in the transmission, mechanisms triggered during a period of financial instability, affecting all those involved and with relevant effects according to the degree of dependence between the different markets, especially after the occurrence of a major economic or financial event. Therefore, the interconnection between markets and the behaviour of financial institutions has led to a faster propagation of financial crises, as well as an important change in the transmission dynamics.

Another relevant point of analysis is the effect that large financial corporations have on systemic risk, a threat that is becoming increasingly greater as large corporations and multinational conglomerates exert greater influence on the global economy. Indeed, significant price movements by these entities have the potential to trigger exceptional volatility in financial markets and, therefore, the impact that the high concentration in terms of the market capitalization of these companies can have on the stability of the entire financial system (Gabaix, 2011).

For example, it is enough for one of these companies to suffer a financial setback or a problem in its data for the effects to spread throughout the global financial system, basically due to its importance and relative weight in one or more market indexes (Farboodi and Veldkamp, 2023). All the above has led to the growth in size of the most important stock exchanges, such as the American or British, due to the creation and presence of large financial conglomerates and multinational corporations.

Such magnitudes, in concomitance with increases in central bank balance sheets, make the size of financial markets as large in terms of valuation and number of assets as they have ever been in the economic history of the world. As a result, diversification, a fundamental principle for investment, may be threatened as these companies continue to dominate the financial spectrum, where investors are increasingly exposed to the specific risks of these same companies (Stulz, 2023).

Therefore, regulators and financial entities must continue to limit their influence on the indexes, managing these risks effectively to maintain the stability of the financial system. A very specific example of the above is reflected in Table 1, which shows the weight of market capitalization by country. Delving a little deeper into the change in financial markets, concepts such as social internetwork show how companies are interconnected with each other, revealing that more than 600 companies, among those listed on the stock exchange, have common financial links so that a single message or error can affect all of them in a matter of minutes. About 92% of the global economy is in one way or another indirectly connected, with which it can be concluded that firms are fully exposed to contagion events (Al Guindy and Riordan, 2019).

Table 1: Global Market Capitalization

Country	Capitalization	Percentage
USA	$40.0b	59%
Japan	$4.1b	6%
United Kingdom	$2.6b	4%
China	$2.5b	4%
Canada	$2.1b	3%
France	$1.8b	3%
Switzerland	$1.6b	2%
India	$1.4b	2%
Australia	$1.4b	2%
Germany	$1.3b	2%

Source: Dimensional Funds

Additionally, HFT (High Frequency Trading) platforms have also caused the volume and speed of transactions to increase asset price movements. This undoubtedly increases the contagion effect between markets and can cause a distorting effect on prices, so that a systemic event in a specific market quickly spreads beyond its borders. By the same token, when the Federal Reserve begins large-scale purchases of US Treasury securities, it can distort the correlation between nominal yields and Treasury Inflation Protected Securities (TIPS) yields (Allen and Hein, 2023).

3. The transformation of the traditional investor into a digital investor

While the markets have changed, the investor has also changed in the same proportion or even more. The change from the concept of a traditional investor to that of a digital investor is a measure that has been expanding strongly since the great subprime crisis of 2008. The use of digital platforms and online management through smartphones is undoubtedly a phenomenon that has changed the modus operandi of financial markets. Phenomena such as network trading, social networks, and the increased capacity for data analysis in decision-making are factors that should be considered as future systematic risks for the financial market itself.

On the other hand, social networks have amplified asset movements and are an influential factor in decision-making, being a clear threat to investor behaviour (Kuchler and Stroebel, 2021). Concepts such as social trading or opinions in networks or group membership and the influence that group behaviour has on the individual have been the subject of academic studies for several decades (Tajfel and Turner, 1980). This is the reason why social networks, such as X (the former Twitter), are entities that can induce and incur a manipulation problem in such markets. The increasingly frequent presence of extremes in terms of a normal distribution of financial asset prices is not surprising.

