Testing for nonlinearity of the relationship between stock prices and exchange rate in Romania[1]

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Abstract

The aim of this paper is to test the nonlinearity of the relation between the stock price in Romania and the nominal Romanian Leu against Euro from March 2000 to March 2014.

The empirical evidence shows that there is a long-run equilibrium between the two variables during the time period investigated. There exist also short-run relationships that were found to be nonlinear in variables involved (exchange rate and stock price) and also regarding the error correction mechanism.

Keywords: Exchange rates, Stock prices, Causality, Nonlinearity

1. Introduction

The relation between equity and currency markets has been the subject of many theoretical and empirical analysis over the past decades. Classical economic theory has two approaches of this problem - the traditional and portofolio balance. The traditional approach is built on the hypothesis that exchange rates causes movements in stock prices. It is based on the view that stock prices represent the discounted present value of a firm so any movements in the exchange rate affects it through the cost of capital.

On the contrary the portofolio balance theory postulates that that movements in stock prices can determine movements in exchange rates via capital account transactions. Changes in stock prices determines the position of investors regarding domestic assets and so causes movements in exchange rate.

The empirical results are mixed in terms of the causal direction between currency and stock prices or the sign of their correlation. For example cointegration and causality studies by Bahmani-Oskooee and Sohrabian (1992) demonstrate a bi-directional relation only in the

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short-run, Granger et al (2000) have found evidence of dual causality between the exchange rate and stock. Ma and Kao (1990) found exchange rates driving stock prices, Yu and Nieh (2009) also argues for the traditional approach in Taiwan in the long-run.

Other authors shows a very week correlation between the two variables. Ravazzolo and Phylaktis (2000) show the financial crisis had a temporary effect on the long-run comovement between the various markets.

Horobets and Ilie (2007) found unilateral or bi-lateral causality from the stock prices to exchange rates in Romania depending on the sub-period used and unilateral causality for the entire period1999 to 2007.

Literature on the study of the relationship refers to three methodologies that relate first to a flow oriented model, and then a portfolio balance approach and finally a cointegration and causality approach.

Many of the papers consider a linear relation between exchange rate and stock prices, but there are also studies which investigate the nonlinear relation. Yu and Nieh, (2009) uses threshold cointegration and found long-term equilibrium and asymmetric relationship in Taiwan and Japan.

Some various non-parametric methods for nonlinear Granger causality are developed by Baek and Brock (1992) using correlation integral between time series, by Hiemstra and Jones (1994), by Diks and Panchenko (2005) that show limitations of by Hiemstra and Jones test in large sample due to ignoring variations in conditional distributions.

The aim of this paper is to test if the relation between the stock price in Romania and the Romanian Leu against Euro is nonlinear in the short-run. I found evidence that a cointegration exist between the two variables so the interesting question is if in the short-run there are relations of dual causality and if these are nonlinear.

In the literature of nonlinear systems a number of methods of detecting nonlinear interdependence were presented. The ideas are similar and are based on constructing a space which contains all the information needed to predict the dynamic behavior of the system in a neighborhood of the point where the system actual state is.

In the paper of Chen, Rangarajan, Feng and Ding (hereafter CRFD) published in 2004 was presented an extended Granger causality to nonlinear problems using a reconstructed space to define the predictor which incorporates the flow of time.

I used the extended Granger causality index defined in CRFD in the context of cointegration to test if the error-correction adjustment mechanism is nonlinear and to test if the causality is also nonlinear. I found evidence that the causality go in either sense between stock price and exchange rate and that in the short-run the error-correction adjustment is also nonlinear.

2. Data

In this study I used monthly data from March 2000 to March 2014 (169 observations) considering that there is more fluctuation in daily data. I used Leu/Euro monthly average of Romanian Stock Exchange Index and BET Index prices in Leu.

This specific period is chosen due to data availability and to the fact that it contains the last financial crisis beginning with 2008 which support the idea that the relationship should be nonlinear.

