

# Value-at-Risk (VaR) Brazilian Real and currencies of emerging and developing markets

## *Value-at-Risk (VaR) Real brasileiro e moedas de mercados emergentes e em desenvolvimento*

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**Abstract:** Globalization has been responsible for increasing exposure to risks related to currency factors for companies and countries. The literature has addressed the issue of currency volatility in emerging and developed countries without a consensus on such a dynamic and there are few studies that estimate and place the risk of the Brazilian real. Thus, this study aimed to measure the risk of the Brazilian exchange rate, as well as test the hypothesis that there is a significant difference in volatility between currencies of emerging and developing countries. Through the parametric VaR set to extreme values distributions, it was observed that the Brazilian real presented at greater risk of exchange rate. The results also showed that the distributional assumptions do not seem to have any specific pattern when faced emerging and developed countries and also emerging countries showed less volatility, reflecting the preponderance of factors external to the foreign exchange market in determining the risk of some currencies.

**Keywords:** Value-at-Risk; Exchange rate; Risk management; Developing and emerging countries.

**Resumo:** A globalização tem sido responsável pela elevação da exposição de empresas e países a riscos relativos a fatores cambiais. A literatura tem abordado a questão da volatilidade da moeda em países emergentes e desenvolvidos sem um consenso sobre tal dinâmica, bem como são escassos os estudos que estimam e situam o risco do real brasileiro. Dessa forma, o presente estudo teve por objetivo mensurar o risco da taxa de câmbio brasileira, bem como testar a hipótese de que existe uma diferença significativa na volatilidade entre moedas de países emergentes e em desenvolvimento. Por meio do VaR paramétrico ajustado para distribuições de valores extremos, observou-se que o real brasileiro apresentou taxa de câmbio de maior risco. Os resultados também revelam que os pressupostos distribucionais não parecem apresentar nenhum padrão específico quando confrontados países emergentes e desenvolvidos, e também que países emergentes apresentaram menor volatilidade, denotando a preponderância de fatores externos ao mercado cambial na determinação do risco de algumas moedas.

**Palavras-chave:** Value-at-Risk; Taxa de câmbio; Risk Management; Países desenvolvidos e emergentes.

## 1 Introduction

The growth of the importance of risk management lies in the volatility of financial variables, among them, we can highlight the exchange rate, interest rate, capital market, and commodity prices. Factors such as the end of fixed exchange rates, interest rate swings, financial crises, and sudden changes in commodity prices contribute to the increase in market unpredictability (Jorion, 1997).

The exchange rate risk can be defined according to Madura (1989) as the unexpected changes in the exchange rate, leading to direct losses (derived from

unhedged exposure), or indirect in the cash flows (Papaionnou, 2006).

Managing exchange rate risk is related to a company's decisions about its exposure to foreign currencies, according to Allayannis et al., (2001) and to manage it, it is crucial to understand the types of risks that are associated with the rate such as: transaction risks (related to cash flow risk); translation risks relating to the balance sheet; and economic risks (related to the present value of the company). Thus, once such risks are understood, it is important to measure them

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in order to manage the risk related to the exchange rate (Papaïonnou, 2006).

After consecutive years of economic instability and increasing inflation, Brazil underwent a process of monetary and exchange rate reform in 1994, during which time the real plan was instituted, and since then the Brazilian real has become the official currency of Brazil (Batista, 1996). Thus, the real consists of a floating exchange rate regime (more specifically a dirty float), that is, a regime that allows the existence of appreciations and depreciation of the currency, leading to exchange rate volatility (Lara, 2005). Volatility is a significant input parameter in the approach to options, both financial and real assets (Oliveira & Pamplona, 2012).

According to Carvalho & Sicsú (2004), the high exchange rate volatility causes an increase in uncertainties, reducing the predictability of financial costs. In this way, it can be inferred that significant devaluations in the local currency can benefit exporting companies, while generating losses to those that present large amounts of debt in foreign currencies.

Thus, the risk of exchange rate fluctuations has a strong impact on the economy and the performance of exporting industries. It is important to know and measure the risk related to the value of the currency (Akhtekhane & Mohammadi, 2012). In addition, the currency can be considered as a financial asset like any other, being subject to fluctuations of supply and demand, as well as speculative attacks.

Therefore, the above factors are highlighted and based on the analysis of the current economic situation in Brazil, in which, in 2014, the dollar increased 13% in relation to the real and the real continues to show strong volatility in the year 2015. From this it is important to measure the risk of this financial variable (Federowski, 2015). The Figure 1 shows the evolution of the real against the dollar.

Despite the plurality of articles that use VaR to measure the risk of different exchange rates, such as Zhan & Tian (2000), Wang et al. (2010), Li et al. (2007), among others, there are few studies that investigate the exchange rate risk of the Brazilian real. Moreover, in the current scenario, in which the country has been facing several economic and political reforms in which the local currency has been showing strong volatility, the measurement of the risk of the real acquires a character of urgency, presenting, therefore, great importance.

Wang et al. (2010) uses EVT (Extreme Value Theory) to estimate the tails of the yuan exchange rate returns, finding high adherence to the Pareto distribution. Although the VaR EVT underestimates the risk to the proposed exchange rate, such an approach still appears to be superior to the traditional

VaR calculation, such as historical simulation and variance-covariance.

The lack of consensus on distributional assumptions and VaR computation methods becomes more pronounced when compared to distinct economic realities, such as assets of developed economies and assets of emerging economies.

In fact, Gençay & Selçuk (2004) still argue that developing economies are much more subject to change in the short term, and therefore, the probability distributions of their returns and estimated parameters are also likely to change with some frequency. In addition, developing markets are more subject to financial swings.

Kittiakarasakun & Tse (2011) argue that financial models are often not applicable to emerging markets as well as developed markets, for example, G7. This could occur because, often, developing countries impose restrictions on the free flow of capital.

The difference in markets is reflected in the tails of probability distributions of returns, which especially for emerging markets, tend to be non-normal. In fact, Longin (2005) argues that distribution tails are different in emerging markets.

However, Kittiakarasakun & Tse (2011) also argue that the differences between Asian and US returns may be merely a matter of scale, since the occurrence of extreme events in Asia is as likely as in the United States, demonstrating that market tails Chinese and the North American market are similar. This denotes that a risk management model would work well for both realities. This fact is verified, since the study conducted by the authors did not find significant differences in the risks measured by VaR.