Studies such as those of the University of California or Boston University show that information through social networks can lead to a higher correlation between the prices of financial assets, which also increases the probability of greater systemic risk in financial markets. Consequently, the amount of information available on social networks may also have effects on market volatility (Lehrer, Xie and Zhang, 2021). In summary, studies suggest that social networks have amplified the influence of information and the spread of fake news in financial markets, which may increase market volatility and risk.

Human beings are social beings who also fear being excluded from certain groups of belonging and losing the opportunity to be part of an experience determined and often conditioned by the group itself. The spread of social networks has given way to a psychological phenomenon that will increasingly occur in the digital age. Behavioural finance, led by the studies of Kahneman and Tversky, introduced the concept of cognitive biases in financial decision-making (Kahneman and Tversky, 1979). Studies such as the one conducted by Hirshleifer show that people often prefer to invest in assets that are popular or fashionable, rather than those that are more profitable or suitable for their risk profile, simply because of the influence that their belonging group exerts on them (Hirshleifer, 2001).

All the above leads us to reflect that "forward guidance" and the ability to transmit the message are becoming increasingly relevant in monetary policy. In short, forward guidance is the use of communication about the central bank's future actions to influence current behaviour. If a central bank can convince markets that it will leave interest rates low for quite some time, allowing for a faster recovery in the future than it would normally tolerate, then investors will have an incentive to start investing more in the present to reap the benefits of that future bonanza. However, recent studies indicate that due to the multiplicity of factors, the results of forward guidance by central bank authorities are far from being equally useful for predicting future changes in monetary policy (Lehtimäki and Palmu, 2022).

This type of guidance predates the global crisis and was born in the late 1990s when the Bank of Japan, in its eagerness to escape its economic stagnation, pledged to leave interest rates at zero until concerns about deflation in the Japanese economy abated. Forward guidance can be an effective tool to stabilize the economy and avoid excessive economic fluctuations, especially in an environment where interest rates have been low for a long time (Müller, Christoffel, Mazelis & Montes-Galdón, 2022). In the same vein, forward guidance can have a significant impact on financial markets, including interest rates, exchange rates and asset prices (Lars, 2015). All these aspects should be considered as a tool that will undoubtedly play a more important role in the coming years.

Another topic that is sure to be of great importance is the development of artificial intelligence. The application of artificial intelligence tools in the financial sector is already a tangible reality and will continue to grow due to the increase in computing capacity. Undoubtedly, all this progress will attract benefits but also risks if these are used automatically and without a process of reinforcement and validation in decisions (Fernández, 2019). The path towards automation shows a new field of analysis regarding new opportunities that previously could not be detected. It is for this reason that monetary authorities need to continue implementing micro and macro-prudential supervision in real time for the management of financial markets. Artificial intelligence and machine learning can enhance the monitoring of AML suspicious transactions by identifying patterns and anomalies often missed by traditional methods (Vučinić & Luburić 2024).

4. Methodology and data

Having defined the theoretical foundations that motivate this research, the present study is developed based on two well-defined objectives. The first objective is to determine the change in volatility thresholds in response to the monetary policy applied during the COVID-19 pandemic, which began in March 2020. The impact of this policy is estimated and evaluated through the development of an index-specific threshold regression model.

The second objective is broader and more challenging, and its purpose is to determine the possibility of causal relationships between central bank balance sheets and market volatility. At the same time and due to the evidence of financial contagion and interdependence between different financial markets at the global level, these correlations should also exist between the different stock market indexes, as was made known in previous research (Piffaut and Rey Miró, 2017; Rey Miró and Piffaut, 2018). For the fulfilment of this second objective, we proceed to the estimation of vector autoregressive models (VAR) and the Granger test to determine the possible causal relationships and interrelationships between changes in central bank balance sheets and stock market volatility.

The data corresponds to stock price values, returns, volatilities, VIX, and balance sheets of the respective central banks for the seven major financial markets. The sample includes developed economy indices such as the S&P500, NIKKEI225, FTSE100, DAX30, IBEX35, CAC40, and EUROSTOXX50, from the United States, Japan, the United Kingdom, Germany, Spain, France, and Europe, respectively. Unfortunately, it is not possible to include China and India in this analysis due to the lack of data with enough observations. The same limitation applies to emerging markets in Latin America.

