Financial Market Volatility Thresholds and its Interrelation with the Currency

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Abstract: The evidence of financial globalization, as well as the quicker and more uniform contagion between the different international financial markets, has been revealed after the outbreak of the crisis in 2007 and the different chapters of financial stress that have been experienced since then, such as the sovereign debt crisis and the Brexit. Despite these specific episodes, volatility in the post-crisis subprime period has been low in historical terms due, among many other factors, to the monetary policies of the central banks which with their increases in money supply and low interest rates have a fundamental change in the financial markets, not only at the national level but also at the supranational level. In the present work, an estimation and quantification of the volatility thresholds for each of the main indexes is carried out in order to contrast the frontiers that must be taken into account in each one of them and thus determine the possible degrees of contagion. Additionally, the degree of volatility interrelation between the financial market and the respective currencies is also determined.

Keywords: Systemic risk, contagion, developing countries, financial econometrics, stock market volatility, VAR analysis, implied volatility, financial crises predictability.

JEL Classifications: C51, C58, E44, F43, F31, C22, G01, G15, C32.

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1. Introduction

Since the beginning of the century, financial markets have undergone a profound transformation (Asli et al., 2009). The outbreak of the crisis in 2007 showed that financial globalization caused a faster and more uniform contagion in all economies. The factors of the economic and financial environment, such as deregulation, financial disintermediation, the evolution of information and communication technologies have favored the interconnection between agents. Thus, it has gone from the rigid national regulations of the seventies to a highly deregulated international market and a completely different picture since the mid1980s where the financial deregulation took place, a process led by the former US president Ronald Reagan. The result of this new framework fostered by financial deregulation, has generated a notable increase in international capital mobility, facilitating a more efficient allocation of resources worldwide, a greater diversification of risks and new growth stimulus of the emerging markets (Mishkin, 2009). Consequently, the elimination of borders between the different intermediaries and markets has led to an increasingly important offer of financial products and services. However, the flip side of the coin is that greater deregulation has also led to greater market complexity and, as a consequence, greater instability, interpreted as a consistent higher volatility of the financial markets. In this sense, in the post-crisis subprime period volatility has been low in historical terms; however, episodes of high volatility have been evidenced at specific moments such as the derived sovereign debt crisis, the Brexit and the oil price crisis, all of them relevant global episodes that have reflected significant increases in volatility and risk.

By the same token, volatility is a concept that carries the variability or instability in prices. It does not necessarily imply changes in the average, but a greater dispersion around that average. Volatility is sensitive to the flow of data that impacts the formation of prices. In this way, if positive or negative changes are observed in the prices, the volatility will increase or decrease depending on the relative magnitude of those variations with respect to the average. According to the study carried out by Piffaut and Rey Miró, less mature markets show higher volatilities. If one looks at the history of the main stock indexes of the different markets, it is noted that those with a higher degree of development tend to register lower volatility than less developed markets (Piffaut and Rey Miró, 2017). In the present work, the authors try to contrast two objectives; the first is to study the volatility threshold of the main indexes. In this, they have been able to

contrast the borders, in terms of volatility, which should be considered in each of the markets as a mechanism to keep in mind in order to determine the possible degrees of contagion. The second objective is to find the degree of interrelation that may exist between the volatility of the financial market and the volatility of the currency associated with each one of them.

2. The transformation of financial markets

According to Bustelo (1999), financial globalization is understood as "the growing mutual financial dependence among the countries of the world caused by the greater volume and variety of cross-border transactions of capital flows". The monetary policy applied by the major central banks during the post-crisis periods, such as increases in money supply and low interest rates, have transformed the financial markets reflecting a change of substance and form. The first substantial change has been the size of the market that was propitiated by the new instruments of the central banks, these being active participants in many of the underlying assets. Globalization, defined as a growing integration and interconnection of several domestic markets into a single international financial market, has considerably changed the economic environment and modified the financial system. In this sense, the monetary policies of the different central banks have caused the increases in the monetary bases to homologate different assets in any market worldwide. While in the past most stock exchanges around the world were limited by national borders and their specific industries (for example, the Spanish stock market was a market consisting mainly of banks and electricity generating companies), today it can be observed an international expansion of financial markets and the consolidation of a strong global financial market, which has caused that monetary policies, conventional and unconventional, have supranational repercussions.

A clear sign of this sensitivity are the stock market indexes where a greater degree of correlation is observed among these indexes, showing that they are increasingly interrelated. Thus, the risks of financial globalization, together with monetary policies, have caused a change in the contagion effect. As defined by Forbes (2001) and Rigobon (2002), contagion is represents changes in the transmission mechanisms unleashed during a period of financial instability in the markets, affecting all those involved, that is, the increase in the degree of dependence between markets after the occurrence of a

shock. As a result, the interconnection of markets and financial institutions has brought greater speed in the propagation of financial crises, reflecting a change in the form of transmission.

Additionally, there is evidence that the HFT (High Frequency Trading) platforms have caused the volume and speed of transactions to increase the movement of asset prices. This undoubtedly increases the effect of contagion between markets and can cause a distorting effect on prices, so that a systemic event in a market might spread rapidly beyond its borders.