Thus, risk measurement has been a major concern among managers and regulators, with Value-at-Risk (VaR) being one of the most commonly used tools for risk measurement.

According to Jorion (1997), VaR is a risk measurement method that uses standard statistical techniques, in other words, VaR measures the worst loss expected over a given time interval within a given confidence level.



**Figure 1.** Evolution of the real against the dollar. Source: Prepared by the authors (2016).

Thus, it is observed that the VaR is an easy-to-understand method capable of providing benefits such as the provision of management information, performance evaluation, as well as contributing to resource allocation decisions, thus constituting one of the most important tools for Risk management (Jorion, 1997).

The literature about VaR is quite extensive and has important works such as Chela et al. (2011), Gaglianone et al. (2008), Jorion (2007), Taylor (2005), Glasserman et al. (2000), so that there are several ways to estimate VaR, among them, nonparametric methods (historical simulation), parametric (variance covariance method), simulation (Monte Carlo method), and conditional heteroscedasticity methods, in particular, the GARCH models (Wang et al., 2010). Since the use of VaR is of interest in addition to companies and financial institutions, regulatory agencies have also been underestimating their importance so that, since 1988 with the Basle Accord, several regulatory initiatives involving VaR (Jorion, 1997).

However, although there is no consensus on which probability distributions to use, and the weaknesses of parametric VaR under normality assumptions, parametric VaR is extremely interesting because of its simplicity of calculation and efficacy when correctly specifying the distribution of returns. And should therefore be abandoned as an alternative to the VaR computation (Moralles et al., 2013).

In view of the above, the main objective of this paper is to measure the risk of the Brazilian exchange rate, as well as to test the hypothesis that there is a significant difference in the volatility between currencies of emerging and developing countries, as stated by authors such as Kittiakarasakun & Tse (2011), Longin (2005) and Gençay & Selçuk (2004).

In view of the above, the main objective of this paper is to measure the risk of the Brazilian exchange rate, as well as to test the hypothesis that there is a significant difference in the volatility between currencies of emerging and developing countries, as stated by authors such as Kittiakarasakun & Tse (2011), Longin (2005) and Gençay & Selçuk (2004). Thus, the study will compare the risk of currencies from different countries, separated into two groups, emerging and developed. The first group consists of: real (BRL); Argentine peso (ARG); Chilean peso (CLP); New Peruvian sun (PEN); Mexican peso (MXN); Chinese yuan (CNY); Indian Rupee (INR); And, won South Korean (KRW). The second group consists of: Australian dollar (AUS); Euro (EUR); Swiss Franc (CHF); Pound sterling (GBP); And, Japanese Yen (JPY). Such sampling was chosen to compare the proposed VaR calculation method between developing markets, developed markets and the asian market. The risk assessment was performed using parametric VaR via the adherence test for extreme values, as presented in (Moralles et al., 2013).

## 2 Value-at-Risk

The problem of measuring and controlling financial risk has motivated researchers and decision makers to seek indicators capable of identifying how risky a decision is (Ribeiro & Ferreira, 2005).

Value-at-Risk (VaR) is one of the most popular risk measurement tools used by the financial sector. It was created in the 1990s, shortly after the financial disasters such as that of Barings, cited above, and can be defined as the maximum expected loss of a portfolio, with a certain level of significance  $\alpha$  (or confidence level  $1-\alpha$ ) in a given time horizon (Moralles et al., 2013, Aragón et al., 2013). For example, if we have a daily VaR of R \$ 1 million with a confidence level of 99%, there is only 1% chance of a loss being more than R \$ 1 million on any business day.

In this way, the VaR provides an indication of the probability of a potential change in the value of a portfolio resulting from the change in market conditions over a given period of time by demonstrating how likely the VaR measure can be exceeded (Crouhy et al., 2006).

Gaio & Pimenta (2012) point out that VaR is one of the most important market risk measurement tools and, undoubtedly, the one most used by institutions and risk managers. Estimating the maximum expected loss, within a period of time and a given level of confidence, one has the known market risk.

### 2.1 Exchange rate regimes

According to Zini (1996), the legal regime refers to the set of characteristics derived from norms, laws and practices that regulate transactions with foreign currencies in the economy. In economic terms, the exchange rate regime consists of the way a country's exchange rate is determined, that is, whether the exchange rate is fixed, fluctuating or assuming some variation between these two (intermediate regimes).

When a country adopts an exchange rate regime, it expects it to assist in economic stability, stimulate foreign trade and investment, provide conditions for fiscal and monetary policy management, and protect the domestic economy from disruptions arising from international finance (Sambatti & Rissato, 2004).

In the fixed exchange regime, the nominal exchange rate is fixed and parity must be maintained through the intervention of the Central Bank in the foreign exchange market, buying or selling currency according to the adjustment needs of that market. If there is excess supply (demand) of foreign exchange, the Central Bank intervenes in the market by buying (selling) currencies at the fixed rate. Thus, the credibility of this system depends on the capacity of intervention of the Central Bank, via available international reserves (Zini, 1996).

Like this, the fixed exchange rate regime tends to provide more stable horizons to the exchange rate, since

it assists in the stability of prices and expectations, serving as a reference in the decision-making of the agents and thus allowing the increase of trade and Investments. Thus, by fixing the exchange rate, the risk of uncertainties caused by high exchange rate variability tends to be eliminated (Frankel, 1999).

The pure floating exchange rate regime is one in which the Central Bank does not intervene in the foreign exchange market. The exchange rate is determined by the supply and demand of foreign currency. In this way, the Central Bank is free to maintain high levels of international reserves (Zini, 1996; Corden, 2001). However, the configuration of this regime is more evident in theory than in practice, since, normally, what is verified is some degree of exchange monitoring in the form of direct intervention in the exchange market, by the Central Bank, in order to avoid movements of high volatility, in the short run, which may compromise certain economic policy objectives, in practice, a regime of managed fluctuation known as dirty flotation. In this case, the Central Bank does not advocate a specific exchange rate, but it intervenes in the exchange market (Corden, 2001).

As a result of the great exchange rate volatility observed after 1973, along with the difficulties encountered in maintaining monetary stability in a context of financial liberalization, especially in the 1980s, discussions on exchange rate regimes, according to Edwards & Savastano (1999) started to incorporate the intermediate regimes, standing out among them: the one of exchange bands; the floating flotation, the crawling peg; the fixed but adjustable exchange rate; the currency board and the full dollarization. Each of these regimes has characteristics that bring them closer to one or the other of the canonical regimes.