Figure 1

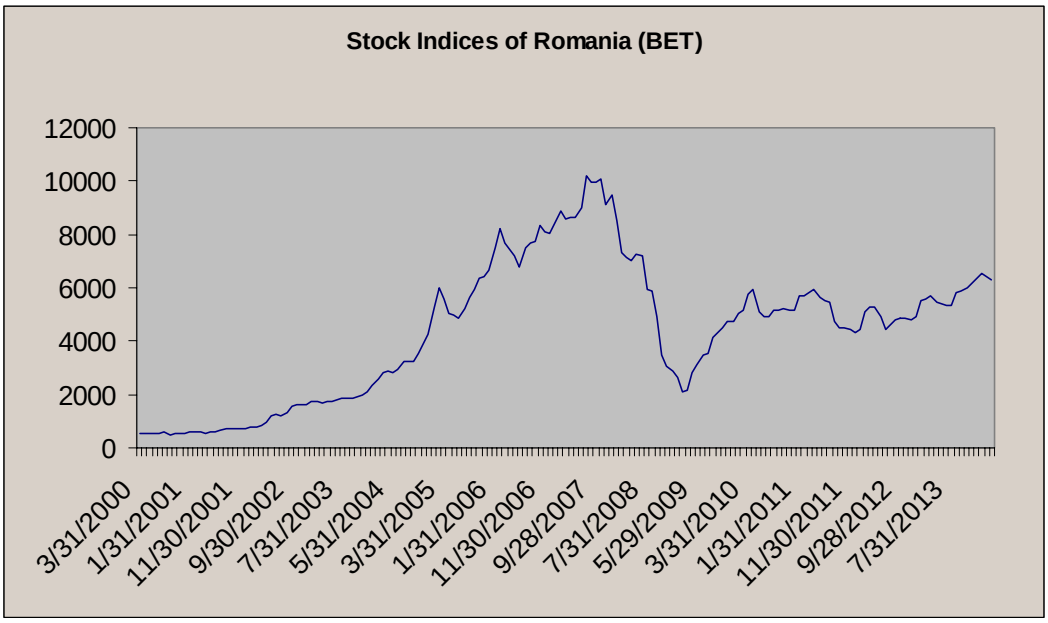
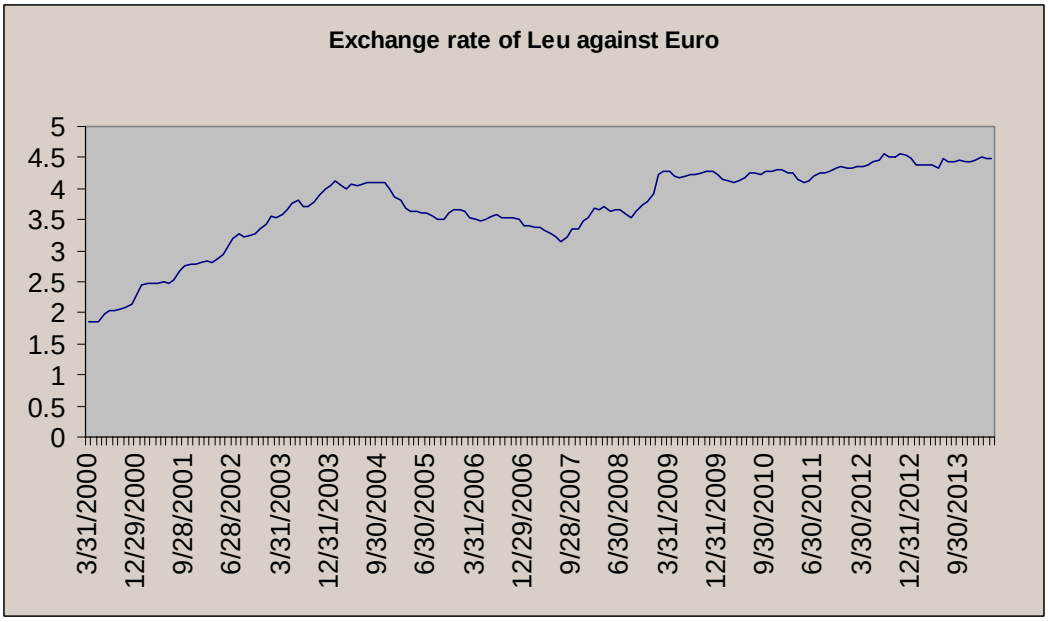