Each series begins on May 3, 2013, and runs through May 4, 2023, for 524 weekly data points. The data is also complemented by the VIX series for the same period. In this regard, VIX is the ticker or abbreviation used to uniquely identify the Chicago Board Options Exchange Market Volatility Index. The VIX is a number derived from option prices contained in the S&P500 index and is a good indicator of global market volatility expectations. Table 2 summarizes the key statistics for the quoted values of the seven stock market indexes, including the VIX series for the same period.

Table 2: Main Statistics

S&P500	N	Average	Std. dev.	Minimum	Maximum
Stock Index	524	2828	875	1597	4783
Volatility	524	0.14	0.10	0.04	0.96
VIX	524	18.05	7.14	9.34	74.62
Federal Reserve	524	4595615	1071321	3059845	7118065
NIKKEI225	N	Average	Std. dev.	Minimum	Maximum
Stock Index	524	21348	4628	13051	30491
Volatility	524	0.18	0.08	0.06	0.59
VIX	524	18.05	7.14	9.34	74.62
BC Japan	524	45055	14466	16927	68805
FTSE100	N	Average	Std. dev.	Minimum	Maximum
Stock Index	524	6938	525	5174	7983
Volatility	524	0.14	0.08	0.04	0.73
VIX	524	18.05	7.14	9.34	74.62
BC United Kingdom	524	701574	217899	481353	1194679
DAX30	N	Average	Std. dev.	Minimum	Maximum
Stock Index	524	11984	2039	7879	16206
Volatility	524	0.17	0.09	0.05	0.78
VIX	524	18.05	7.14	9.34	74.62
BC Europe	524	1889361	1520472	88986	4766311
IBEX35	N	Average	Std. dev.	Minimum	Maximum
Stock Index	524	9239	1078	6344	11701
Volatility	524	0.18	0.09	0.06	0.83
VIX	524	18.05	7.14	9.34	74.62
BC Europe	524	1889361	1520472	88986	4766311
CAC40	N	Average	Std. dev.	Minimum	Maximum
Stock Index	524	5260	885	3695	7539
Volatility	524	0.17	0.09	0.04	0.80
VIX	524	18.05	7.14	9.34	74.62
BC Europe	524	1889361	1520472	88986	4766311
Eurostoxx50	N	Average	Est. dev.	Minimum	Maximum
Stock Index	524	3429	393	2474	4390
Volatility	524	0.17	0.09	0.05	0.79
VIX	524	18.05	7.14	9.34	74.62
BC Europe	524	1889361	1520472	88986	4766311

Source: BSE and CBOE. Weekly data for the period May 2013 - May 2023.

Regarding frequency, while financial market data are high frequency with daily values of quotes, volatilities, and returns, the data used in the respective econometric models correspond to weekly frequency data. The reason behind this approach to data frequency lies in the fact that while high-frequency data, such as daily data, are rich in information, weekly frequency data provide, in the authors' judgment and experience, the ideal combination given that 52 annual observations are sufficient to capture market swings and events, avoiding the deep variations during episodes of euphoria and panic in the financial markets.

As usual, when analyzing time series data, the presence of unit roots must be considered in both index series and central bank balance sheet data. In the case of financial series, returns are obtained from the logarithmic difference between the present value and its first lag, which makes the series naturally stationary. However, for the case of stock price values, volatilities, VIX, and central bank balance sheets, it is necessary to perform the respective unit root tests. The unit root tests applied are the traditional Dickey-Fuller ADF test (Dickey and Fuller, 1979), the PP test (Phillips and Perron, 1988), and the KPSS test which takes stationarity as the null hypothesis (Kwiatkowski, Phillips, Schmidt and Shin, 1992).

Nevertheless, and as Perron (1989) points out, unit roots and structural change in series are closely related considering that conventional unit root tests, such as those already noted, are biased towards a spurious null unit root, especially when the data are trend stationary with a structural break such as stock price data or central bank balance sheet data. This observation made by Perron has stimulated the development of a large literature describing unit root tests that remain valid in the presence of a structural break (; Zivot and Andrews, 1992; Banerjee, Lumsdaine & Stock, 1992; Vogelsang and Perron, 1998; Hansen, 2001).