## 2.2 Convertibility

As a natural consequence of acceptability at the international level, one has the characteristic of currency convertibility. The currencies, under the exchange rate aspect, are classified as: convertibles; and, inconvertible.

Convertible currencies are those that are freely accepted by other countries, without any restriction and in any market, known as Strong Currency. Nonconvertible currencies are those that do not have an easy international course or that are not accepted by other countries in foreign exchange transactions. Chart 1 shows the main examples of convertible and inconvertible currencies.

### 2.1 Foreign exchange risk

The fixed exchange rate regime was widely used until the mid-1980, however, with improved markets, high capital mobility, this type of regime was losing strength and fans, and today most countries use floating exchange rate regimes (Lara, 2005).

The fixed exchange regime is a system in which the Central Bank of a country establishes a fixed value for the parity between the local currency and the dollar.

The floating exchange rate regime allows the currency to appreciate and depreciate, which causes exchange rate volatility (Lara, 2005). This type of scheme was introduced for the first time in 1973, and since its introduction, the exchange rates of several currencies have a much more volatile behavior than the factors governing their behavior, such as domestic and international money supply, Prices, and the international balance of payments (Lintz, 2004). This feature emphasizes the importance of understanding these fluctuations and managing the risk of this financial variable.

The exchange rate concept consists of the reference value of a currency in relation to a second currency. Therefore, an increase in the exchange rate means the devaluation of the currency in question against the reference. The opposite is true.

According to Madura (1989) exchange rate risk is related to the effects of unpredicted exchange rate changes on contracts involving more than one currency, that is, their recurring obligations and rights.

**Chart 1.** Convertible and inconvertible currencies.

Convertible Currencies	Non-convertible currencies
US Dollar (USD)	Chilean Peso (CLP)
Canadian Dollar (CAD)	Indian Rupee (INR)
Australian Dollar (AUS)	Argentine Peso (ARG)
Pound Sterling (GBP)	Real (BRL)
Swiss Franc (CHF)	New Peruvian Sol (PEN)
Japanese Yen (JPY)	Mexican Peso (MXN)
Euro (EUR)	Chinese Yuan (CNY)
Danish Kroner (DKK)	South Korean Won (KRW)

Source: Prepared by the authors (2016).



According to Jorion (1997) the VaR can be used to determine the exposure of financial risks such as the exposure to currencies, that is, exchange rate risk.

For such, one can use the three methods described above, and their returns are calculated from the difference between the daily quotation of one currency against the other, and the dollar is used for the most part as a reference (Papaionnou, 2006).

For example, papers such as Papaionnou (2006) calculate the exchange rate risk for companies. Wang et al. (2010) estimates the risk of the Chinese yuan through the use of VaR based on extreme value. The work of Zhan & Tian (2000) measures the risk in the Japanese yen. While Li et al. (2007) propose a model to estimate the VaR of a portfolio of Canadian dollars and Japanese Yen. Akhtekhane & Mohammadi (2012) calculate the Rial-Euro VaR using the parametric method and the historical (non-parametric) simulation method. It is possible to find other articles and researches that approach the theme.

## 2.2 Volatility between currencies of emerging and developing countries

The First World represents developed countries, with great potential in the industrial area, in structured policy and high Human Development Index, such as: Norway, United States, Sweden, Japan, Germany, France, and Italy.

No rules are defined regarding the classification of developed, emerging and underdeveloped countries. It is based on market statistics. Those located in the central area of Asia, according to the United Nations, do not fall under any of these classifications. They are: Kazakhstan, Uzbekistan, Kyrgyzstan, Tajikistan and Turkmenistan. Nor is Mongolia in the class. These countries are in another category, that of countries in transition. However, they are related in conjunction with developmental ones.

It is worth mentioning the G7 or Group of Seven that it is a forum composed of seven nations that together represent half the world economy. It is comprised of Germany, Canada, the United States, France, Italy, Japan and the United Kingdom.

The exchange rate represents an important element to be considered for the growth trajectory in developed and emerging nations, underlining the effects of the exchange rate volatility of exchange rate regimes in inflationary contexts on the growth of the latter (Araújo, 2009). The Chart 2 represents some authors who studied the real exchange rate and economic performance.

The implied volatility of developed country currencies outperformed emerging markets for the first

time in a year. Growing doubt about central banks' ability to generate growth and inflation in Japan and Europe and the optimism that emerging countries will avoid a generalized economic slowdown have affected exchange rate patterns (África21, 2016).

Currency gains due to weakening dollar are not welcome in developed countries struggling to boost economic growth, but on the other hand are well received by central banks of emerging market countries, which fight capital outflows and Depreciations. The outlook for emerging markets has also improved since concerns about China's growth slowed, and the recovery in commodity prices boosted revenues for producers such as South Africa or Brazil (África21, 2016), as China adopts a fixed exchange rate in relation to the US dollar and, like Russia, uses the currency anchor.

## 3 Research method

The present research has interests focused mainly on the measurement of risk in the local currency (real) to compare it with other currencies, in order to position the volatility of the real against other currencies, as well as verify the hypothesis that developing economies have More volatile currencies. This work starts from the calculation of the parametric VaR adjusted for different theoretical probability distributions according to the Kolmogorov-Smirnov and Anderson-Darling adhesion tests for the extreme values of Morales et al. (2013).

The US dollar (USD) was the currency selected as the reference currency, since it is the currency most used in international transactions, as well as being used as an international reserve worldwide. Given the above, the historical series of the Brazilian real (BRL) and other twelve currencies were collected, based on their value against the dollar. Sampling will be divided into two groups: emerging and developed countries. The first group consists of: Argentine peso (ARG); Chilean peso (CLP); New Peruvian sun (PEN); Mexican peso (MXN); Chinese yuan (CNY); Indian Rupee (INR); And, won South Korean (KRW). The second group consists of: Australian dollar (AUS); Euro (EUR); Swiss Franc (CHF); Pound sterling (GBP); And, Japanese Yen (JPY). Such sampling was chosen to compare the proposed VaR calculation method between developing markets, developed markets and the Asian market.

