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Benjamin M. Tabak

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Edited by Research Department (Depep) – E-mail: workingpaper@bcb.gov.br

Editor: Benjamin Miranda Tabak – E-mail: benjamin.tabak@bcb.gov.br
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The Dynamic Relationship between Stock Prices and Exchange Rates: evidence for Brazil

Benjamin M. Tabak*

Abstract

This paper studies the dynamic relationship between stock prices and exchange rates in the Brazilian economy. We use recently developed unit root and cointegration tests, which allow endogenous breaks, to test for a long run relationship between these variables. We performed linear, and nonlinear causality tests after considering both volatility and linear dependence. We found that there is no long-run relationship, but there is linear Granger causality from stock prices to exchange rates, in line with the portfolio approach: stock prices lead exchange rates with a negative correlation. Furthermore, we found evidence of nonlinear Granger causality from exchange rates to stock prices, in line with the traditional approach: exchange rates lead stock prices. We believe these findings have practical applications for international investors.

JEL Classification: F400; G150.
Keywords: Stock Prices, Exchange Rates, Bivariate Causality, Nonlinear Causality.

* Banco Central do Brasil, Research Department. E-mail: benjamin.tabak@bcb.gov.br

Introduction

The literature that studies the relationship between exchange rates and stock prices is far from conclusive. There are two main theories that relate these financial markets. The first is the traditional approach, which concludes that exchange rates should lead stock prices. The transmission channel would be exchange rate fluctuations which affect firm's values through changes in competitiveness and changes in the value of firm's assets and liabilities, denominated in foreign currency, ultimately affecting firms' profits and therefore the value of equity[1].

Alternatively, changes in stock prices may influence movements in exchange rates via portfolio adjustments (inflows/outflows of foreign capital). If there were a persistent upward trend in stock prices, inflows of foreign capital would rise. However, a decrease in stock prices would induce a reduction in domestic investor's wealth, leading to a fall in the demand for money and lower interest rates, causing capital outflows that would result in currency depreciation. Therefore, under the portfolio approach, stock prices would lead exchange rates with a negative correlation.

In January 1999, Brazil abandoned the crawling peg exchange rate regime and adopted a floating exchange rate[2]. From January 14th to March 3rd, the Brazilian Real depreciated drastically, 49,51%. The BOVESPA Index (the São Paulo Stock Exchange Index, the most important stock index in the country) increased 4.097 points in the same period (59.34% rise). This effect on the domestic stock index is very different from that observed in Asian economies at the start of the Asian crisis. Therefore, the Brazilian case provides an interesting opportunity to study the dynamics between stock prices and exchange rates.

The rapid increase of the stock index could have occurred because the economic agents believed that the currency was overvalued, and that depreciation would lead to an increase in firm competitiveness, enhancing exports and raising profits. Moreover, many firms that comprise the stock index have American Depository Receipts (ADR); these stock prices would respond almost immediately through arbitrage mechanisms,

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[1] Even firms that are not internationally integrated (low ratio of exports and imports to total sales and a low proportion of foreign currency-denominated assets and liabilities) may be indirectly affected.

[2] Campa et al. (2002) studied the credibility of the crawling peg and target zone (maxiband) regimes and have a nice description of the period prior to the maxi-devaluation of the Real in 1999.

since, with the rapid depreciation, domestic traded stocks would be very cheap *vis-a-vis* their ADR.

We analyze the dynamics between the stock index and the exchange rate using linear, and nonlinear, Granger causality tests. We employ series filtered for volatility and linear dependence when performing the nonlinear causality tests. We make use of unit root and cointegration tests, which allow endogenous breaks, to test for a long-run equilibrium relationship between these variables. Furthermore, we use impulse response functions to test the validity of both the traditional and portfolio approaches.

This paper is organized as follows. In the next section, we present a brief literature review and the main findings in developed and emerging countries. Section 3 presents the data and methodology employed. Section 4 shows the empirical evidence for the interdependencies between stock prices and exchange rates in Brazil. Section 5 concludes the paper and gives some directions for further research.

1. Literature Review

The relationship between exchange rates and stock prices is of great interest to many academics and professionals, since they play a crucial role in the economy. Nonetheless, results are somewhat mixed as to whether stock indexes lead exchange rates or *vice versa* and whether feedback effects (bi-causality) even exist among these financial variables.

Aggarwal (1981) argued that changes in exchange rates provoke profits or losses in the balance sheet of multinational firms, which induces their stock prices to change. In this case, exchange rates cause changes in stock prices (traditional approach).

Dornbusch (1975) and Boyer (1977) presented models suggesting that changes in stock prices and exchange rates are related by capital movements. Decreases in stock prices reduce domestic wealth, lowering the demand for money and interest rates, inducing capital outflows and currency depreciation.

Bahmani-Oskooee and Sohrabian (1992) analyzed the relation between stock prices and exchange rates in the US economy. They found no long-run relationship among these variables, but a dual causal relationship in the short-run using Granger (1969) causality tests[3]. Amihud (1994) and Bartov and Bodnar (1994) found that lagged, and not contemporaneous, changes in US dollar exchange rates, explain firms current stock returns.

Ratner (1993) applied cointegration analysis to test whether US dollar exchange rates affect US stock prices, using monthly data from March 1973 to December 1989. His results indicated that the underlying long-term stochastic properties of the US stock index and foreign exchange rates are not related, since the null of no cointegration could not be rejected, even when dividing the sample into sub-periods.

Ajayi and Mougoué (1996) analyzed the relationship between stock prices and exchange rates in eight advanced economies (Canada, France, Germany, Italy, Japan, the Netherlands, the United Kingdom and the United States)[4]. Using an error correction model, they found significant short and long run feedback between these two variables.