Consequently, and applying the unit root tests for time series with structural break probability in its two versions, Innovative Outlier unit root and Additive Outlier unit root, we find the presence of unit roots for all the stock price series and for the balance sheets of the central banks of Japan (BOJ) and Europe (ECB). Therefore, these series should be included in first-order differencing in the respective econometric models.

Regarding structural crashes, it is interesting to note that most of these events are concentrated between the final weeks of 2019 and throughout 2020, the period during which the most critical stage of the COVID-19 pandemic unfolded. The exception to this rule is Japan, whose structural crashes are mostly concentrated during the second half of 2015, a period in which the Japanese economy, and particularly the Bank of Japan (BOJ), applied extraordinary and unconventional measures to combat the deflationary process of its economy. As also noted by Ongan and Gocer, these changes in the monetary base may lead to different sizes or sign impacts on the money supply in a nonlinear manner (Ongan and Gocer, 2023). Continuing with the case of the series used in this research and which present a unit root, these have been included in first-order differencing and, therefore, are stationary time series. However, even when there is no unit root in the complete series, it may be the case that unit roots are present in certain segments of the series.

5. Determination of regions and volatility limits in the financial markets

Following the methodology described at the beginning of this section, an estimation and quantification of the volatility thresholds for each of the five markets is carried out. The estimation is done on the basis and implementation of threshold regression models which, unlike Markov-Switching models, assume that the transitions between states of a variable, volatility for the case of this study, are triggered by observable variables that at some point in time cross certain limits and the values of these limits can be estimated (Tong, 1983; Hansen, 1997; Gonzalo, & Pitarakis, 2002; Linden, 2017).

Formally, let's consider a threshold regression with two regions defined by a threshold γ as

$$y_t = x_t\beta + z_t\delta_1 + \epsilon_t \qquad if -\infty < w_t \leq \gamma$$
$$y_t = x_t\beta + z_t\delta_2 + \epsilon_t \qquad if \quad \gamma < w_t < \infty$$

Where y_t is the dependent variable, x_t is a vector of dimension *1xk* of covariates possibly containing lagged values of y_t, β is a $kx1$ vector of invariant parameter region, ϵ_t is an error of type IID (independent and identically distributed random variable) with mean zero and variance σ^2, z_t is a vector of exogenous variables with region-specific coefficients vectors δ_1 y δ_2 and finally w_t which is a threshold variable which can also be one of the variables in x_t or in z_t.

The parameters of interest in the model are represented by δ_1 y δ_2. Region 1 is defined as the subset of observations for whose value of w_t is less than the threshold value γ. Similarly, region 2 is defined as the subset of observations for which the value of w_t is greater than the threshold γ. Inference on the gamma parameter (γ) can be econometrically challenging due to its non-standard asymptotic distribution (see Hansen, 1997; Hansen, 2000).

A threshold regression uses conditional least squares to estimate the model parameters. Thus, by structuring a model that includes volatility and its lagged values as variables, as well as stock market returns, four models are estimated that include zero to three lags, of which two models compete: the 2 and 3 lagged volatility models. The overall model is structured as follows:

$$\Psi_t = \delta_{10} + \delta_{11} L.\Psi + \delta_{12} R + \varepsilon_t \qquad if -\infty < L.\Psi \leq \gamma \tag{1}$$

$$\Psi_t = \delta_{20} + \delta_{21} L.\Psi + \delta_{22} R + \varepsilon_t \qquad if \;\; \gamma < L.\Psi < \infty \tag{2}$$

Where Ψ represents volatility and R represents stock returns. The operator L indicates that it corresponds to the lag of the variable specified in the equation.

Consequently, for the proposed model defined by equations (1) and (2) and considering the usual information criteria (Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Hannan-Quinn Information Criterion (HQIC)), the best fitting model for all stock indexes is the threshold model with three lags for volatility and returns.