For the accomplishment of the experiment, the daily quotation of the currencies shown in Chart 3 and the quotation of the Brazilian currency between the years of 2008 and November 9, 2015 through the website of the Central Bank of Brazil were collected. The choice of this time horizon seeks to encompass

**Chart 2.** Authors who studied the real exchange rate and economic performance.

Author(s)/Population of study/Sample	Objectives/Results found
Damiani (2008)/26 countries, 13 emerging and 13 developed/(1971-2006)	This paper aims to discuss the exchange rate relationship with economic growth for emerging countries compared to developed countries. The empirical results found in this paper support the importance of the exchange rate as a relevant element to be considered for growth trajectory, for rich and emerging countries, underlining the effects of the exchange rate volatility of exchange rate regimes in inflationary contexts on the growth of the latter. The article presents the results generated by a dynamic panel that tested the relationship of economic growth with the exchange rate volatility and the choice of the exchange regime of 26 countries. The results of the emerging countries suggest a greater vulnerability to exchange rate volatility, as well as a greater relevance to the exchange rate regime adopted. For the developed ones, only the choice of regimes is relevant; However, in a considerably more attenuated way.
Araújo (2009)/90 emerging countries/(1980-2007)	The author investigated the relationship between economic growth and exchange rate volatility in emerging and developing countries. It was estimated a model that relates the economic growth to the exchange rate volatility in a data panel. The estimates indicated a negative and highly significant impact of exchange rate volatility on economic growth, confirming the theoretical prediction that exchange rate instability has negative effects on the real economy. Estimates have shown that exchange rate volatility has a negative and significant effect on economic growth in the countries studied, suggesting that these countries would benefit from policies that would contribute to greater stability of their exchange rates.
Schnabl (2007)/41 countries on the periphery of the European Monetary Union/(1994-2005)	The author studied the real exchange rate and economic performance, and as results the estimates revealed an inverse and statistically significant relationship between exchange rate volatility and economic growth in developing countries with financial openness. For the group of European non-monetary European industrialized countries the benefits of stable exchange rates appeared to be weaker. This may be due to the fact that the more developed capital markets have made them less vulnerable to exchange rate variation.
Aghion et al. (2009)/83 countries/(1960-2001)	The empirical results indicated that real exchange rate volatility has a negative impact on long-term productivity growth, and the effect depends critically on the level of financial development. The results showed robust for time window, alternative measures of financial development and exchange rate volatility and discrepant values.
Kittiakarasakun & Tse (2011)/Return on equity indexes in Asia/(1989-2009)	The authors analyzed whether stock returns in Asian markets are characterized by infinite variance or by large variation, which has an important implication for the applicability of many financial models to Asian market data. The Value-at-Risk method was applied using Asian and North American data and no significant difference in performance was found. The Extreme Values Theory (TVE) was also applied to characterize the return distributions of the stock indices. The authors noted that Asian stock markets are more volatile than developed markets, but the occurrence of extreme price changes is as likely in Asian markets as in developed markets.
Bekaert & Harvey (2000)/17 countries/(1977-1996)	The objective of this study was to identify breaks in the capital flows of seventeen countries. Of these, sixteen are interrupted by an increase in net capital flows. In some countries, it appears that the flows of securities precede capital flows. It was analyzed that the expected returns decrease after significant decreases in capital flows. In addition, the risk decreases, at least as measured by the country's rating, and the correlations of capital returns with the world market is larger. It was analyzed that the increase in capital flows is associated with a lower cost of capital, higher correlation with world market returns, lower concentration of assets, lower inflation, larger market size in relation to GDP, more trade, and slightly Higher per capita economic growth.

Source: Prepared by the authors (2016).

the period of financial crises beginning in 2008 and the current volatility of the brazilian currency.

Then, from the daily closing value of each currency against the Real, the daily returns were calculated through Equation 1.

$$R_t = \ln r_t - \ln r_{t-1} \tag{1}$$

In that  $R_t$  corresponds to the daily return,  $\ln r_t$  represents the value of the asset on day t and,  $\ln r_{t-1}$  corresponds to the value on day t-1. For all distributions

**Chart 3.** Exchange rates used.

Group 1 - Emerging	Group 2 - Developed
ARG/USD	EUR/USD
CLP/USD	CHF/USD
MXN/USD	GBP/USD
PEN/USD	AUS/USD
CNY/USD	JPY/USD
INR/USD	
KRW/USD	
BRL/USD	

Source: Prepared by the authors (2016).

that do not admit negative values, Equation 1 was calculated in logarithmic terms in order to maintain percentage proportionality, but using terms in positive values (Moralles et al., 2013), as shown in Equation 2.

$$R_p = e^{R_t} \tag{2}$$

Rp are the returns expressed in exponential terms from the returns Rt obtained in Equation 2. Once this has been done, the accumulated empirical probability distribution of the various currencies will be assembled, representing their return. In order to better parameterize the empirical distribution, as well as to capture the extreme values of the left tail, and consequently to obtain a VaR that best represents reality, the extreme value theory (EVT) will be applied, reducing the importance of the central values and the right tail. It is better to predict the movements related to the extreme values that consist of the method developed by Moralles et al. (2013).

In this way, a second series will be constructed for each coin, and this new series will be composed by the 10% lower returns found during the studied period. Thus, this work aims to apply extreme value theory (EVT) in order not to overestimate or underestimate risk exposure. Being that, when working with the extreme values, a probabilistic distribution is obtained that better adheres to the left tail, which will result in a more realistic VaR.

Subsequently, these distributions will be compared with other theoretical distributions. Then, the Kolmogorov-Smirnov adhesion test and the Anderson-Darling adhesion test will be used, which will indicate the degree of agreement between the sample distribution and the theoretical distribution (Moralles et al., 2013). The Kolmogorov-Smirnov and Anderson-Darling adhesion test was performed from a routine developed by EasyFit 5.6.

Thus, the distribution to be used in the VaR calculation will be based on (Equation 3).

$$KS = \max_x |F_n(x) - F(x)| \tag{3}$$

If

$KS \leq K_{1-\alpha}$  which  $K_{1-\alpha}$  are values critical to a significance  $\alpha$ .

And,

Additionally,  $\phi_i$  it is specified by (4),

$$A^2 = - \frac{\left\{ \sum_{i=1}^n (2i-1) [\ln(\phi_i) + \ln(1-\phi_{n+1-i})] \right\}}{n} - n \tag{4}$$

Which,  $\phi_i$  is a given probability distribution

$$\text{If, } A^2 \leq A_{1-\alpha}$$

Which,  $A_{1-\alpha}$  are values to a significance  $\alpha$  for a distribution  $\phi_i$ .