Abdalla and Murinde (1997) investigated interactions between exchange rates and stock prices in India, Korea, Pakistan, and the Philippines. Using monthly observations in the period from January 1985 to July 1994. Within an error correction model framework, they found evidence of unidirectional causality from exchange rates to stock prices in all countries, except for the Philippines. There, they found that stock prices Granger influence exchange rates.

Ong and Izan (1999) used weekly data of "spot and 90-day forward" exchange rates for Australia and the G-7 countries and "spot and 90-day forward" futures prices for equity prices in Australia, Britain, France and the US, during the period from October 1986 to December 1992. They were unable to find a significant relationship between equity and exchange rate markets. They suggested that the use of daily data (or even intra-day) could improve their empirical results.

Ajayi et al (1998) used daily data and reported that causality runs from the stock market to the currency market in Indonesia and the Philippines, while in Korea it runs in the opposite direction. No significant causal relation is observed in Hong Kong, Singapore, Thailand, or Malaysia. However, in Taiwan, they detected bi-directional causality or feedback. Furthermore, contemporaneous adjustments are significant in

[3] They use the S&P 500, the effective exchange rate, and monthly data over the period from July 1973 to December 1988.
[4] Their sample runs from April 1985 to July 1991.

only three of these eight countries. In developed countries, they found significant unidirectional causality from stock to currency markets and significant contemporaneous effects[5].

Granger et al. (2000) found strong feedback relations between Hong Kong, Malaysia, Thailand and Taiwan. They used daily data and their sample period started January 3, 1986 and finished June 16, 1998. Furthermore, they found that the results are in line with the traditional approach in Korea, while they agree with the portfolio approach in the Philippines.

Nieh and Lee (2001) found no significant long-run relationship between stock prices and exchange rates in G-7 countries, using both the Engle-Granger and Johansen's cointegration tests[6]. Furthermore, they found ambiguous, and significant, short-run relationships for these countries. Nonetheless, in some countries, both stock indexes and exchange rates may serve to forecast the future paths of these variables. For example, they found that currency depreciation stimulates Canadian and UK stock markets with a one-day lag, and that increases in stock prices cause currency depreciation in Italy and Japan, again with a one-day lag.

In general, empirical findings suggest that there are no long-run equilibrium relationships between these two financial variables (exchange rates and stock prices) in most countries. However, many studies have found that these variables have "predictive ability" for each other, although the direction of causality seems to depend on specific characteristics of the country analyzed. To the best of our knowledge, this is the first paper that addresses this issue in the Brazilian economy.

2. Data and Methodology

The data, obtained from Bloomberg, consists of 1.922 observations, from August 1, 1994 to May 14, 2002, of daily closing prices in the São Paulo Stock Exchange Index (IBOVESPA) and foreign exchange rate (units of Real per US dollar). We use daily data since the use of monthly data may not be adequate to capture the effects of short-term capital movements.

[5] They analyze Canada, Germany, France, Italy, Japan, the UK and the US. For advanced economies, they use a database that covers the period from April 1985 to August 1991 and, for emerging markets, the period begins in December 1987 and ends in September 1991.

[6] They use daily data during the period from October 1, 1993 to February 15, 1996.

Figure 1 presents the Real exchange rate in the sample period. By simply visualizing the data, the pronounced structural break at the beginning of 1999 becomes evident. The Real suffered a noticeable depreciation in mid-January reaching a peak of 2.16 on March 3. The Central Bank introduced a floating exchange rate regime and an inflation-targeting monetary policy in order to stabilize expectations and gain credibility.

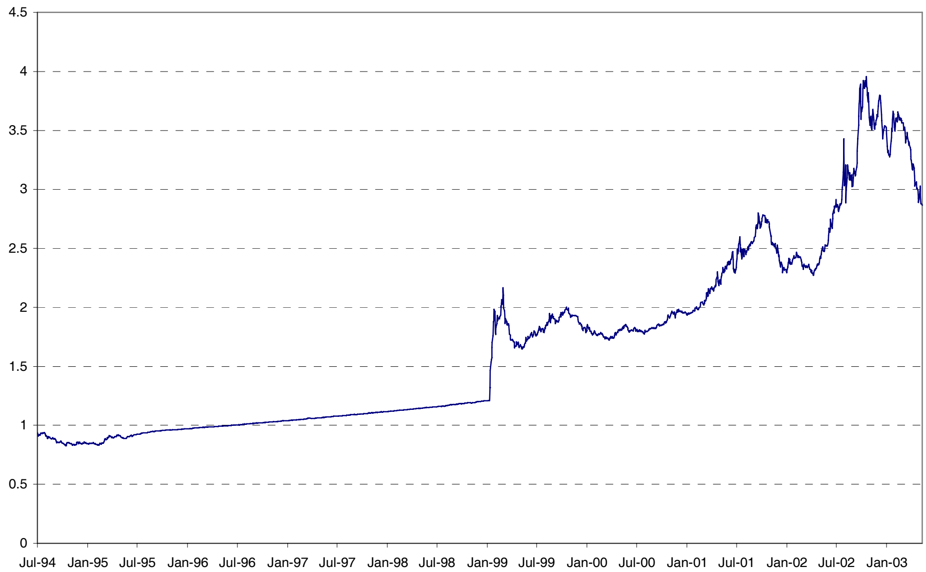

Figure 1. Time Series of the Brazilian Exchange Rate (Real) (R$/US$)

Figure 2 shows the IBOVESPA time series. Differently from the Asian crisis, in which most Asian countries had huge currency depreciation associated with plunges in equity markets, the Brazilian currency depreciation was followed by a sharp increase in the equity prices index. This could be due to the widely held belief that the currency was overvalued and that depreciation would lead to a higher competitiveness increasing domestic firm's profits. Furthermore, most firms that had American Depository Receipts had huge increases in their prices as arbitrage opportunities appeared (at least momentarily).