The values of the different models and criteria are presented in Table 3, while the results of the models are shown in Table 4, where the respective volatility threshold values are shown, which, as expected, show appreciable differences between the pre-pandemic and post-pandemic indices. As relevant information, it is observed that the largest differences between both thresholds correspond to the French CAC40, the EUROSTOXX50, and the German DAX30 with a difference of 14.50, 11.95, and 11.82, respectively, indices extremely sensitive to the decisions of their respective central banks. Regarding the same, it is not striking that the least affected index is Japan's NIKKEI225 with a difference of less than one. Such an explanation can be deduced from the high and aggressive intervention of the Bank of Japan (BOJ) in the economy. In this regard, as the central bank's balance sheet expands, its ability to influence interest rates through open market operations may be reduced, which is well reflected in the case of Japan (Cuñado, Pérez de Gracia & Rivas, 2005).

Finally, as can be seen in the results of Table 4 for each of the estimations, the Durbin-Watson statistic for serial autocorrelation of a lag is close to its ideal value of 2.0 or no less than 1.5, which validates the robustness of the models estimated in this section (Durbin & Watson, 1951).

Table 3: Selection Criteria Threshold Models

Stock Index	AIC 2Lags	AIC 3Lags	BIC 2Lags	BIC 3Lags	HQIC 2Lag	HQIC3Lags
Nikkei 225	-3723.28	-3750.82	-3684.96	-3712.52	-3708.27	-3735.81
FTSE 100	-3935.74	-3942.10	-3897.42	-3903.79	-3920.73	-3927.09
DAX 30	-3725.56	-3746.81	-3687.24	-3708.51	-3710.55	-3731.81
IBEX 35	-4121.11	-4123.46	-4082.79	-4085.15	-4106.10	-4108.45
CAC 40	-3879.55	-3892.96	-3841.23	-3854.66	-3864.54	-3877.95
EURO STOXX 50	-3872.86	-3873.71	-3834.54	-3835.41	-3857.85	-3858.70

Source: Models and values estimated by the authors

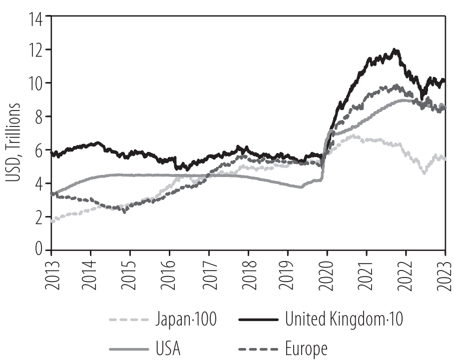
Table 4: Results Threshold Models

Stock Index	Pre-pandemic	Post-pandemic	Durbin-Watson
S&P 500	18.42	23.34	1.89
NIKKEI 225	24.88	25.78	1.77
FTSE 100	18.60	20.41	1.68
DAX 30	13.18	25.00	1.63
IBEX 35	20.42	26.35	1.72
CAC 40	9.96	24.46	1.69
EURO STOXX 50	13.89	25.84	1.64

Source: Models and values estimated by the authors

From the results in Table 4, it can be inferred that both the high volatility and the effect of the pandemic on the world economy restructured the volatility tolerance thresholds in practically all markets. Another factor that could induce higher volatility in the post-pandemic period has been the active role of central banks in maintaining the stability of the financial system and the economy, with unconventional and ultra-expansionary monetary policies, reflected in the high liquidity present in the post-pandemic world. Figure 1 details the evolution of the liquidity of assets on the balance sheet of the main central banks. For correct visualization, both the Federal Reserve and the ECB have been divided by one million, the BOJ figures by 10,000, and the BoE figures by 100,000.

Figure 1: Central Bank's Balance Sheet



Source: Refinitiv Datastream

In this sense, the main instruments of unconventional monetary policy have marked an unprecedented implementation plan, but despite having been implemented on a temporary and exceptional basis, they had and continue to have a great impact on the financial system. Undoubtedly, the dichotomy between conventional policy and balance sheet policy is not always clear in practice. Indeed, conventional policy actions may affect term premium, but, on the other hand, Quantitative Easing announcements often affect expected future rates, as suggested by several studies in the last decade (Woodford, 2012?/check references; Bauer and Rudebusch, 2014; Neely, 2015; Bhattarai and Neely, 2016).