Once the distributions that best represent the series were obtained, the calculation of the daily VaR, obtained from the same software, was performed at a significance level of 50% for the composite series of the 10% lower values, in order to obtain a Level of significance of 5% for the whole series.

In these terms, the model presented for the VaR calculation will be (Equation 5).

$$VaR(x) = \phi_i^{-1}(p | \mu, \sigma, \xi) = [x : \phi(x | \mu, \sigma, \xi)] \tag{5}$$

Which,

p is the level of significance used for the VaR calculation.

$\mu, \sigma, \xi$  are respectively parameters of mean, standard deviation, and distribution format  $\phi_i$  using iterative numerical methods.

$\phi_i^{-1}(x)$  is the *inverse cumulative density function* of the probability distribution to be specified by the goodness-of-fit tests.

Finally, to validate the VaR calculation method, backtesting was performed (Kupiec 1995), which calculates the interval for VaR acceptance given by the likelihood ratio of a Bernoulli distribution of (Equation 6).

$$L = -2 \ln[(1-p)^{T-N} p^N] + 2 \ln[(1-(N/T))^{T-N} (N/T)^N] \tag{6}$$

Whose interval limit is given by (Equation 7),

$$2 \ln(L) - 2 \ln(L0) \sim \chi_{(1)}^2 \tag{7}$$

Thus, the interval created by the Kupiec test allows one to evaluate if the estimated VaR is under control, that it, to verify if it is not underestimated or overestimated.

### 4 Results

Regarding the evolution of the Brazilian real against the dollar at the end of each month between January 2008 and November 2015, it is stated that the currency suffered a strong devaluation in the recent period, with the Real depreciating by 49.4%. In the last 12 months,

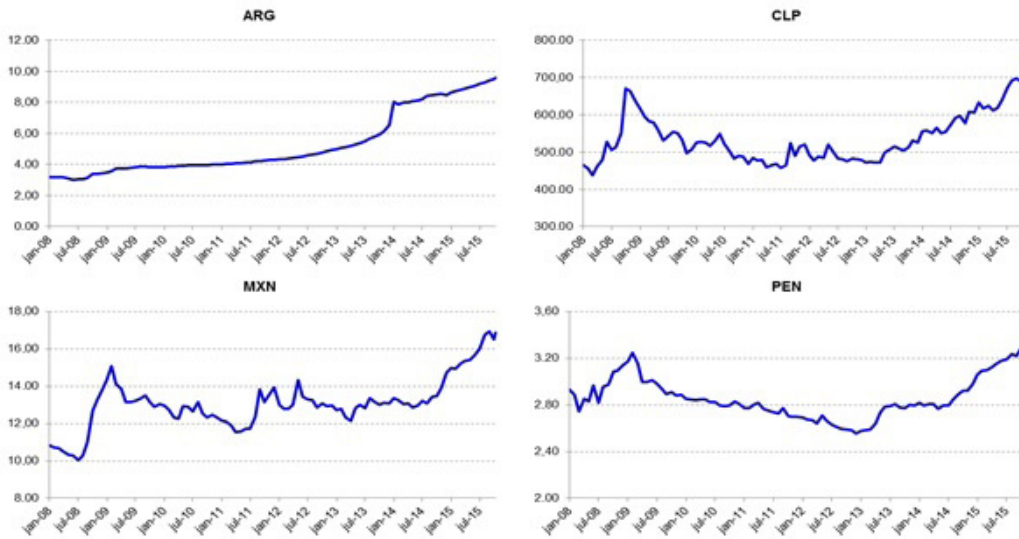
reaching its maximum price of R\$ 4.21 during the study period on September 29, 2015. Moreover, the currency was very volatile between 2008 and 2009. It is important to note that both in 2008 and 2009 Brazil has experienced economic crises, and today the country is experiencing a strong economic recession, which justifies the volatility presented by the currency during the periods highlighted.

In the graphs shown in Figure 2, prices are shown at the end of each month in each of the Latin American countries - Argentina, Chile, Mexico and Peru. Figure 3 shows the same observation for the currencies of the European Union, Switzerland, the

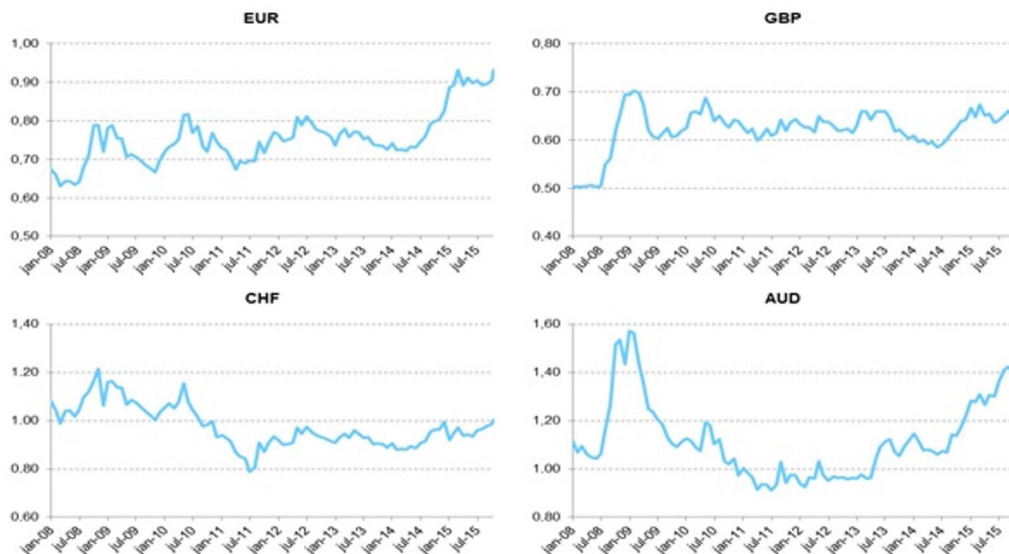
United Kingdom and Australia. Finally, in Figure 4, it is possible to observe the behavior of the currencies of Japan, South Korea, China and India.

Note that for the great majority of currencies there were more pronounced fluctuations during periods of crisis, especially in the second half of 2008 and beginning of 2009, when volatility spikes are more pronounced. It is also possible to observe that, for more recent dates, the graphs show a greater volatility when compared to previous periods, although it is less marked than that between 2008 and 2009.