Figure 2. Time Series of the Brazilian Stock Index (IBOVESPA)

From Figures 1 and 2 we can infer that the Brazilian case differs from that of most Asian countries, and provides a particularly interesting opportunity to study the relationship between stock prices and exchange rates. We studied the full sample and divided it into two sub-periods. The first, begins on August 1, 1994 and ends on January 12,1999. The second sub-period, begins on January 13, 1999 and ends on May 14, 2002[7].

A concern about this approach is that the analysis of the first sub-period may not provide useful insights, as the nominal exchange rate is pegged to the US dollar. However, the currency fluctuates, although to a limited degree, which provides some justification for conducting the analysis, in the same vein as Granger et al. (2001) have done.

3.1. Unit roots

We used the Augmented Dickey and Fuller (1981) (ADF) test for unit roots, using both a trend and an intercept. In general, an ADF(p) model is given by

$$\Delta x_t = \alpha + (1-\phi)x_{t-1} + \gamma t + \sum_{i=1}^{p} \beta_i \Delta x_{t-i} + \varepsilon_t \ . \tag{1}$$

[7] On average the Real depreciated 7% on a yearly basis until 1999. On January 13, the Real depreciated 8.53% in a single day.

The Bayesian Schwarz Information criterion was used to choose the order of lags (p) in equation (1). Furthermore, we imposed an additional requirement, that the resulting model has white noise residuals. If the resulting model has serial correlation, the order of lags is augmented until residuals with no serial correlation are obtained.

Since the failure to reject the null of a unit root may be due to the low power of unit root tests against stationary alternatives, Kwiatkowski, Phillips, Schmidt, and Shin (1992) proposed a test where the null is stationary and the alternative is a unit root. This test is given by

$$KPSS = \frac{1}{T^2} \sum_{t=1}^{T} \frac{S_t^2}{s^2(L)}, \tag{2}$$

where

$$S_t = \sum_{i=1}^{t} e_i \qquad t = 1,2,3....T \ , \tag{3}$$

and

$$s^2 = \frac{1}{T} \sum_{t=1}^{T} e_t^2 + \frac{2}{T} \sum_{s=1}^{L} \left(1 - \frac{s}{(L+1)}\right) \sum_{t=s+1}^{T} e_t e_{t-s} \ . \tag{4}$$

The residuals are given by the e_i´s, T is the number of observations and L is the lag length.

Since we have seen that both, the exchange rate and the stock index, may contain structural breaks, we use a unit root test that allows for an endogenous break[8]. We use the Zivot and Andrews (1992) unit root test. They suggested the following model:

$$\Delta x_t = \alpha + (1-\phi) x_{t-1} + \gamma t + \kappa D_t(\kappa) + \sum_{i=1}^{p} \beta_i \Delta x_{t-i} + \varepsilon_t \ , \tag{5}$$

where $D_t(\kappa) = 1$ for $t > \kappa T$ and zero otherwise; κ represents the location of the structural break. The idea of Zivot and Andrews (1992) is to choose the breakpoint that

[8] This avoids problems associated with pre-testing.

gives the least favorable result for the null of a unit root, that is, κ is chosen to minimize the t-statistic for the null of $\phi = 1$.

2.2. Cointegration

2.2.1. Engle and Granger (1987) two-step methodology

The first test that we used was the Engle and Granger (1987) methodology for non-cointegration. In the first step, we assessed the order of integration of each variable. Secondly, we ran the following OLS regressions

$$S_t = \alpha + \beta ER_t + \eta_{1t} \tag{6}$$

$$ER_t = \alpha + \beta S_t + \eta_{2t} \tag{7}$$

Finally, we ran ADF tests on the estimated residuals $\hat{\eta}_{1t}$ and $\hat{\eta}_{2t}$. The null of non-cointegration is rejected if these residuals are I(0).

2.2.2. Cointegration test with endogenous break

Gregory and Hansen (1996) applied the Zivot and Andrews (1992) unit root test to perform an Engle-Granger type cointegration test allowing for endogenous structural breaks. They proposed the following model:

$$S_t = \alpha + \beta t + \kappa D_t(\kappa) + \omega_1 ER_t + \eta_t \, . \tag{9}$$

The next step is to test whether η_t is stationary or has a unit root by using the standard ADF tests.

2.3. Vector autoregressive model and causality tests

We used a bivariate VAR model to test for linear causality. The following formulation can be employed in case no cointegration between exchange rates and stock prices is found:

$$\Delta S_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta S_{t-i} + \sum_{i=1}^{p} \alpha_{2i} \Delta ER_{t-i} + \xi_{1t} \, , \tag{10}$$

$$\Delta ER_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta S_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta ER_{t-i} + \xi_{2t} \ . \tag{11}$$

If stock prices and the exchange rate are cointegrated, the VAR should include an error correction term:

$$\Delta ER_t = \beta_0 + \delta_2 \left(S_{t-1} - \gamma ER_{t-1} \right) + \sum_{i=1}^{p} \beta_{1i} \Delta S_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta ER_{t-i} + \xi_{2t} \ , \tag{12}$$

$$\Delta S_t = \alpha_0 + \delta_1 \left(S_{t-1} - \gamma ER_{t-1} \right) + \sum_{i=1}^{p} \alpha_{1i} \Delta S_{t-i} + \sum_{i=1}^{p} \alpha_{2i} \Delta ER_{t-i} + \xi_{1t} \ . \tag{13}$$

3.4. Nonlinear Causality Tests

Consider $\{x_t\}$ and $\{z_t\}$ two strictly stationary and weakly dependent time series. Let x_t^m be the m-length lead vector of x_t, $x_t^m = \{x_t, x_{t+1}, ... x_{t+m}\}$. Given values of m, $\ell_x \geq 1$ and $\ell_z \geq 1$ where these are ℓ_x-length and ℓ_z-length vectors of x and z, respectively and $e > 0$, z does not Granger cause x if

$$\begin{aligned} &P\left(\left\| x_t^m - x_s^m \right\| < e \ \middle| \ \left\| x_{t-\ell_x}^{\ell_x} - x_{s-\ell_x}^{\ell_x} \right\| < e, \left\| z_{t-\ell_z}^{\ell_z} - z_{s-\ell_z}^{\ell_z} \right\| < e \right) = \\ &P\left(\left\| x_t^m - x_s^m < e \right\| \ \middle| \ \left\| x_{t-\ell_x}^{\ell_x} - x_{s-\ell_x}^{\ell_x} \right\| < e \right\} \Big) \end{aligned} \tag{14}$$

where $P(\cdot)$ stands for probability, and $\|\cdot\|$ for the maximum norm.