A financial shock, such as the crisis in the North American mortgage market, the sovereign debt crisis of the European Union, or recently the oil price shock quickly triggered negative effects in the rest of world markets, causing a high uncertainty about the risk valuation.

3. Indexes as a benchmark for the financial markets

A standard definition of stock market index refers to the "(...) weighted average of the market capitalization of a specific and relatively static list of values" (Lo, 2015). For that reason, indexes are basically a statistical measure designed to follow the aggregate behavior or variations in the value of a list or basket of assets that meet certain characteristics that can be updated from time to time. They are estimated or calculated "as a mathematical result of a formula that reflects the trend of a given sample" (Elbaum, 2004). The stock market indexes are therefore, the barometer that must reliably demonstrate the behavior of the financial market, therefore the indexes have a substantive importance in the stock markets because they are used by multiple agents as aggregate indicator information of the current financial situation, historical and comparative behavior of the various markets or various asset classes at a global, regional, national or even industry levels. The value of the index and its change constitute relevant information for all of them, since investment strategies and policies are born, of which and for the most part, they serve as structured instruments such as options, futures, ETFs, CFDs, Warrants, etc.

Stock indexes are defined indicators constructed by the stock exchanges, that is, by institutions or companies linked to the stock markets. So for instance, the Standard &

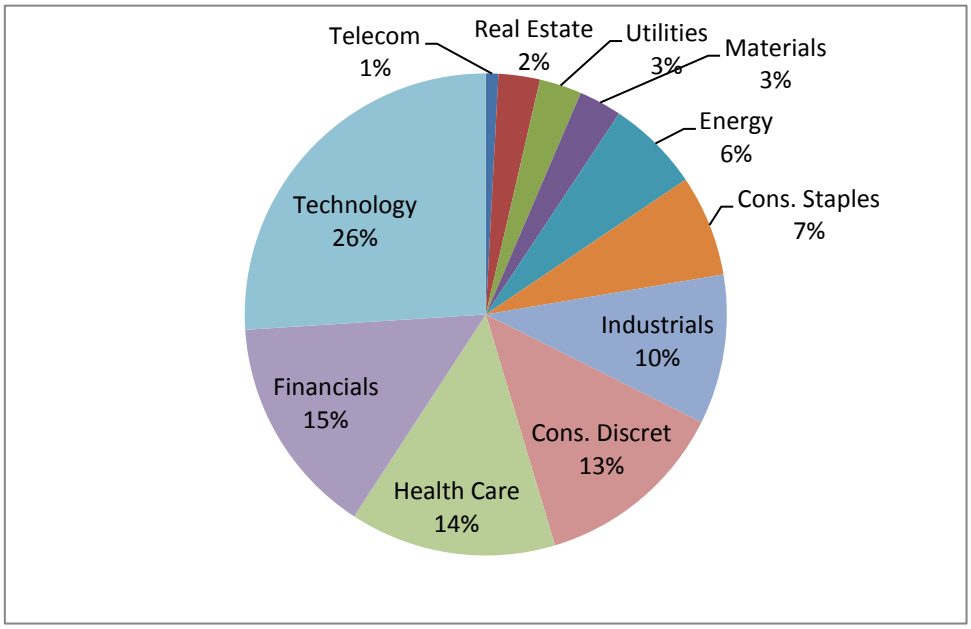
Poor's and Dow Jones are two of the big companies that build various indexes and stock index families. Similarly, the London Stock Exchange Group (corresponding to the London Stock Exchange) owns FTSE Rousell, which in turn owns the FTSE indexes. Morgan Stanley and The Capital Group Companies are the shareholders of Morgan Stanley Capital International, owner of the MSCI indexes, while BME owns the indexes of the IBEX family.

Stock indexes are important for the generation of value and due to their existence, we can have quantitative evidence of the value of a basket of shares of companies that fulfill a certain characteristic and that allows us to draw correlations that provide empirical evidence of the effects in the creation of value. With this, the indexes have been reaching relevance and have been a matter of market classification of the markets. For example, the MSCI classifies the family of indexes referring to emerging markets or the indexes of frontier markets. Such classification has an important impact for international investors, which in turn translates into capital inflows or outflows, that is, investments or divestments to the companies that compose the index, affecting their stock prices. Therefore, certain aspects must be determined for the construction and calculation of an index, such as the following:

Type of value: Shares, bonds, currencies, raw materials, among others.
Scope: Global, national, or regional.
Special features: Sector and /or business size.
Selection criteria: Criteria for filtering (by market capitalization, liquidity, free float, etc.), incorporation or exclusion of companies in the index.
Calculation: Mathematical formula that includes the type of weighting according to price, capitalization, equality and geometric mean, as well as the adjustments for dividends, splits, liquidity, etc.
Update frequency: Frequency for which stock values are evaluated and selected again determining, if appropriate, a new portfolio.

A factor to take into account in the development of the benchmark index is its composition. To illustrate, the following chart shows the weight of each sector of the S&P500 index (Figure 1).

Figure 1: S&P500 Index Composition



Source: Bloomberg and authors' elaboration.