Figure 2



It can be observed from figure 1 that stock indices experienced an mild increase until the beginning of 2004 followed by an upward trend until October 2007 and by a sharp decrease until March 2009 when a recovery commenced followed by a almost stationary price until the end of the period. Corresponding the movements in exchange rate (figure 2) are negatively correlated with changes in stock price in the period with sharp changes figure1 (from the beginning of 2004 until March 2009) and presented almost stationary levels until the end.

The two figures combined shows that the increase in stock accompanied exchange rate depreciation and vice versa except for the first period until 2004. Table 1 presents summary statistics.

Table 1

Summary statistics

	BET	**Ex**
Mean	4397.190	3.697774
Std. Dev.	2590.941	0.677604
Maximum	10207.09	4.562370
Minimum	505.2986	1.845948
Skewness	0.112563	-0.969609
Kurtosis	2.160343	3.280160
Jarque-Bera Test	5.321427	27.03334

3. Methodologies and empirical results

Since all the variables are non stationary at level, I tested for linear cointegration by means of Johansen cointegration. In table 2 are shown these tests that proved the existence of long-term equilibrium relationship between nominal exchange rate Leu against Euro and stock prices (BET).

Table 2

Johansen Cointegration Test

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None *	0.095258	17.13259	12.32090	0.0073
At most 1	0.002482	0.415044	4.129906	0.5829

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level				
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.
None *	0.095258	16.71755	11.22480	0.0050
At most 1	0.002482	0.415044	4.129906	0.5829
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level				

The issue of causality between the stock prices and exchange rate was tested. The Granger causality test in vector error correction form allows the examination of linear dynamic casual interaction amongst the stock prices and exchange rates.

In this paper we are interesting in testing if the short-run error-correction mechanism and the causality between the two prices are nonlinear. We proceed by calculating an extended Granger causality index for decreasing sizes of the neighborhood until the index drops.

Extended Granger Causality Index

In the paper of Chen, Rangarajan, Feng and Ding (hereafter CRFD) published in 2004 was presented an extended Granger causality to nonlinear problems using a reconstructed space to define the predictor which incorporates the flow of time.

The idea is that if a relationship(function) is nonlinear it can be approximated on a small neighbourhood of a point from the support by a linear model.

Consider two time series x(t) and y(t) with a dynamic structure that could be defined by:

$$\begin{pmatrix} x(t+1) \\ y(t+1) \end{pmatrix} = \sum_{i=1}^{m} A_i \begin{pmatrix} x[t+(i-1)] \\ y[t+(i-1)] \end{pmatrix} + \begin{pmatrix} \varepsilon_{x|y} \\ \varepsilon_{y|x} \end{pmatrix} \quad (1)$$

where $\begin{pmatrix} \varepsilon_{x|y} \\ \varepsilon_{y|x} \end{pmatrix}$ represents the prediction error.

If there is no causality between x and y then the system is described by:

$$x(t+1) = \sum_{i=1}^{m} \alpha_i x(t+(i-1) + \varepsilon_x$$
$$y(t+1) = \sum_{i=1}^{m} \beta_i y(t+(i-1) + \varepsilon_y \quad (2)$$

Similar to the ideas from Granger causality it can be defined a test which would tell if there is causality from y to x if the ratio $\frac{\text{var}(\varepsilon_{x|y})}{\text{var}(\varepsilon_x)}$ is less than 1 and respectively there is causality from x to y if the ratio $\frac{\varepsilon_{y|x}}{\varepsilon_x}$ is less than 1.