This is the conditional probability in which two arbitrary m-length leading vectors of $\{x_t\}$ are within a small distance of each other, given that the corresponding ℓ_x-length of vectors of $\{x_t\}$ and ℓ_z-length vectors of $\{z_t\}$ are within e of each other.

The nonparametric test of Hiemstra and Jones (1994) is given by

$$\frac{C_1 \left(m + \ell_x, \ell_z, e \right)}{C_2 \left(\ell_x, \ell_z, e \right)} = \frac{C_3 \left(m + \ell_x, e \right)}{C_4 \left(\ell_x, e \right)}, \tag{15}$$

where

$$\sqrt{n}\left(\frac{C_1(m+\ell_x,\ell_z,e)}{C_2(\ell_x,\ell_z,e)}-\frac{C_3(m+\ell_x,e)}{C_4(\ell_x,e)}\right)\overset{A}{\sim} N\left(0,\sigma^2(m,\ell_x,\ell_z,e)\right). \tag{16}$$

Define $I(x_1, x_2, e)$ as a kernel that equals 1(one) when two vectors, x_1 and x_2, are within the maximum-norm distance e of each other, and zero if otherwise. Then, the correlation-integral estimators of the joint probabilities in equation (8) can be written as:

$$C_1(m+\ell_x,\ell_z,e,n)=\frac{2}{n(n-1)}\sum_{t<s}\sum I\left(x_{t-\ell_x}^{m+\ell_x},x_{s-\ell_x}^{m+\ell_x},e\right).I\left(z_{t-\ell_z}^{\ell_z},z_{s-\ell_z}^{\ell_z},e\right), \tag{17}$$

$$C_2(\ell_x,\ell_z,e)=\frac{2}{n(n-1)}\sum_{t<s}\sum I\left(x_{t-\ell_x}^{\ell_x},x_{s-\ell_x}^{\ell_x},e\right).I\left(z_{t-\ell_z}^{\ell_z},z_{s-\ell_z}^{\ell_z},e\right), \tag{18}$$

$$C_3(m+\ell_x,e)=\frac{2}{n(n-1)}\sum_{t<s}\sum I\left(x_{t-\ell_x}^{m+\ell_x},x_{s-\ell_x}^{m+\ell_x},e\right), \tag{19}$$

$$C_4(\ell_x,e)=\frac{2}{n(n-1)}\sum_{t<s}\sum I\left(x_{t-\ell_x}^{\ell_x},x_{s-\ell_x}^{\ell_x},e\right), \tag{20}$$

where $t,s=\max(\ell_X,\ell_Z)+1,...T-m+1$ and $n=T+1-m-\max(\ell_X,\ell_Z)$.

In order to implement our nonlinear causality tests, we first filter our series for both linear dependence and volatility effects. We estimate a GARCH(1,1) for these series in the full sample and the sub-periods and use the residuals divided by the predicted value of volatility. If the GARCH(1,1) is found to be non-stationary we estimate an IGARCH(1,1). We then run linear causality tests using volatility-filtered returns. The residuals from the linear causality tests are then employed to test for further nonlinear relationships[9].

The nonlinear approach is motivated by recent research on both exchange rates and stock markets, which concludes that there are nonlinearities in the dynamics of these series. Taylor and Peel (2000) have shown that the relationship between the exchange rate and economic fundamentals is nonlinear. Their results are in line with

[9] This approach is employed in Silvapulle and Choi (1999) and Hiemstra and Jones (1994) to test for the relationship between stock prices and volume.

other studies that have analyzed the possibility of nonlinear adjustment in exchange rates, such as Bleaney and Mize (1996), Ma and Karas (2000), Meese and Rose (1991) and O'Connell (1998).

3. Empirical Results

Augmented Dickey Fuller unit root and KPSS stationarity tests are presented in Table 1. These tests reveal that the data is non-stationary and integrated to first order.

Table 1. Unit Root And Stationarity Tests (Full Sample)

Variables	ADF-level	ADF-1st dif.	KPSS-level	KPSS-1st dif.
S_t	-2.31	-33.01*	0.86*	0.03
ER_t	-2.84	-19.09*	0.67*	0.06

* Significant at the 1% level.
Breakpoint in brackets

However, due to the structural breaks that the Brazilian economy suffered in the late nineties, we also employed a unit root test with an endogenous break following Zivot and Andrews (1992). Table 2 presents our results. We cannot reject the unit root hypothesis for the stock price index, but we rejected it for the exchange rate, due to the 1% significance level.

Table 2. Unit Roots With Endogenous Break

Variable	ZA
S_t	-3.36
	[.74]
ER_t	-4.0*
	[.50]

* Significant at the 1% level.
Breakpoint in brackets

We applied the two-step cointegration procedure suggested by Engle and Granger (1987) as well as the Gregory and Hansen (1996) cointegration test with an endogenous break. In both cases, our results suggested that these series do not cointegrate, and thus, causality tests may be performed using a simple VAR without an error correction term.