In view of this volatility presented in all currencies studied, it is possible to emphasize again the need



**Figure 2.** Evolution of the exchange rate of Latin American countries. Source: Prepared by the authors (2016).



**Figure 3.** Evolution of the exchange rate currencies of the European Union, Switzerland, the United Kingdom and Australia. Source: Prepared by the authors (2016).



and importance in measuring and knowing the risks involved in exchange rates.

Once the returns for each coin were obtained, the adhesion test was performed for the lowest 10% values of each distribution, in order to obtain the probability distribution that best portrayed the left tail of each series.

The results obtained by the adhesion test performed by the software EasyFit 5.6 are shown in Charts 4 and 5.

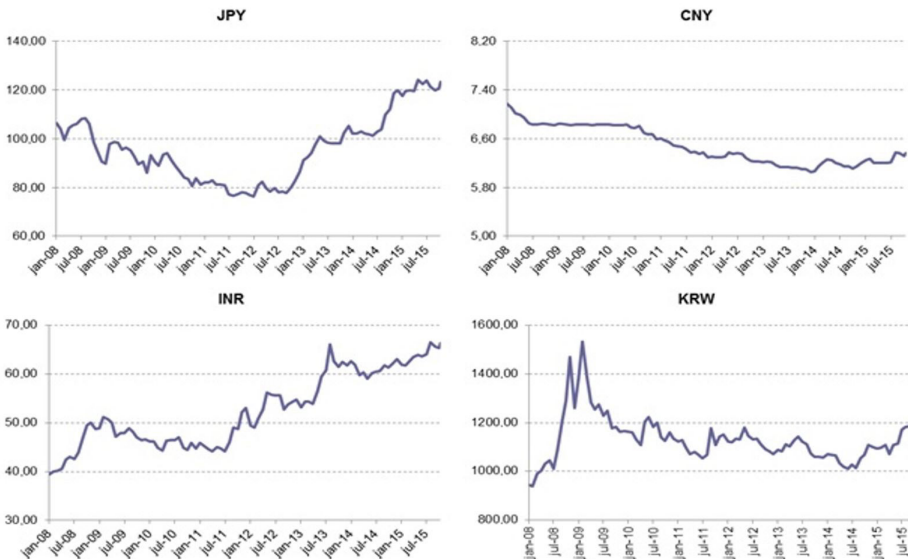
The Chart 4 shows that different distributions for the same series, with the exception of the Chilean peso, of the Canadian dollar and the Indian rupee were obtained for the different test types, in which both tests resulted in the adherence of one Same distribution - General Extreme Value (GEV). Moreover, it is notorious that coins of the same group exhibited relatively similar behavior. As the similarities are more recurrent in the comparison between currencies

of the same group, than when comparing currencies of different groups.

The Chart 5 shows that the probability distribution that best describes the series of returns of different exchange rates for the Kolmogorov-Smirnov test consists of the general extreme value distribution (GEV), appearing ten times, whereas for The Anderson-Darling test, both GEV functions and power function appeared 3 times.

From the distributions obtained as well as the parameters of each distribution, it was possible to calculate the VaR of the real and other currencies.

The average daily VaR of the real equals -1.45%, ie on a business day, there is only 5% probability of the actual loss being greater than 1.45%. Mean VaR was obtained by averaging the VaR calculated by the Kolmogorov-Smirnov test and the Anderson-Darling test. The results obtained can be seen in Chart 6.



**Figure 4.** Evolution of the exchange rate of the currencies of Japan, South Korea, China and India. Source: Prepared by the authors (2016).

**Chart 4.** Result of the adhesion test.

		Adherence tests	
		Kolmogorov-Smirnov	Anderson-Darling
Group 1	ARG/USD	Gen. Extreme Value	Johnson SB
	CLP/USD	Gen. Extreme Value	Gen. Extreme Value
	MXN/USD	Gen. Extreme Value	Power Function
	PEN/USD	Gen. Extreme Value	Log-Pearson 3
	JPY/USD	Power Function	Power Function
Group 2	EUR/USD	Gen. Extreme Value	Kumaraswamy
	GBP/USD	Power Function	Dagum
	CHF/USD	Dagum	Weibull (3P)
	CAD/USD	Gen. Extreme Value	Gen. Extreme Value
	CNY/USD	Gen. Extreme Value	Power Function
	INR/USD	Gen. Extreme Value	Gen. Extreme Value
	KRW/USD	Gen. Extreme Value	Kumaraswamy

Source: Prepared by the authors (2016).

**Chart 5.** Frequency of adhesion test results.

		Adherence tests	
		Kolmogorov – Smirnov	Anderson-Darling
<b>Distribution</b>	<b>Gen. Extreme Value</b>	<b>10</b>	<b>3</b>
	<b>Power Function</b>	<b>2</b>	<b>3</b>
	<b>Dagum</b>	<b>1</b>	<b>2</b>
	<b>Kumaraswamy</b>	<b>0</b>	<b>2</b>
	<b>Johnson SB</b>	<b>0</b>	<b>1</b>
	<b>Log-Pearson 3</b>	<b>0</b>	<b>1</b>
	<b>Weibull (3P)</b>	<b>0</b>	<b>1</b>

Source: Prepared by the authors (2016).

Before analyzing the observed results, the backtesting was performed, in order to verify if the method proposed for the VaR calculation presented acceptable VaR values. The results obtained in the backtesting step can be observed in Chart 7. It can be observed that the proposed method presented acceptable results, within the confidence interval. There was only one observation outside the acceptable region, which consisted of the VaR calculated by Anderson-Darling for the South Korean Won. That is, in general, the proposed method - calculation of the VaR by the parametric method through the test of adherence to extreme values - points VaR values that do not overestimate or underestimate the risk.

The Chart 8 shows the results in descending order in absolute terms for each type of test, while Chart 9 shows the mean VaR values in descending order.

From the previous charts, it is observed that the Real presents the highest risk among all currencies studied, with only the Australian dollar surpassing the risk of the Real in the Kolmogorov-Smirnov test. In addition, it is possible to note that the currencies of the emerging countries have the lowest risk, with an average VaR of -0.78% and a median of -0.78%.

However, the low value of the group’s average VaR can be explained by the fact that the Argentine currency presents a very small risk, with a VaR of -0.16%, which can be justified by the presence of an interventionist government that Does not allow the currency to float freely in the market. This fact can also be observed in Figure 2, where it is noticed that, although the currency has devalued over time, it consisted of a regular and constant devaluation. By including the Real in the average of the emerging group, the VaR rises to -0.78% (Chart 10).