As seen on Figure 1, among the ten largest companies in the S&P500 are those belonging to the technology sector such as Apple, Microsoft, Facebook and Amazon being the most weighing, reaching 26% of the index capitalization. This is a relevant nuance when observing the evolution and behavior of the index in question. The higher weigh of the technology sector could induce higher volatilities in the future if the sector moves in a more or less uniform way. However, the most important thing is not so much the weight of the sector, but whether the index represents the financial market well. In other words, its relevance also resides if the fundamentals of the index are conditioned by the financial market it represents.

4. Financial market development and growth

According to Solow (1956), throughout the twentieth century it has been found that macroeconomic stability, realistic expectations of private agents, income distribution, the development of the financial system, and the quality of policy regulation are key factors for the growth of a country.

The attempt to prove the causal relationship between the development of the financial system and economic growth has been a recurrent investigative task, taking for it a set

of variables that can measure the degree of development of the financial system of a specific country. In this sense, there has been a multitude of empirical works that have found that greater financial development means greater growth. King and Levine (1993), who present evidence concordant with Schumpeter, conclude that the degree of financial intermediation is a good predictor of long-term economic growth rates. Demirgüç, Kunt and Levine (2004) argue that the primary capital market constitutes a very important source of resources for companies, both in emerging and developed economies. Wong and Zhou (2007) have analyzed the relationship between capital markets and economic development in countries such as China, the United States, the United Kingdom and Japan through econometric studies.

These models study how the development of the financial market drives financial innovation, generating a greater allocation of resources, efficiency and technological progress, with an impact on savings, investment and, therefore, the economy. According to Cortés (2014), one of the measures to take into account for the development of a market is the liquidity of the capital market, its size, as well as its volatility and integration in world capital markets. In addition to a financial structure that promotes economic growth, it is essential that countries present a legal and regulatory stability that reflects an environment of stability. It is at this point that the study aims to demonstrate that the strength of a financial market, with more limited volatilities, demonstrates greater macroeconomic stability and can also reflects the stability of its own currency. Then, it is argued that financial development is possible when there is an environment that allows the proper functioning of financial market entailing an improvement in the channeling between savings and investment.

5. Methodology and data

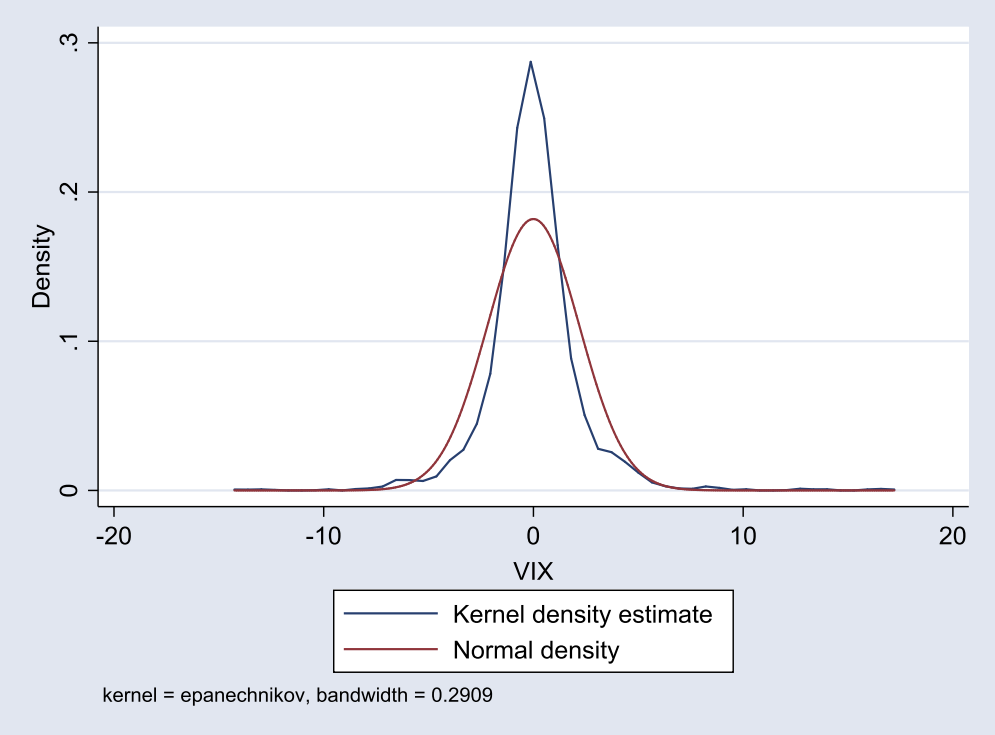
Defined the theoretical foundations that motivate this research, the present study is developed on the basis of two well-defined objectives; First, to determine the existence of a volatility threshold, defined as the variance in the market price value, for the different financial indexes and, by extension, of the financial markets in order to estimate that threshold and its specific value. Consequently, this first objective is dual since in addition to specifying the levels of volatility that characterize each market, it also underlies the pretense that this specific level or threshold is also an indication of the

degree of how well develop is that market. This means if the authors' hypothesis is correct, less developed markets are more volatile, presenting higher levels of volatility thresholds compared to more developed markets. Although this hypothesis seems intuitively simple and perhaps trivial, empirical evidence is not yet able to demonstrate this interrelation. In this way, this first objective is addressed and developed through the development of a threshold model (Threshold Regression) specific to each index and financial market included in this study.