Table 3. Cointegration tests based on residuals

Dependent Variable	EG	GH
1994-2002		
S_t	-2.46	-3.46
		[0.52]
ER_t	-2.84	-4.16
		[0.51]

The significance of the EG test was assessed using the McKinnon's (1990) response surface for critical values and for the GH we used Gregory and Hansen's (1996) critical values. Breakpoint in brackets

We assessed whether stock prices causally affected exchange rates or vice versa. We selected the appropriate lag structure using the Bayesian Schwarz information criteria. In Table 4, we present the results for the linear Granger causality tests. In the full sample, we found that stock prices lead exchange rates, but, for both sub-periods, there is evidence of bi-directional causality, in agreement with both the portfolio and the traditional approaches.

Table 4. Linear Causality Tests

	Full Sample	1994-1999	1999-2003
$S_t \not\rightarrow ER_t$	48.58*	17.30*	51.98*
	(0.00)	(0.00)	(0.00)
$ER_t \not\rightarrow S_t$	0.81	5.19**	3.93**
	(0.37)	(0.02)	(0.05)

The symbol $\not\rightarrow$ stands for no Granger causality.
* significant at the 1% level, ** significant at 5% level, *** significant at 10% level

Caporale and Pittis (1997) have shown that if we omit variables in our system then the causality structure is invalid. Therefore, as a robustness check, we perform these causality tests using two different variables. The first one is the return of the Standard & Poors 500 (a US stock index) since the US has some influence on the Brazilian domestic market. Furthermore, we also used the change in the federal funds rate as a proxy for fundamental shocks (following Granger et al. (2000))[10]. Our results remain qualitatively the same including either variable, or both, in the VAR system. Additionally, the lead-lag structure remains unaltered.

Table 5 presents results for the impulse response functions (IR). These IR agree with the Granger causality tests performed before. They also give additional information

[10] The US stock market could serve as a conduit through which the foreign exchange rate and the local markets are linked.

regarding the short-term dynamics of the lead-lag relationship between changes in stock prices and in exchange rates.

Table 5. Estimation Result Of Impulse Response Function

Panel A: response of exchange rates from one-unit shock in stock returns			
Period (days)	Full sample	1994-19990	1999-2003
2	-0.0490*	-0.01542*	-0.1158*
3	-0.0116*	-0.0018*	-0.0231*
4	-0.0021*	-0.0003***	-0.0029***
5	-0.0004*	0.0000	-0.0002
6	-0.0001	0.0000	0.0000
7	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000
Panel B: response of stock returns from one-unit shock in exchange rate changes			
Period (days)	Full sample	1994-19990	1999-2003
2	0.0565	-0.5449**	0.109***
3	0.0134	-0.0646***	0.0217***
4	0.0025	-0.0104	0.0027***
5	0.0004	-0.0016	0.0002
6	0.0001	-0.0002	0.0000
7	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000

* significant at 1% level, ** significant at 5% level, *** significant at 10% level

We purged volatility effects by running a GARCH estimation for the changes in stock prices and exchange rates in order to run causality tests. ARCH terms are present in both series. Table 6 presents our results for the GARCH(1,1) model for the whole sample and for each of the sub-sample periods. The coefficients for the ARCH and GARCH terms are significant in all sub-periods. This suggests that there may be volatility effects, which drive the causality tests performed before.

Table 6. Results for the GARCH(1,1) estimation for ΔS_t and ΔER_t

$$\begin{aligned} \Delta S_t &= c + \varepsilon_t \\ h_t &= \varpi + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} \end{aligned} \quad \text{and} \quad \begin{aligned} \Delta ER_t &= c + \varepsilon_t \\ h_t &= \varpi + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} \end{aligned}$$

Changes in Exchange Rates					
	c	ϖ	α	β	$\alpha+\beta$
Full Sample	0.0003***	1.9E-06*	0.1909*	0.7924*	0.98
	(.0573)	(0.0000)	(0.0000)	(0.0000)	
1994-1999	0.0003	3.1E-06*	0.2276*	0.6617*	0.89
	(0.1533)	(0.0000)	(0.0000)	(0.0000)	
1999-2003	0.0002	2.1E-06*	0.1961*	0.7950*	0.99
	(0.3952)	(0.0000)	(0.0000)	(0.0000)	
Changes in the Stock Price Index					
Full Sample	0.001428*	2.36E-05	0.158547	0.809143	0.97
	(0.0012)	(0.0000)	(0.0000)	(0.0000)	
1994-1999	0.002335*	1.53E-05*	0.216197*	0.792611*	1.01
	(0.0001)	(0.0004)	(0.0000)	(0.0000)	
1999-2003	0.000568	7.95E-05*	0.072964*	0.728863*	0.80
	(0.3609)	(0.0000)	(0.0006)	(0.0000)	
IGARCH(1,1)	Stock Price				
	.0023*	0.00001*	0.2099*	0.7901*	1
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	

* significant at 1% level, ** significant at 5% level, *** significant at 10% level

One of the problems we detected in our estimation was that in some cases the sum of the coefficients is close to 1(one) (in one case it exceeds 1). In order to circumvent this difficulty we also estimated Integrated GARCH IGARCH(1,1) models for these series and verified the robustness of the results. It was necessary to impose the IGARCH(1,1) modeling only for the first sub-period, since, for all others, the results remained qualitatively the same using both GARCH and IGARCH models.

In Table 7, we present linear causality tests using volatility-filtered series. The only difference from Table 4 is that now we cannot reject the absence of causality from changes in exchange rates to stock prices in the first sub-period. The causality tests show that stock prices seem to be more useful in predicting exchange rates than the other way around. This issue deserves more attention; therefore, we employed nonlinear causality tests to analyze the causality relation more deeply.