In absolute terms, the developed group had an average VaR equal to -1.15%, 37% above the VaR

of the emergent group. It is worth noting that the low risk observed in the Chinese currency is due to the presence of a strong and interventionist government that, together with the high international reserves, controls the exchange rate variation of the currency according to its internal policies. Thus, group 2 (developed) showed to be the group with a riskier exchange rate. As can be seen in Chart 10.

Given the above, it can be inferred that the Brazilian currency presents a divergent behavior of the currencies studied. Its risk was closer to the Australian dollar, whose VaR is 1.22% lower than the Real VaR (Chart 11). The high risk presented by the Brazilian currency can be explained by the current political and economic crisis that the country is going through, being a crisis almost exclusive of the country, so the volatility of the period is much higher than the others, which increases its risk.

The similarity between the VaR observed between some currencies, as in the case of european currencies, may be related to the fact that the exchange rates are exposed to the same risk factors, which can be explained by similar economies, cross-politics and the same geographic region. Finally, it is possible to infer that the Brazilian real (BRL) is the currency with the highest risk of the dollar among the portfolio of currencies studied, while the Australian dollar (AUS) is the one that presents a risk similar to the Brazilian currency. The Argentine peso (ARG) proved to be the least risky currency in the period studied, followed by the Chinese yuan (CNY). It was also possible to observe that there was a relative similarity in the behavior among the currencies of the same group, and the group formed by the developed countries was the one that presented the highest risk among the other groups, contradicting the expectation that developed countries have more stable currencies Than those of developing countries.

**Chart 6.** VaR by Currency Group.

		<b>Kolmogorov-Smirnov %</b>	<b>Anderson-Darling %</b>	<b>VaR Médio %</b>
Group 1	BRL	-1.41	-1.50	-1.45
	ARG	-0.16	-0.16	-0.16
	CLP	-1.08	-1.08	-1.08
	MXN	-1.04	-1.12	-1.08
	PEN	-0.47	-0.48	-0.47
	CNY	-0.17	-0.18	-0.17
	INR	-0.75	-0.75	-0.75
	KRW	-0.99	-1.16	-1.07
	Média	-0.76	-0.80	-0.78
Mediana	-0.76	-0.80	-0.78	
Group 2	EUR	-1.07	-1.10	-1.08
	GBP	-0.95	-0.98	-0.97
	CHF	-1.15	-1.24	-1.19
	AUS	-1.43	-1.45	-1.44
	JPY	-1.08	-1.08	-1.08
	Média	-1.14	-1.17	-1.15
	Mediana	-1.08	-1.10	-1.08

Source: Prepared by the authors (2016).

**Chart 7.** Backtesting.

Currency	Sample Size	Confidence Interval	Número de superações		
			Kolmogorov-Smirnov	Anderson-Darling	Average VaR
<b>BRL</b>	<b>2048</b>	<b>81&lt;T&lt;125</b>	<b>99</b>	<b>90</b>	<b>94</b>
<b>ARG</b>	<b>2048</b>	<b>81&lt;T&lt;125</b>	<b>103</b>	<b>99</b>	<b>102</b>
<b>CLP</b>	<b>2048</b>	<b>81&lt;T&lt;125</b>	<b>111</b>	<b>111</b>	<b>111</b>
<b>MXN</b>	<b>2048</b>	<b>81&lt;T&lt;125</b>	<b>108</b>	<b>90</b>	<b>100</b>
<b>PEN</b>	<b>2048</b>	<b>81&lt;T&lt;125</b>	<b>101</b>	<b>101</b>	<b>101</b>
<b>EUR</b>	2048	81<T<125	<b>107</b>	<b>103</b>	<b>105</b>
<b>GBP</b>	2048	81<T<125	<b>104</b>	<b>98</b>	<b>102</b>
<b>CHF</b>	2048	81<T<125	<b>105</b>	<b>89</b>	<b>96</b>
<b>AUS</b>	2048	81<T<125	<b>94</b>	<b>92</b>	<b>93</b>
<b>JPY</b>	2048	81<T<125	<b>98</b>	<b>98</b>	<b>98</b>
<b>CNY</b>	2048	81<T<125	<b>103</b>	<b>97</b>	<b>100</b>
<b>INR</b>	2048	81<T<125	<b>101</b>	<b>101</b>	<b>101</b>
<b>KRW</b>	2048	81<T<125	<b>104</b>	<b>77</b>	<b>90</b>

Source: Prepared by the authors (2016).

**Chart 8.** VaR in ascending order by adherence test.

	<b>Anderson-Darling %</b>		<b>Kolmogorov-Smirnov %</b>
<b>BRL</b>	<b>-1.50</b>	<b>AUS</b>	<b>-1.43</b>
<b>AUS</b>	<b>-1.45</b>	<b>BRL</b>	<b>-1.41</b>
<b>CHF</b>	<b>-1.24</b>	<b>CHF</b>	<b>-1.15</b>
<b>KRW</b>	<b>-1.16</b>	<b>CLP</b>	<b>-1.08</b>
<b>MXN</b>	<b>-1.12</b>	<b>JPY</b>	<b>-1.08</b>
<b>EUR</b>	<b>-1.10</b>	<b>EUR</b>	<b>-1.07</b>
<b>CLP</b>	<b>-1.08</b>	<b>MXN</b>	<b>-1.04</b>
<b>JPY</b>	<b>-1.08</b>	<b>KRW</b>	<b>-0.99</b>
<b>GBP</b>	<b>-0.98</b>	<b>GBP</b>	<b>-0.95</b>
<b>INR</b>	<b>-0.75</b>	<b>INR</b>	<b>0.75</b>
<b>PEN</b>	<b>-0.48</b>	<b>PEN</b>	<b>-0.47</b>
<b>CNY</b>	<b>-0.18</b>	<b>CNY</b>	<b>-0.17</b>
<b>ARG</b>	<b>-0.16</b>	<b>ARG</b>	<b>-0.16</b>

Source: Prepared by the authors (2016).