The coefficients from (1) and (2) are functions of the size of the neighbourhood delta so in CRFD it is defined the Extended Granger Causality Index (EGCI) as the average over the a neighbourhood of the following index:

$$\Delta_{y\to x} = average_V \left\langle 1 - \frac{\text{var}(\varepsilon_{x|y})}{\text{var}(\varepsilon_x)} \right\rangle \qquad (3)$$

where $V = \{\mathbf{z}(t) = (\mathbf{x}(t), \mathbf{y}(t)) : |\mathbf{z}(t) - \mathbf{z}(t_0)| \le \delta\}$

$\mathbf{x}(t) = (x(t), x(t-1),..., x(t-m1)); \mathbf{y}(t) = (y(t), y(t-1),..., y(t-m2))$

m1 and m2 constitute the embedded dimension of the reconstructed space $\boldsymbol{R}^{m1+m2}$, which usually is determined by false nearest neighbourhood technique but because we are using some special case of dynamic system we used AIC (Akaike Information criterion) to determines the lags from the model (1).

I used this index to test if the short-run relations between stock price and exchange rate and the errors from the cointegration equation is nonlinear. The embedded dimension determined by AIC is m=1 and in order to efficiently determine the size of the neighbourhood I standardized the variables.

In figure 3 it could be seen that while the dimension of the neighbourhood (delta) is decreasing the indexes for the causality between stock price (BET) and exchange rate (Ex) are increasing and are nonzero even for large delta. An index being nonzero for all delta means that there is a relation of causality and that the standard Granger Causality would have detected the causality.

The fact that the EGCI is increasing while delta decrease show that the relation between variables is nonlinear. Indeed, the fact that it depends on the size of neighbourhood means that the coefficients matrix in the linear approximation (1) are non constant.

Also we found out that the smaller the neighbourhood the better is the prediction achieved.

The dimension delta is chosen so that there are enough points in the neighbourhood to validates the linear model but also small enough to determines a good approximation of the nonlinear model.

Figure 3

Extended Granger Causality Index as a function of the size of neighbourhood for the causal relation between stock price and exchange rate