Table 7. Linear Causality Tests With Volatility Filtered Series

	Full Sample	1994-1999[¥]	1999-2003
$S_t \dashv\rightarrow ER_t$	95.37*	7.7022*	99.63*
	(0.0000)	(0.0055)	(0.0000)
$ER_t \dashv\rightarrow S_t$	1.98	12.6050*	4.15E-05
	(0.1589)	(0.0004)	(0.9949)

The symbol $-/\rightarrow$ stands for no Granger causality, * significant at 1% level.
[¥] Employing IGARCH(1,1) to filter volatility.

In Table 8, we present the IR, which agree with the Granger causality tests. We found the expected negative correlation between shocks in equity prices, and changes in exchange rates. Furthermore, the "peak impact" is one day following the shock and it takes 3 to 4 days for shocks to disappear. Hence, the relationship between these variables must be assessed employing high frequency data.

Table 8. Estimation Result Of Impulse Response Function With Volatility Filtered Series

Panel A: response of exchange rates from one-unit shock in stock returns			
Period (days)	Full sample	1994-1999[¥]	1999-2003
2	-0.2048*	-0.0808**	-0.3012*
3	-0.0270*	-0.0109	-0.0295**
4	-0.0040*	-0.0006	-0.0022
5	-0.0006***	0.0000	-0.0001
6	-0.0001	0.0000	0.0000
7	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000
Panel B: response of stock returns from one-unit shock in exchange rate changes			
Period (days)	Full sample	1994-1999[¥]	1999-2003
2	-0.0305	0.1069*	-0.0002
3	-0.0040	0.0144*	0.0000
4	-0.0006	0.0008	0.0000
5	-0.0001	-0.0001	0.0000
6	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000

* significant at 1% level, ** significant at 5% level, *** significant at 10% level

¥ Employing IGARCH(1,1) to filter volatility.

It is a widely held view that exchange rate movement should affect the value of a firm. This should be especially true during the domestic currency's post devaluation period. Our empirical results suggest that, for the latter period, exchange rates do not linearly Granger cause stock prices. We checked the robustness of this result by analyzing the predictable portion of stock prices and exchange rate changes, and by testing nonlinear Granger causality.

One interpretation for the fact that exchange rates do not help explain changes in stock prices, is that firms are able to efficiently hedge exchange rate risk, and thus, firm value is invariant to shocks in exchange rates. This explanation seems implausible for the Brazilian economy, as most agents are sold in foreign currency and unexpected devaluations should decrease domestic wealth. Therefore, in order to hedge for exchange rate risk, most firms face high premiums and very short maturity instruments such as futures, options, and debt linked to the US dollar[11].

Based on the linear causality results, we could use one of the series in order to forecast the other. Table 9 presents a comparison of the predictable portion of stock price and exchange rate changes. The results in this table help us visualize the relative importance of each variable in forecasting the other. The first line presents the dependent variable, either the exchange rate or the stock price, and the number of lags used (indicated by p). Changes in stock prices predict a substantial portion of exchange rate changes, using both the unadjusted series and the volatility filtered ones. However, exchange rates possess little forecasting power for stock prices (at most approximately 20% using two lags, even when using volatility filtered series).

[11] In Brazil, there are two main sources of hedge. Firms can hedge buying futures and options (which carry substantial premiums) that have liquidity only for very short term maturities (one to two months) and also the Treasury issues debt linked to exchange rate variations.

Table 9. A Comparison of the Predictable Portion of Stock Price and Exchange Rate Changes for the Full Sample.

	ER_t, p =1	ER_t, p =2	S_t, p=1	S_t, p=2
$\bar{R}_1^2$	0.037372	0.0397	0.002348	0.002252
$\bar{R}_2^2$	0.058446	0.059222	0.002265	0.002773
$\bar{R}_2^2$ vs $\bar{R}_1^2$	43.99%	39.47%	-3.60%	20.74%
Volatility Filtered Series				
$\bar{R}_1^2$	0.007527	0.008394	0.006959	0.006637
$\bar{R}_2^2$	0.048051	0.048259	0.0074	0.008043
$\bar{R}_2^2$ vs $\bar{R}_1^2$	145.83%	140.73%	6.14%	19.16%

The statistic $\bar{R}_2^2$ vs $\bar{R}_1^2$ is calculated as $\frac{\bar{R}_2^2 - \bar{R}_1^2}{\left(\bar{R}_2^2 + \bar{R}_1^2\right)/2}$

Finally, in Table 10, we present the results of the nonlinear Granger causality tests. There is evidence that exchange rates nonlinearly lead stock prices for both sub-periods and for the full sample. This is in line with the traditional approach and suggests that the empirical results in the literature, that do not find evidence of causality in this direction, should test for nonlinear causality as well.

Table 10. Nonlinear Causality Tests

			S_t -/→ ER_t		ER_t -/→ S_t	
	$\ell_x = \ell_y$	e	CS	TVAL	CS	TVAL
Full Sample	1	1.5	0.0020	1.0165	0.0076	2.9454*
		1	0.0029	1.0848	0.0103	2.6544*
		0.5	0.0036	1.2485	0.0058	1.0731
	$\ell_x = \ell_y$	e				
1994-1999	1	1.5	0.0021	1.0933	0.0027	1.2971
		1	0.0054	1.8829***	0.0070	1.8349***
		0.5	0.0062	2.0362**	0.0279	4.2426*
	$\ell_x = \ell_y$	e				
1999-2003	1	1.5	0.0013	0.4433	0.0143	3.8657*
		1	0.0023	0.6027	0.0160	3.3223*
		0.5	0.0016	0.4553	0.0081	1.9787**

The symbol -/→ stands for no nonlinear Granger causality.
* significant at 1% level, ** significant at 5% level, *** significant at 10% level

Our empirical results suggest that we can reject neither the traditional approach nor the portfolio approach when employing both linear and nonlinear causality tests. We found strong evidence supporting both approaches (in the full sample and both sub-periods). The nonlinear causality is not due to volatility effects or volatility spillover as we employed volatility filtered series.