Consequently, the Federal Reserve's asset purchase programs changed bond yields, especially during the first quantitative easing (QE). The quantitative easing implemented in 2020 after the outbreak of the pandemic marks a historic milestone in asset purchases and intervention. The active intervention of central banks by providing liquidity injections, expanding the list of eligible collateral, or outright purchases in the public and private fixed-income markets, known as quantitative easing or QE, has influenced not only market volatility but also the real economy, which has translated into a sharp increase in the price level, leading to a rise in inflation globally.

Empirical evidence has shown that any quantitative easing (QE) type measure alters long-term interest rates (Krishnamurthy and Vissing-Jorgensen, 2011). Another factor to consider is the communication and the orientation of monetary policy in the medium and long term. In this sense, the so-called forward guidance of central banks has created a clearer and more concise message for agents, translating into improved expectations on the part of participants, even though it does not lessen the effects of monetary expansion. Applying international standards is essential for effective project management in central banks (Vučinić & Luburić, 2023).

The empirical evidence necessarily leads to a relevant conclusion, and that is that the increase in all volatility thresholds has been and is induced by ultra-expansionary monetary policies that mark a scope of increasingly supranational character, Then, such monetary policies would have a greater impact on markets where central banks have made a more direct intervention policy, such as in the United States and Europe (Curcuru, Steven, Canlin & Rodriguez, 2018).

Such intervention by central banks after the pandemic has shown a disparate impact on the macroeconomic environment and financial markets. The macroeconomic environment has been reflected in the higher volatility of real economy indicators versus financial market indicators. The sustained increase in the price level, not seen since the 1980s, as well as rises and falls in industrial production unusual in previous economic cycles, are aspects that support the above. Similarly, in the latest post-COVID-19 interventions by the Federal Reserve and the European Central Bank, there has been an increase in market volatility, which would indicate that forward guidance by central banks will be increasingly important to maintain the stability of the system.

To conclude, after the fall of Lehman Brothers, the US experience notes that there have been discrepancies between market expectations and the path of the Federal Open Market Committee (FOMC) and such discrepancies are a systemic danger in the face of increasingly constant intervention by central banks (Curcuru et al., 2018).

6. Volatility of financial markets and its relation to central banks' balance sheet

In this section, Vector Autoregressive (VAR) models are implemented to determine the effect and the possible existence of a Granger-type causal relationship between changes in central bank balance sheets and financial market volatility. Previously, it was estimated and determined that the optimal number of lags for the proposed VAR models ranges between five and seven lags based on the usual information criteria (AIC, BIC, and HQIC), which indicates the present high persistence of volatility, extending its effects on financial markets for several weeks.

It is worth mentioning that before the implementation and estimation of the VAR models constructed in this study, Johansen's test was performed to determine the possible presence of cointegration in the series, that is, the existence of some mathematical relationship between two or more data series in the long run. The main results based on the trace test suggest, with a significance level of 0.05 or 5%, the presence of at least one cointegration equation for each of the estimated models.

Because of this cointegration between the series, the VAR equations are no longer a valid estimation and the models must necessarily be estimated using vector error correction equations (VEC), which allows the inclusion of that correction factor necessary for a correct estimation, derived precisely from the existence of cointegration in the series. Only after this correction has been made is the Granger causality test applied to establish possible causal relationships between changes in the balance sheet structure of central banks and the increase in volatility in market indices.

Based on the results of the VEC models, it is concluded that there is a Granger causality-type relationship between changes in the balance sheet structure of central banks and financial market volatility, for all the indices included in this analysis. It is also concluded that this relationship is statistically significant at the 5% level for the S&P500, DAX30, FTSE100, IBEX35, CAC40, and EUROSTOXX50 indexes and 10% for the NIKKEI225 index. Table 5 summarizes the results derived from the VEC models.