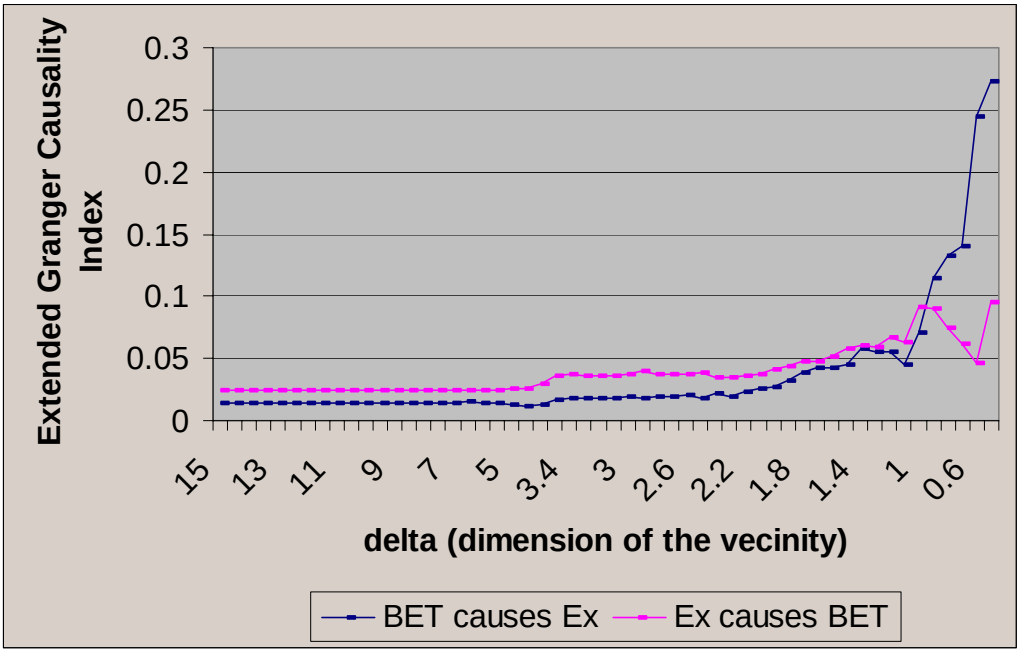
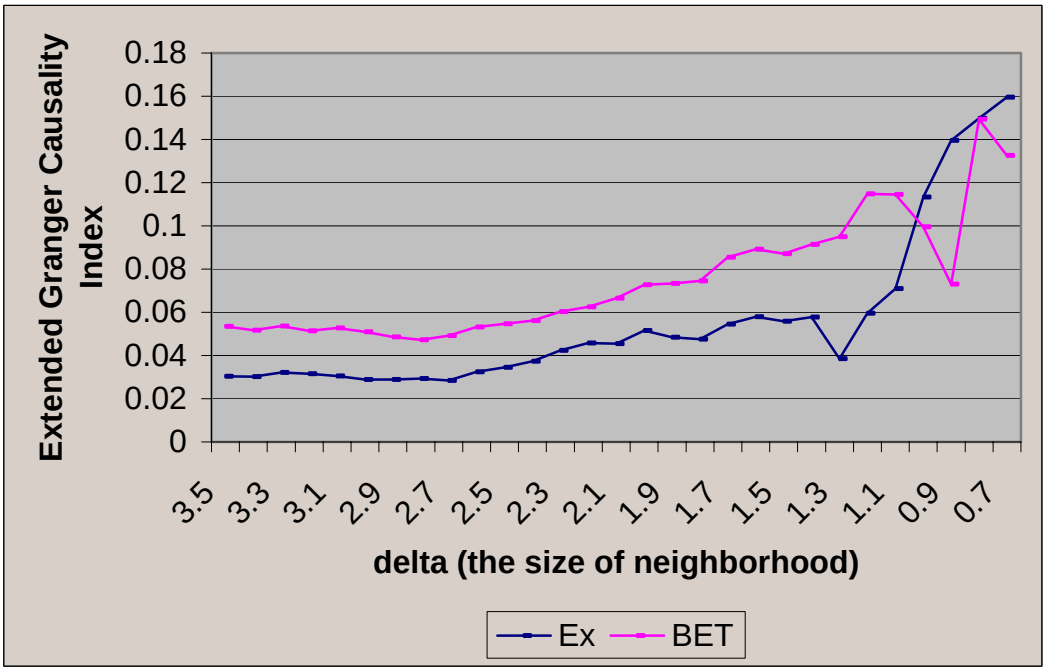


Figure 4

Extended Granger Causality Index as a function of the size of neighbourhood for the error-correction mechanism to equilibrium



The fact that one index (Ex cause BET) presents some downward trend as delta becomes very small illustrated the difficulty of choosing the optimal smallest delta, there are too few observation in the neighbourhood so the linear model hasn't been significant. I accepted as rule for statistical significance of the linear model the condition that there are at least 15 samples in the neighbourhood.

In figure 4 it is shown that while the dimension of the neighbourhood (delta) is decreasing the indexes for the short-run relations between stock price (BET) and exchange rate (Ex) with error-correction mechanism are increasing and are nonzero even for large delta. An index being nonzero for all delta means that there is a relation of causality and that the standard Granger Causality would have detected the causality.

Conclusions

Many empirical studies argue that exchange rates and stock prices exhibits nonlinearities and, consequently, linear causality tests may not be accurate in deciding if causal relationships exists.

The empirical evidence suggest that there is a long-run equilibrium between Leu/Euro and the stock price BET of the Romanian market during the time period investigated.

It shows that the causality and the short-run relation is nonlinear without explicit specification. It approximate the nonlinear function by some linearization in a neighborhood of the point where prediction is needed. This local property of the methodology provides relative independence from the data sample. In addition to other nonlinearity tests proposed in the last years this method provides an option to approximate the nonlinear function involved.

The optimal size of the neighborhood (delta) is achieved choosing the smaller values for which statistical determination of the model is achieved as long as an extended Granger causality index is increasing. Once delta is chosen the liniar aproximation of the real nonlinear relation could be used for predictions.

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