There are many ways to explain the nonlinear relationship found between stock prices and exchange rates. Krugman (1991) has derived a target zone model in which a nonlinear relationship between exchange rates and fundamentals, arise. In this paper, the stock market can be seen as a proxy for fundamentals and their expectations, but that can be sampled on a high-frequency basis. Our findings are in line with a nonlinear relationship between fundamentals and exchange rates, but do not corroborate Krugman's target zone model, as the nonlinear causality runs in the opposite direction. A possible explanation is that the imperfect credibility of the target zone has an effect on the relationship between exchange rates and stock prices. Campa et al. (2002) argued that credibility has changed over time (it was poor prior to February 1996, but improved afterwards).

Another common explanation found in the literature is the existence of fads or noise trading, which can create persistent departures from the linear relationship between these variables (see Summers (1986) and Black (1986)). The speculative behavior of rational investors can create these nonlinearities. Furthermore, the stock exchange has depended heavily on foreign capital, during this period, after the loss of capital controls in the beginning of the nineties. As we can see from Figure 3, the net inflows in the Stock market have been highly volatile, and nonlinearities could arise from the behavior and influence of foreign capital, which is dependent on many issues such as world liquidity, global risk aversion and others.

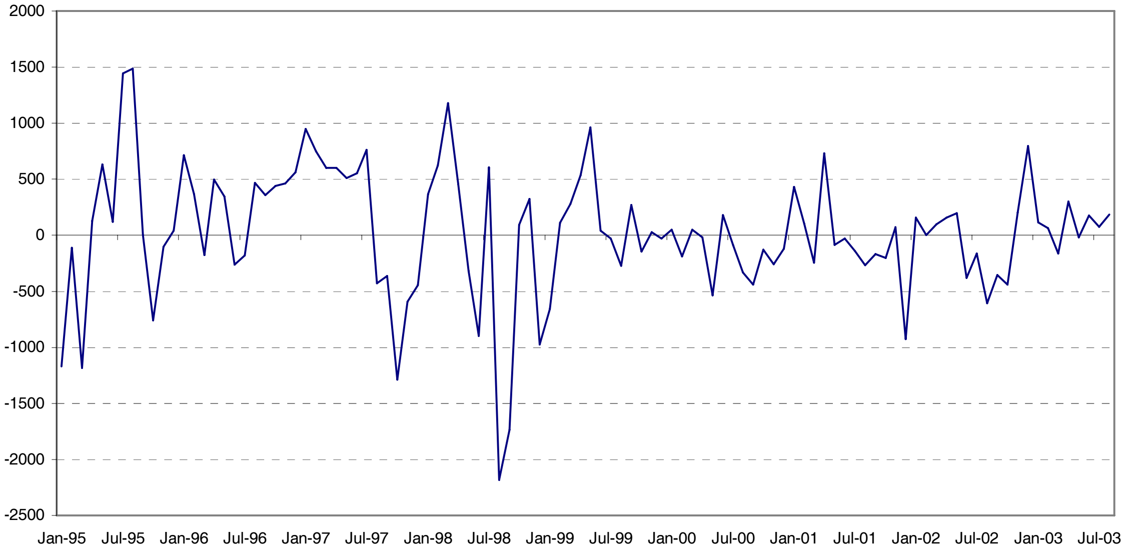

Figure 3. Foreign Net Investment in the Brazilian Equity Market
(in US$ million)

The results of the second sub-period are in line with Krugman and Miller (1993) who derived a nonlinear relationship between exchange rates and fundamentals, within a floating exchange rate regime. The authors argue that traders may pull out of risky assets as the net worth of their assigned portfolios declines (for example, after the exchange rate breaks a threshold), using stop-loss strategies. When these trades exit the market, other traders buy domestic assets and sell foreign assets, causing a change in the risk premium of the foreign assets. These risk premium changes entail a break in the exchange rate path.

Figure 4 presents the stock of assets held by foreign investors in the Brazilian equity market. There is a clear upward trend in the beginning of the series until the Asian Crisis in mid 1997, where portfolio capital flows reversed. Only after the devaluation of the Real in the beginning of 1999 we observe an upward trend, which is reversed in 2001 after the Argentinean default and the September 11 events[12].

[12] Additionally, a domestic energy shortage led the government to implement a severe rationing program.