The second objective is broader and more challenging, whose purpose is to determine the different interrelationships, if any, between the volatility of the financial markets and the volatility of the currency for that particular market. Intuitively, it would seem logical that more volatile financial markets also exhibit more unstable exchange rates and that in some way these volatilities correlate with the volatilities of their respective markets. At the same time and due to the evidence of financial contagion and interdependence between the different financial markets at the global level, these correlations should also exist between the stock indexes of emerging countries and developed countries (Piffaut and Rey Miró, 2016). For the fulfillment of this second objective, it follows the estimation of autoregressive vector models (VAR) and the Granger test to determine the possible relationships and interrelations of causality between the different variables.

The data to be used corresponds to the returns, volatilities and values of the respective currencies for the ten main financial indexes, a sample that includes indexes of developed economies as well as of some emerging countries. In the case of developed countries, each series begins in January 1990 and runs until May 2018. In the case of emerging countries, the series consists of data for the period between February 2002 and May 2018. As above-stated all theses time series are also complemented with the Volatility Index ticker or Chicago Options Market Volatility Index for the same period. The VIX is a number derived from the prices of the options contained in the S&P500 index. It is a good indicator of market volatility expectations and clearly it is a very leptokurtic variable and outside the ranges of a normal distribution (curve in red), as most of the macroeconomic financial series (Figure 2).

Figure 2: VIX Kernel Density



Concerning data frequency, although the data of the financial markets are of high frequency with daily prices, volatilities and returns, the data used in the respective econometric models correspond to data of weekly frequency. The reason behind this approach in terms of frequency of data resides in the fact that while high frequency data, such as daily data, are rich in information, weekly frequency data provide, in judgment of the authors, the ideal combination given that 52 annual observations is enough to capture the swings and events of the markets, avoiding outliers as it happens with the daily variations, mainly during episodes of euphoria and panic of the financial markets. Table 1 summarizes the main descriptive statistics for the ten indexes and the VIX from January 1990 to May 2018.

Table 1: Stock Indexes

Index	N	Mean	St. Dev.	Mínimum	Maximum
S&P 500 (U.S.A)	1480	1174,93	566,67	302,89	2844,35
Nikkei 225 (Japan)	1480	15825,55	5133,12	7256,93	38493,82
DAX 30 (Germany)	1480	5523,96	3045,52	1358,67	13415,31
FTSE 100 (UK)	1480	5039,52	1476,80	1997,76	7794,42
IBEX 35 (Spain)	1377	8433,09	3149,38	1969,53	15848,02
Shanghai SE (China)	1334	1977,15	1038,95	295,14	5960,35
Sensex 30 (India)	1480	1174,93	566,66	302,89	2844,35
Bovespa (Brazil)	1480	29836,23	25143,16	0,01	86216,16
Merval (Argentina)	1375	3676,44	6236,93	210,05	34527,08
Ipsa (Chile)	1272	2497,42	1474,42	588,01	5856,14
VIX (CBOE)	1480	19,34	7,74	9,34	72,92

Weekly data from January 1990 to May 2018. Source: BSE and CBOE.

As usual, when analyzing time series data, the presence of unit roots must be taken into account both in the index series and in the data relating to the exchange rate. In the case of financial series, the returns are obtained from the logarithmic difference between the current value and its first lag, which makes the series naturally stationary. The same procedure is carried out for currencies and for exchange rate indexes. In the case of market volatilities, the VIX index, and the variation of the exchange rate for each currency, the presence of unit roots is verified and, therefore, these series were included in first differences in the respective econometric models. The unit root tests applied are the traditional ADF test of Dickey-Fuller (Augmented Dickey and Fuller, 1979), the PP test (Phillips and Perron, 1988) and the KPSS test that takes stationarity as a null hypothesis (Kwiatkowski, Phillips, Schmidt and Shin, 1992).

It is important to emphasize that of all these tests, the one developed by KPSS is the most consistent and perhaps the most rigorous when determining the presence of unit

roots in the series, especially if the series does not represent an abundant number of observations (Metes, 2005). Ideally, the KPSS test with the auto-covariance function specification weighted by the quadratic spectral core instead of the Bartlett kernel, in addition to the automatic bandwidth selection specification, determines the maximum number of lags for the optimal bandwidth, thus avoiding biases in the detection of unit roots (Newey and West, 1994; Hobijn et al., 1998). For the case of the series used in this study and for those than have been necessary to use them in first differences, all successfully pass the total set of unit root tests, so that the series fully included in all the models are stationary time series.

6. Volatility and thresholds in financial markets

Following the methodology described at the beginning of this section, an estimation and quantification of the volatility thresholds for each of the markets is carried out. The estimation is made on the basis of models of the Threshold Regression type that unlike the Markov-Switching models assume that the transitions between states of a variable, volatility are triggered by observable variables that at some point of time cross certain limits and the value of these limits can be estimated (Tong, H., 1983; Hansen, B. E., 1997; Gonzalo, J., and J.Y. Pitarakis, 2002; Linden, A., 2015).