It is important to mention that this relationship is unidirectional for five of the seven cases, a relationship that moves from the volatility of stock market indices to the change in the balance sheet structure, i.e., higher volatility induces central banks to restructure their balance sheets to stabilize markets. In the case of Japan, this relationship is inverse in the sense that the causal relationship moves from the change in the central bank's balance sheet structure to volatility, which is in line with the BOJ's efforts to contain the deflationary process in its economy. The Bank of Japan's unconventional monetary policies, including near-zero and negative interest rates, can significantly alter the asset portfolios of economic agents. As a result, the money multiplier in Japan tends to be highly volatile and unstable, rendering the money supply uncontrollable or endogenous for the BOJ (Ongan and Gocer, 2023).

Table 5: Causality Relationship Volatility-Balance Sheet BC

Index	Causality	Address	Probability
S&P 500	Yes	Unidirectional	0.02
NIKKEI 225	Yes	Unidirectional	0.07
FTSE 100	Yes	Bidirectional	0.02 / 0.00
DAX30	Yes	Unidirectional	0.01
IBEX35	Yes	Unidirectional	0.05
CAC 40	Yes	Unidirectional	0,03
EUROSTOXX 50	Yes	Unidirectional	0.02

Source: Authors' elaboration from VEC model estimation

It is interesting to note that for the UK FTSE100 index, this relationship between changes in the central bank balance sheet and volatility is bidirectional, a relationship that is very likely to have been triggered by the Brexit event that began in 2016 and culminated on January 31, 2020. However, it is important to keep in mind that other factors may be influencing these relationships and for which there is no data or information available, but which will motivate future research work. Finally, the serial autocorrelation test was performed on all the VEC models, and no evidence of autocorrelation was found in the lag variables.

Conclusions

This research highlights several key insights, notably the profound impact of unconventional monetary policies on investors' risk perceptions. The shifts in upward volatility contagion thresholds observed across pre- and post-pandemic markets underscore the active role central banks play in maintaining financial stability through ultra-expansionary policies. Systematic intervention by central banks has effectively reshaped volatility tolerance thresholds in nearly all markets.

These findings emphasize the growing influence of monetary policy on financial markets. For instance, following the banking crises involving Silicon Valley Bank (SVB), Credit Suisse, and First Republic Bank, financial markets experienced only moderate, contained volatility spikes. This reflects the stabilizing effects of central bank interventions and reinforces the Granger causal relationship between balance sheet expansions and market volatility.

A noteworthy observation is the directionality of this relationship. In most cases, volatility drives balance sheet increases, except in the Anglo-Saxon market, where the relationship is bidirectional, and in Japan, where the directionality is reversed. The Anglo-Saxon market's bidirectional dynamic reflects heightened sensitivity to monetary and fiscal policy changes. In Japan, the unidirectional relationship—flowing from balance sheet increases to volatility—can be attributed to decades of aggressive deflation-fighting policies. These results suggest that central bank policies aimed at addressing specific economic conditions can influence volatility patterns uniquely across markets.

Importantly, if volatility primarily drives balance sheet expansions, it could signal rising market risks. This feedback loop—where volatility prompts central bank intervention, which may, in turn, exacerbate future volatility—raises concerns about market stability. Additionally, central banks' expanded role in financial markets signals a shift from being neutral arbiters to active participants, potentially undermining their independence.

Future research could explore critical questions, such as the optimal balance between a central bank's balance sheet size and GDP fluctuations. This is particularly relevant as central banks face challenges in reducing their balance sheets. Quantitative Tightening (QT) could introduce greater market volatility than seen during the post-COVID-19 period. Thus, balance sheet reductions must be gradual, passive, and predictable, with forward guidance playing an increasingly crucial role in mitigating uncertainty.

Finally, the credibility of central banks may be tested as they navigate the complexities of QT. Even with phased reductions, reliance on asset roll-offs or non-renewals could impact perceptions of institutional credibility and, by extension, monetary policy effectiveness. These considerations, along with the broader implications of central bank intervention, offer fertile ground for future research into the evolving dynamics of monetary policy and financial market interactions.

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