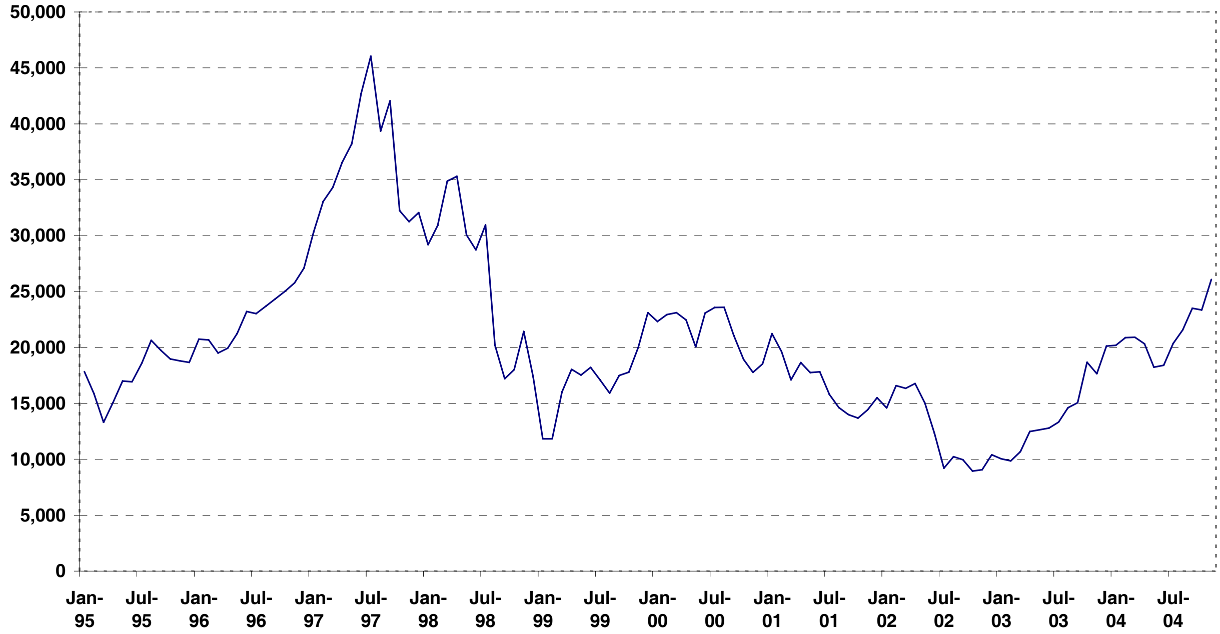

Figure 4. Foreign Investment's stock of assets in US$ million
(provided by the Sao Paulo Stock Exchange and CVM).

From these figures one cannot discard stop-loss trading strategies that imply a nonlinear reaction in the equity market. The government adopted measures to contain the exchange rate overshooting, which would naturally occur as predicted in Krugman and Miller's (1993) model but the central bank increased the issuance of dollar-indexed securities in order to contain it. Therefore, changes in exchange rates that reach a certain limit (specific threshold) may trigger large sells in the equity market, which not necessarily are channeled to the spot exchange rate market, but instead, may be channeled to the dollar-indexed bond market.

Finally, nonlinearities in government monetary policies may be another factor, which would explain nonlinearities in the relationship between stock and exchange rate prices. Figure 5 presents the official short-term interest rate in the Brazilian economy during the period in analysis. As we can see, there have been many jumps in these interest rates, mainly in the period before the devaluation, which intended to reduce capital outflows and maintain a certain level of international reserves.

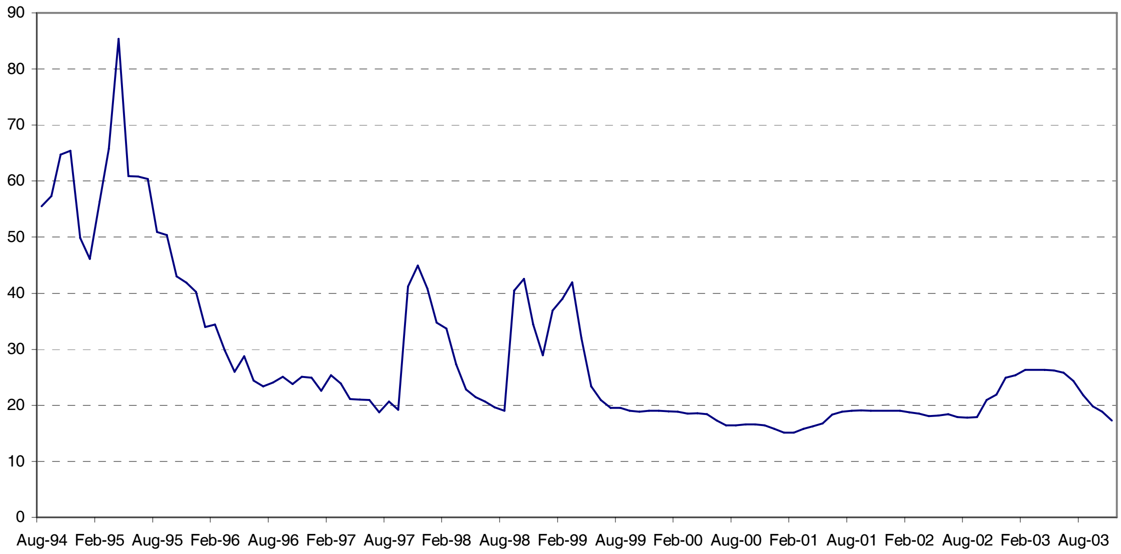

Figure 5. Official Interest Rates in Brazil - SELIC

More research is needed in order to ascertain the origins of these nonlinearities and enhancing our understanding of what forces drive the dynamics of exchange rates and equity prices.

5. Conclusions

The empirical evidence presented in this paper suggests that there are significant relationships between exchange rates and stock prices in the Brazilian economy. By employing linear Granger causality tests and impulse response functions, we found evidence supporting the portfolio approach during the recent period (post devaluation of the domestic currency), and rejected the traditional approach. However, nonlinear causality tests suggest that there is causality from exchange rates to stock prices, which is in line with the traditional approach. Our empirical results suggest that tests focusing on the relationship between exchange rates and stock prices should employ nonlinear causality tests, to complement the widely employed linear Granger causality tests. The nonlinear causality does not stem from volatility spillover as we used volatility-filtered series.

We found no long-run relationship between the nominal exchange rate and the stock market in the Brazilian economy, in line with previous research in other countries (see for example Granger et al. (2000)).

To the best of our knowledge, this is the first paper that has addressed the joint dynamics of exchange rates and equity prices in the Brazilian economy. Our empirical results suggest that these markets are indeed related and one has predictive power to forecast the other.

One of the practical applications of portfolio management is that the relationship between equity returns and exchange rate movements may be used to hedge their portfolios against currency movements. Additionally, risk management must take into consideration that these markets are correlated.

An interesting extension would be to build forecasting models and check whether the inclusion of lagged equity prices improves the "predictive power" beyond that of the random walk model for forecasting exchange rates. The use of intraday data could give some further insights as well.

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