Formally, consider a Threshold Regression with two regions defined by a threshold γ as

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

$$y_t = x_t\beta + z_t\delta_2 + \epsilon_t \qquad si \;\; \gamma < w_t < \infty$$

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

In the model, the parameters of interest are δ_1 and δ_2. Region 1 is defined as the subset of observations whose value of w_t is less than the threshold value γ. Similarly, region 2 is defined as the subset of observations in which the value of w_t is greater than the threshold γ. The inference on the gamma parameter (γ) can represent an econometric challenge due to its non-standard asymptotic distribution (see Hansen, 1997 and Hansen, 2000).

A threshold regression uses conditional least squares to estimate model parameters. In this way, and structuring a model that includes as volatility variables and their lag values, as well as the returns of stock markets, four models are estimated from one to three lags, of which there are two models that clearly compete; the model of 2 and 3 lags for volatility. The general model is structured as follows:

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

$$\Psi_t = \delta_{20} + \delta_{21} L.\Psi + \delta_{22} R + \varepsilon_t \qquad si\ \gamma < L.\Psi < \infty \qquad (2)$$

Where Ψ represents the volatility and R the stock returns. The operator L indicates that it corresponds to the lag of the variable specified in the equation. Consequently, for the proposed model and 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 model that best fits the Dax30, FTSE100 and the S&P500 is the threshold model with two lags for volatility and returns, while for the rest of the stock indexes, consisting mainly of those of emerging economies with the exception of the Nikkei225, the model that best fits is that of three lags. In the case of the VIX and due to the nature of the index, the model that best fits is that of a single lag with values of 2226.42, 2274.18 and 2244.19, respectively for each of the criteria. The values of the different models and criteria are presented in Table 2. As is proper and prior to their estimation, the presence of unitary root was discarded for all the variables, including the second and third lag, using the Dickey-Fuller tests, Phillips-Perron, and the KPSS unit root test. The results of the models are shown in Table 3 with the respective volatility threshold values in percentage.

Table 2: Threshold Models Information Criteria

Index	AIC 2Lags	AIC 3Lags	BIC 2Lags	BIC 3Lags	HQIC 2Lags	HQIC 3Lags
S&P 500 (U.S.A)	-2031.57	-2009.44	-1983.89	-1961.76	-2013.79	-1991.66
Nikkei 225 (Japan)	-738.63	-756.31	-690.94	-708.63	-720.85	-738.53
DAX 30 (Germany)	-1276.28	-1251.35	-1228.60	-1203.67	-1258.51	-1233.58
FTSE 100 (UK)	-2059.45	-2033.57	-2011.75	-1985.88	-2041.67	-2015.79
IBEX 35 (Spain)	-1008.48	-1030.60	-961.44	-983.57	-990.88	-1013.01
Shanghai (China)	1853.95	1836.81	1900.70	1883.56	1871.47	1854.33
Sensex 30 (India)	3867.65	3829.15	3915.30	3876.79	3885.42	3846.91
Bovespa (Brazil)	1035.50	967.00	1083.19	1014.69	1053.28	984.78
Merval (Argentina)	787.98	731.78	835.00	778.79	805.57	749.37
Ipsa (Chile)	-1196.95	-1209.75	-1150.63	-1163.44	-1179.55	-1192.35
VIX (CBOE)	2293.35	2297.84	2341.03	2345.51	2311.13	2315.61

Source: Models and values estimated by the authors.

Table 3: Threshold Models Estimation

Index	Pre-crisis threshold	Post-crisis threshold	Durbin-Watson
S&P 500 (U.S.A.)	16,94	13,09	1,747
Nikkei 225 (Japan)	32,33	20,83	1,894
DAX 30 (Germany)	32,71	19,12	1,971
FTSE 100 (UK)	23,94	17,36	1,901
IBEX 35 (Spain)	31,43	28,30	1,816
Shanghai SE (China)	49,67	26,20	1,894
Sensex 30 (India)	37,15	17,66	1,558
Bovespa (Brazil)	58,03	53,95	1,843
Merval (Argentina)	42,46	41,78	1,821
Ipsa (Chile)	23,89	23,24	1,836
VIX (CBOE)	28,49	27,48	2,214

Weekly data from January 1990 to May 2018. Source: Barcelona Stock Exchange and BME.

From the results of Table 3, it can be inferred that the volatility and the harshness of the financial crisis of 2008, in addition to the imposition of a stricter regulation of the stock market, restructured the thresholds of tolerance towards the volatility of most of the financial markets. Another factor that could lead to lower volatility in the post-crisis period has been the active role of central banks in maintaining the stability of the financial system with ultra-expansive monetary policies. In this sense, the main instruments of the unconventional monetary policy have marked an unprecedented unconventional execution plan, but although they have been implemented temporarily and exceptionally, they have had a great impact on the financial system.