**Chart 9.** Average VaR in descending order.

	Kolmogorov-Smirnov %	Anderson-Darling	VaR Médio %
<b>BRL</b>	<b>-1.41</b>	<b>-1.50</b>	<b>-1.45</b>
<b>AUS</b>	<b>-1.43</b>	<b>-1.45</b>	<b>-1.44</b>
<b>CHF</b>	<b>-1.15</b>	<b>-1.24</b>	<b>-1.19</b>
<b>EUR</b>	<b>-1.07</b>	<b>-1.10</b>	<b>-1.08</b>
<b>CLP</b>	<b>-1.08</b>	<b>-1.08</b>	<b>-1.08</b>
<b>JPY</b>	<b>-1.08</b>	<b>-1.08</b>	<b>-1.08</b>
<b>MXN</b>	<b>-1.04</b>	<b>-1.12</b>	<b>-1.08</b>
<b>KRW</b>	<b>-0.99</b>	<b>-1.16</b>	<b>-1.07</b>
<b>GBP</b>	<b>-0.95</b>	<b>-0.98</b>	<b>-0.97</b>
<b>INR</b>	<b>-0.75</b>	<b>-0.75</b>	<b>-0.75</b>
<b>PEN</b>	<b>-0.47</b>	<b>-0.48</b>	<b>-0.47</b>
<b>CNY</b>	<b>-0.17</b>	<b>-0.18</b>	<b>-0.17</b>
<b>ARG</b>	<b>-0.16</b>	<b>-0.16</b>	<b>-0.16</b>

Source: Prepared by the authors (2016).

**Chart 10.** Mean VaR.

	Average %	Medium
<b>Group 1</b>	<b>-0.68</b>	<b>-0.72</b>
<b>Group 2</b>	<b>-1.15</b>	<b>-1.08</b>
<b>Group 1 + BRL</b>	<b>-0.78</b>	<b>-0.78</b>

Source: Prepared by the authors (2016).

**Chart 11.** Variation of VaR in relation to Real VaR.

	VaR Middle Absolute Terms %	Variation in relation to the Real %
BRL	1.45	0.00
AUS	1.44	-1.22
CHF	1.19	-17.94
EUR	1.08	-25.59
CLP	1.08	-25.69
JPY	1.08	-25.69
MXN	1.08	-26.01
KRW	1.07	-26.28
GBP	0.97	-33.58
INR	0.75	-48.24
PEN	0.47	-67.58
CNY	0.17	-88.03
ARG	0.16	-89.23

Source: Prepared by the authors (2016).

## 5 Conclusions

The exchange rate is a fundamental variable in the process of economic development. Being that it composes one of the pillars of the Brazilian economy. Given its importance, the focus of this paper was to understand the volatility of the Brazilian currency in comparison with currencies of other countries, in order to establish a relationship between them by calculating Value-at-Risk (VaR).

The currencies studied were divided into two groups: currencies of emerging countries; and, currencies of developed countries. The first group consisted of:

real (BRL); Argentine peso (ARG); Chilean peso (CLP); New Peruvian sun (PEN); Mexican peso (MXN); Chinese yuan (CNY); Indian Rupee (INR); and, won South Korean (KRW). The second group consisted of: Australian dollar (AUS); Euro (EUR); Swiss Franc (CHF); Pound sterling (GBP); And, Japanese Yen (JPY). Such sampling was chosen to compare the proposed VaR calculation method between developing markets, developed markets and the Asian market.

It should also be noted that the currencies of the developed countries are convertible currencies, that



is, they are freely accepted by other countries, without any restriction and in any market, since the currencies of the emerging countries are inconvertible currencies, that is, they are Those currencies that do not have an easy international course or that are not accepted by other countries in foreign exchange transactions. Thus, this aspect was also considered as a parameter of classification of the two groups.

For this, the VaR of each coin was calculated by the parametric method by applying the extreme value theory (EVT) in order to best represent the extreme values, and the Kolmogorov-Smirnov and Anderson-Darling adhesion tests were performed to reflect more accurately the actual historical distribution, resulting in a calculation method that proved to be effective, since the results obtained were within the confidence interval proposed by the backtesting, except for one sample. From this, it was possible to conclude that the average daily VaR of the real against the US dollar was -1,45%, a risk 65% higher than the average values obtained for the other twelve currencies studied. That is, the obtained VaR implies that there is only 5% probability in the real to incur a loss above 1,45% on a business day.

It was also observed that group 1 (emergent) had an average VaR of -0.78%, consisting of the lowest risk group, that is, the currencies of emerging countries presented a lower risk in relation to the US dollar among the groups studied. It is important to note that the Argentine peso was the one that resulted in the lowest VaR equal to -0.16%, being, therefore, the less risky currency. Group 2 (developed) presented an average VaR of -1.15% and proved to be the group with the most risky exchange rates.

It is worth mentioning that in the period studied Argentina was in fact not very connected to international markets, which may explain the resistance of the peso to external shocks - that is, it is not only the degree of intervention that explains the paradoxical result of the performance of the Argentine peso. The results showed that economies in similar stages and near maturity levels show a similar exchange rate behavior, so the results obtained for currencies of the same group were within the same range of values. The results showed that the Argentine peso (ARG) was the least risky currency in the period studied, followed by the Chinese yuan (CNY), the new Peruvian sol (PEN) and the Indian rupee (INR).

Thus, the findings of the present study are in agreement with the one found by Schnabl (2007), which verifies an inverse relationship and between exchange rate volatility and economic growth in developing countries with financial openness. Also, the results presented contradict Damiani (2008), which states that emerging countries are more vulnerable to exchange rate volatility, since the calculated VaR lower are in the fashions of emerging nations.

And, following the same reasoning, the findings of the present study contradict Araújo (2009), which states that exchange rate volatility has a negative and significant effect on economic growth.

Therefore, in general terms, the volatility of currencies and their relation to development seem to be much more related to the level of government intervention on the value of currencies than with market factors described above. Thus, a mode with totally fluctuating change, although more volatile, points to the efficiency of the regulatory mechanisms of an exchange with low intervention. Regarding the predictability of the VaR methods, Kittiakarasakun & Tse (2011) and Gençay & Selçuk (2004) argue that financial models are often not applicable to both emerging and developed markets, as well as the difference in markets reflected in the tails of probability distributions of returns. However, the results presented show a high incidence of generalized extreme value distribution (VEG) by the Kolmogorov-Smirnov test; And a pattern indistinct by the Anderson-Darling test. Like this, in terms of VaR computation, distributional assumptions do not seem to have any specific pattern when confronted with emerging and developed countries, so it is not possible to say that developing country currencies are actually more volatile.

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