The active intervention of central banks providing liquidity injections, the expansion of the list of eligible collateral assets or direct purchases in the public and private fixed income markets (Quantitative Easing - QE), have had a great influence on volatility of the markets. This is because there is empirical evidence that any measure of the "Quantitative Easing" type alters long-term interest rates (Krishnamurthy, Vissing-Jorgensen, 2011). Another factor to take into account has been the communication and orientation of monetary policy in the medium and long term. In this sense, the forward guidance of the central banks has created a clearer and more concise message for the agents, which has translated into an improvement in future expectations on the part of the participants. It can also be seen that, in general, financially advanced markets have lower levels of volatility both for the pre-crisis and post-crisis stages, while the opposite is seen in emerging markets.

Moreover and in a logical way, it is observed that countries with lower volatilities and by nature, markets with less uncertainty, ranks at higher positions in the ease in doing business index. The falls of the volatility thresholds do not have a direct relationship with the rises or falls in the Doing Business classification, however, it is unequivocally observed that the lower volatility thresholds present better classifications on the easy of doing business rank.

There are three peculiarities in the reading of Table 4; Spain, India and Chile. In the Spanish case, the particularity is induced in a great improvement of the Doing Business in these 10 years, even when the thresholds are still high. The explanation for this uniqueness is induced by the weighting of the banking sector that has more than 40% of the weight of the index, which leads to episodes of greater volatility in the face of the vagaries of the different debt crises. The other particularity is India, which despite being

in the 100th position, its threshold of volatility is low. The explanation for this is the clear improvement in the Doing Business ranking that goes from position 120 to 100 and its economy shows the greater dynamism worldwide. In the case of Chile, in spite of the significant deterioration of the Doing Business, it is observed that the volatility frontiers are very contained thresholds, which have been maintained and have not shown a downward trend like the rest of the financial markets (Table 4).

Table 4: Volatility Thresholds and Doing Business

Index	Pre-crisis threshold	Post-crisis threshold	2008 Rank	2018 Rank
S&P 500	16,94	13,09	3	6
Nikkei 225	32,33	20,83	12	34
DAX 30	32,71	19,12	20	20
FTSE 100	23,94	17,36	6	7
IBEX 35	31,43	28,30	38	28
Shanghai SE	49,67	26,20	83	78
Sensex 30	37,15	17,66	120	100
Bovespa	58,03	53,95	122	125
Merval	42,46	41,78	109	117
Ipsa	23,89	23,24	33	55

Source: The World Bank, Barcelona Stock Exchange and BME.

Nevertheless, it can also be concluded that the decrease in the volatility of all the thresholds has been and is induced by the monetary policies that mark an increasingly supranational scope. However, these monetary policies would have a greater impact on markets where central banks have made a policy of more direct intervention, which is why it can be seen that the greatest fall in the volatility thresholds has been in the Japanese and German markets with a decrease in the 71% in both cases. In reference to emerging markets and for the case of India, a market that goes beyond the rule of volatility, the explanation lies in the strong growth registered in the region in recent years, being currently the economy that grows the most in the world. Similarly, the Chilean stock market with its Ipsa index also departs from the volatility rule determined by the models. Indeed, for the Chilean index, low volatility thresholds are due to the fact that it is still considered a relatively "young" and small market, but its limited range

values of 23,894 in pre-crisis and of 23,237 in post-crisis, are mainly due to the strict regulation imposed after the serious debt crisis that occurred between the years 1982-1985, where practically all the banks in the country were declared insolvent and were later intervened and "rescued" by the Central Bank of Chile until they were sufficiently solvent for the subsequent purchase of its own debt to the same monetary authority. Additionally, during this period the entire financial and banking industry of the country was restructured. The previous result is also consistent with the theory that volatility, once present, is more persistent in emerging markets than in more mature and developed financial markets.

As for the VIX and as expected, the pre- and post-crisis values are very similar with 28,494 and 27,476, respectively. The important thing about this limited range between these two values is that it is very likely that for higher VIX values of 27,476, the markets will begin to operate in environments of high volatility and uncertainty, so this data can be considered as a limit between the operation of a market under "normal" conditions and one operating under conditions of financial stress.

Finally, and as can be seen in the results, the Durbin-Watson test yields results very much in line with and within the norm of the statistician in all the models, indicating that all the threshold models do not present serial correlation of first order, which it also validates the methodological robustness of this research.

7. Financial market volatility and its relation with the exchange rate

Finally, it is interesting to determine the possible effect of the volatility of the financial markets on the currencies of the respective countries. The approach to this question is an Autoregressive Vector (VAR) model for each index. Table 5 summarizes the descriptive variables for those included in the models. The frequency of the data is also weekly.

Table 5: Descriptive Summary Variables VAR Models

S&P 500 (U.S.A.)	N	Mean	SD	Min	Max
Volatility	1479	15,17	9,06	3,53	83,43
Return	1479	0,00	0,01	-0,04	0,02
Exchange Rate (ER)	1479	9,39	3,21	2,94	27,57
Exchange Rate Variation	1479	1,21	0,14	0,83	1,58
VIX (CBOE)	1479	19,34	7,74	9,34	72,91

Nikkei 225 (Japan)	N	Mean	SD	Min	Max
Volatility	1480	21,93	10,16	6,44	114,78
Return	1480	0,00	0,01	-0,06	0,03
Exchange Rate (ER)	1480	10,99	4,98	3,05	51,42
Exchange Rate Variation	1480	133,17	20,35	90,20	196,76
VIX (CBOE)	1480	19,34	7,74	9,34	72,92

FTSE 100 (UK)	N	Mean	SD	Min	Max
Volatility	1482	15,38	8,26	5,23	79,49
Return	1482	0,00	0,01	-0,05	0,03
Exchange Rate (ER)	1482	7,44	2,96	1,64	26,60
Exchange Rate Variation	1482	0,75	0,09	0,58	0,96
VIX (CBOE)	1482	19,33	7,74	9,34	72,92

Shanghai SE (China)	N	Mean	SD	Min	Max
Volatility	1329	28,41	23,06	2,61	258,89
Return	1329	0,00	0,01	-0,04	0,18
Exchange Rate (ER)	1325	9,73	8,19	3,19	146,14
Exchange Rate Variation	1329	8,84	1,28	6,40	11,25
VIX (CBOE)	1329	19,18	7,90	9,34	72,91

Sensex 30 (India)	N	Mean	SD	Min	Max
Volatility	1471	15,10	9,03	3,53	83,44
Return	1471	0,00	0,01	-0,04	0,03
Exchange Rate (ER)	1471	10,62	5,06	0,00	56,97
Exchange Rate Variation	1471	53,56	15,53	20,09	88,09
VIX (CBOE)	1471	19,30	7,74	9,34	72,92

Bovespa (Brazil)	N	Mean	SD	Min	Max
Volatility	1326	31,22	17,96	10,67	134,71
Return	1326	0,00	0,01	-0,05	0,05
Exchange Rate (ER)	1322	14,84	8,34	3,99	77,08
Exchange Rate Variation	1326	2,40	1,02	0,01	4,50
VIX (CBOE)	1326	19,37	8,02	9,34	72,92

Merval (Argentina)	N	Mean	SD	Min	Max
Volatility	940	30,42	14,36	11,47	106,00
Return	940	0,00	0,01	-0,08	0,09
Exchange Rate (ER)	936	14,26	31,16	0,47	483,65
Exchange Rate Variation	940	6,80	5,39	0,83	28,83
VIX (CBOE)	940	19,73	8,64	9,34	72,92

Ipsa (Chile)	N	Mean	SD	Min	Max
Volatility	850	13,59	7,24	4,66	70,09
Return	850	0,00	0,01	-0,04	0,03
Exchange Rate (ER)	850	11,25	3,82	4,92	26,71
Exchange Rate Variation	850	713,88	57,81	567,09	895,78
VIX (CBOE)	850	19,21	8,81	9,34	72,92

Weekly data from January 1990 to May 2018. Source: Barcelona Stock Exchange and BME.

Prior to the analysis, it was determined that the optimum number of lags for the proposed VAR models is five lags based on the usual information criteria (AIC, BIC and HQIC), which indicates the high persistence present in the volatility extending its effects on the markets for several weeks. At the same time, the presence of a unit root in the third lag was discarded using the Dickey-Fuller, Phillips-Perron and KPSS tests.

It is worth mentioning that the Johansen's test was performed before the implementation and use of the VAR models built in this study. The main objective of this action was to rule out the possible presence of cointegration in the series. The main results based on the trace test suggest the presence, in some cases, up to four cointegration equations at the 0.05 level. Then, and for all the VAR equations, the corresponding vector error correction (VEC) model was derived from the results of cointegration tests. Only after this correction was made, the Granger causality test was applied to establish possible causal relationships between the indexes and the corresponding currency.

Based on the results of VEC models, it is concluded that there is Granger causality relation between the volatility of the financial market and the volatility of the currency

of the respective countries for the S & P 500, Nikkei 225, Shanghai SE, Bovespa and Ipsa. It is also concluded that this relationship is statistically significant at levels of 5% and in some cases of 1%. This relationship is unidirectional in the case of the S&P 500, Shanghai SE and Bovespa with respect to their currencies US Dollar, Chinese Renminbi and Brazilian Real, respectively and bidirectional in the case of the Nikkei 225 and Ipsa for the respective Japanese Yen and Chilean Peso currencies. . No relationship was observed between the volatilities of Dax 30, Ibex 35, FTSE 100, Sensex 30 and Merval, with respect to their currencies.

It is necessary to emphasize that for each estimated model, the Durbin-Watson statistic for serial autocorrelation is very close to the ideal value of 2.0, which validates the robustness of the VEC models estimated in this section (Durbin, J. and Watson, GS, 1951). Table 6 summarizes the results derived from the VEC models.

Once again and based on the previous results, it can be seen that there is a relationship between the level of development of the financial market and the effects of volatility on the currency and, consequently, on the real variables of the economy. It is very likely that this relationship is consistent with the maturity and with the relatively strong regulation imposed on them, rather than with the size of those markets. Perhaps the exception to the rule is the relationship between the Bovespa index and the Brazilian Real.

Table 6: Volatility and Exchange Rates

Index	Granger Causality	Direction	Sig. Level	Durbin-Watson
S&P 500	Yes	Unidirectional	5%	2.003
Nikkei 225	Yes	Bidirectional	5%	2.005
Dax 30	No	-	-	1.999
Ibex 35	No	-	-	1.992
FTSE 100	No	-	-	2.002
Shanghai SE	Yes	Unidirectional	5%	1.995
Sensex 30	No	-	-	1.999
Bovespa	Yes	Unidirectional	1%	2.002
Merval	No	-	-	1.937
Ipsa	Yes	Bidirectional	5%	2.009

Source: Authors' elaboration based on VEC models.

8. Conclusions

Among the most relevant aspects derived from this research, it is increasingly evident that volatilities with greater containment must provide superior returns. From the point of view of the frontiers, volatilities below 22% suggest more mature markets. In general terms, it is noted that financial markets with narrower borders present a better business climate. Despite finding exceptionalities, it can be seen that the financial markets that have fallen their volatility thresholds also reflect an improvement in the quality of doing business. Although this assertion is not fulfilled for the Japanese case, in part of the unconventional monetary policy followed by the BOJ that has been the only central bank that has directly purchased all types of underlying assets to support the Japanese market.

With respect to currencies, the results suggest the existence of a coupling between the volatility of the financial markets and their respective currencies in both mature markets and those of developed economies. Exactly the opposite happens in economies with a lower degree of development where the relation between the currency and the degree of financial development is not so evident. In the case of the Nikkei 225, the bidirectional relationship could be induced by the "carry trade", strategies where investors try to obtain the difference between interest rates. Therefore, both the currency and the market show contagion between the two markets because the yen is an instrument that acts as a safe haven and is appreciated when risk aversion increases in financial markets as investors seek refuge in the Japanese currency that remains strong in times of uncertainty, mainly due to the large reserves of yen that Japan has in pension funds.

Following this line of analysis, the study shows that countries with higher volatilities have less economic development. However, the greater integration of the markets has led to more uniform volatilities, but it is evident that the quality and reputation of the market are also fundamental factors that investors evaluate, especially those that come from far away latitudes from the host country. In this sense, emerging countries must necessarily regulate their financial markets limiting their risks, while encouraging countries with a higher degree of development to have the incentive to invest more in the form of foreign direct investment. Therefore, it is clear that as the financial market

develops, a positive effect is observed in the real economy in the medium and long term.

A clear example of this is represented by Brazil and Argentina, where their post-crisis volatility thresholds surpass 50% and 40%, respectively, with practically no change compared to their pre-crisis values. The opposite occurs with China, a country that descended from a high volatility frontier for the pre-crisis period of 49.67% to a low volatility border, reaching a current average value of 26.20%. The reduction that China has made regarding its volatility frontier is a clear example of good governance if the right mechanisms are put in place and that these volatility borders are points of attention for the agents, intermediaries, and monetary authorities of each country.

At the systemic risk level, the fall of the volatility thresholds in the vast majority of financial markets could show a more complacent feeling in the face of future global risks. However, the risks of contagion between the different financial markets could increase due to the fact that the borders are smaller and therefore episodes of contagion with lower volatilities can be triggered in comparison to previous crises. Recent lessons on financial and economic crisis suggest that the indicators of financial stress developed by the main central banks or the VIX itself remained at low levels and did not indicate the proximity of a crisis until it occurred. In this sense, it is concluded that the above-estimated thresholds should be a warning signal in the future to come. In addition, this risk could increase in future crises due to three main factors; first, the effects of monetary policy adopted by central banks. In this sense, what has been seen has been a large increase in the assets of the central banks and, therefore, also in their liabilities. Given the normalization of their balance sheets, the risks of contagion between markets, if there is no coordination between them, could translate into greater risk, mainly from more developed markets, where unconventional monetary policies have been more relevant, though also more aggressive. The prevalence of very lax financial conditions, favorable in the short term, can have negative consequences on economic activity in the medium and long run.

The second factor is the great growth of passive management. In this regard, the strong increase in ETFs (Exchange Trade Fund) may cause counterpart risks in the future, if market risks increase. The reason behind this effect is that synthetic ETFs that replicate the profitability of an index using SWAP contracts, that is, exchange-traded funds that

have a basket of values that may not necessarily be related to the index they follow, could cause liquidity in case the participants want to liquidate their positions.

Finally, the third factor is the HFT effect (High Frencuency Trading). The intensive use of this type of operation can entail greater risks of contagion due to the speed of its execution and also due to its transmission mechanisms towards the real economy. Technological advances have led this type of trading strategy to show a latent risk before positions that are canceled immediately and that incur an operational risk in the face of the movements of the market itself. Although the HFT and the operators can present arbitrage opportunities between the different platforms, the capacity of high frequency trading can lead to episodes of greater volatility.

After a few years of low volatility, as pointed out by the last Federal Reserve notes, when agents perceive a low risk environment, they are incentivized endogenously to assume more risks, which ultimately may culminate in another financial crisis. This is the point of view expressed in this work, supporting the thesis that future crises can be induced in environments with lower historical volatilities and that potential financial turmoil can spread more quickly as global markets are more interdependent.

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