Testing for nonlinear causation between capital inflows and domestic prices

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Abstract

The nonlinear cointegration and Granger causality tests are applied in a bi-variate framework to investigate the effects of capital inflows, monetary expansion and interest rates on domestic price levels. The key message of the analysis is that there is a significant inflationary impact of capital inflows, money supply-to-GDP ratio and domestic debt, in particular during period of large capital inflows from 2001 to 2008. Whereas, interest rate and exchange rate do not have any significant nonlinear causal links with domestic price levels during the examined periods.

JEL Classification: C32; F21; F32
Keywords: Capital Inflows, Inflationary Pressures, Monetary Expansion, Nonlinear Dynamics

1. Introduction

In economics, any change tends to have both positive and negative outcomes. Despite access to foreign funds in general and foreign direct investment (FDI) in particular have helped to finance economic development and encouraged positive growth externalities –as increased in efficiency and a better allocation of resources, and associated transfer of technology – the abrupt improvement of the process of integration of emerging market countries with international capital markets has brought problems for the host economies. Some researchers have analyzed that capital inflows create some difficulties for the recipient countries in the form of real appreciation of their currencies. These difficulties include loss of competitiveness by exporters, spending boom, asset market bubbles, banking crises and the undermining of a strategy to achieve monetary stability by pegging the exchange rate.

Efforts to maintain a peg definitely imply that the central bank must intervene by absorbing the foreign exchange brought in by the capital inflows. However, such purchases increase the monetary base, generating inflationary dynamics. Capital inflows also may lead to the expansion of bank deposits and loans. Moreover, the expansion of bank balance sheets owing to capital inflows may deteriorate the fragility of the banking system if bank supervision is not fully effective.

Stevens (2006) addresses the consequences of capital inflows and appropriate monetary measures to control its effects on Australian economy. He stated that many open economy have perhaps less scope to allow large exchange rate moves without significant first-round inflationary or deflationary effects. Gupta (2005) analyzed the effects of financial liberalization on inflation. His results indicate a positive and statistical significant association between inflation and financial repression. Musinguzi and Benon (2002) discussed the management of inflows in Uganda. Using monthly data and an Autoregressive Distributed Lag (ARDL) Approach to Cointegration, they concluded that the capital inflows, nominal exchange rate and base money significantly and positively drive the composite headline annual inflation in Uganda in the long run. Gruben and McLeod (2000) in their study about capital account liberalization and inflation in the 1990s address two puzzles. The results suggest that sustained removal of one of the four restrictions inventoried by the IMF can reduce average annual inflation by as much as 3%.

Taking into account the above mentioned theoretical as well as empirical facts, in this study, we therefore examine the nonlinear short- and long-run causal linkages between capital inflows, interest rate, exchange rate and domestic price levels.

2. The Empirical Methodology and Data

The KPSS (Kwiatowski et al. (1992)) methodology (the LM statistic) is used to test for the stationarity. Under this method, the null hypothesis is stationarity and the alternative is the presence of a unit root. This ensures that the alternative will be accepted (null rejected) only when there is strong evidence for (against) it. The KPSS test statistic (the LM statistic) is defined as follows[1]:

$$\hat{\eta} = T^{-2} \sum \frac{S_t^2}{s^2(l)}$$

where S_t is the partial sum process of the residuals ξ_t are from a regression of the respective variable on only intercept in case of level stationary, and on intercept and

[1] Critical values of the LM test statistic are based upon the asymptotic results presented in KPSS (1992, Table 1, p. 166).

trend in case of trend stationary; that is defined as: $S_t = \sum_{i=1}^{t} \xi_i$ and $s^2(l) = T^{-1} \sum_{t=1}^{T} \xi_t^2 + 2T^{-1} \sum_{m=1}^{l} w(m,l) \sum_{t=m+1}^{T} \xi_t \xi_{t-m}$, where $w(m,l)$ is an optional weighting function; this is, $w(m,l) = 1 - m/(1+l)$, where l is the maximum lag.

The nonlinear cointegration test developed by Lin and Granger (2004) is applied to explore the nonlinear long-run relations between the variables. The test is defined as follows:

Let x_t be a linear integrated process and y_t and x_t is called nonlinearly cointegrated with function f provided $u_t = y_t - f(x_t)$ has asymptotic order smaller than those of y and $f(x)$. Lin and Granger (2004) defined the following steps to test the null of nonlinear cointegration against of alternative of no nonlinear cointegration.

1. Identify the possible nonlinear function for using Alternative Conditional Expectation (ACE) criterion (i.e., logarithm, exponential, square root, Box-Cox transformation, etc.).
2. Apply the Nonlinear Least Square (NLS) method the estimate the parameters of the specified function.
3. Obtain the residuals from the estimated model and store.
4. Apply KPSS test for estimated residual to test the null of nonlinear cointegration.

Lin and Granger (2004) said that if the null hypothesis is specified as cointegration, KPSS-test would give the right distribution under the null hypothesis and power approaching one as sample size grows under the alternative.

To examine the nonlinear short-run causality, we use the Hristu-Varsakkeis and Kyrtsou (2006) nonlinear Granger causality test – know as the bivaraite noisy Mackey-

Glass model and is based on a special type of nonlinear structure developed by Kyrtsou and Labys (2006). The model is given below:

$$X_t = \alpha_{11} \frac{X_{t-\tau_1}}{1+X_{t-\tau_1}^{c_1}} - \delta_{11} X_{t-1} + \alpha_{12} \frac{Y_{t-\tau_2}}{1+Y_{t-\tau_2}^{c_2}} - \delta_{12} Y_{t-1} + \xi_{1t} \qquad \xi_{1t} \approx N(0,1) \tag{1}$$

$$Y_t = \alpha_{21} \frac{X_{t-\tau_1}}{1+X_{t-\tau_1}^{c_1}} - \delta_{21} X_{t-1} + \alpha_{22} \frac{Y_{t-\tau_2}}{1+Y_{t-\tau_2}^{c_2}} - \delta_{22} Y_{t-1} + \xi_{2t} \qquad \xi_{2t} \approx N(0,1) \tag{2}$$

where X and Y are a pair of related time series variables, the α_{ij} and δ_{ij} are parameters to be estimated, τ_i are delays, c_i are constants. The best model (1) is that allowing the maximum Log Likelihood value and minimum Schwarz information criterion.

As mentioned in Kyrtsou and Labys (2006, 2007), and Kyrtsou and Vorlow (2007), the principle advantage of model (1) over simple VAR alternatives is that the nonlinear Mackey-Glass (hereafter M-G) terms are able to capture more complex dependent dynamics in a time series. The identification of significant M-G terms in a pair of series reveals the nonlinear feedback law between X and Y and elucidate qualitative features of this law.

The test aims to capture whether past samples of a variable Y have a significant nonlinear effect (of the type $\frac{Y_{t-\tau_2}}{1+Y_{t-\tau_2}^{c_2}}$) on the current value of variable X. Test procedure begins by estimating the parameters of a M-G model that best fits the given series, using ordinary least squares. To test reverse causality (i.e., from X to Y), a second M-G model is estimated, under the constraint $\alpha_{22} = 0$.

The latter equation represents null hypothesis. Let $\hat{\xi}_{1t}, \hat{\zeta}_{1t}$ be the residuals produced by the unconstrained and constrained best-fit M-G models, respectively. Next, compute the sums of squared residuals $S_c = \sum_{t=1}^{N} \hat{\zeta}_{1t}$ and $S_u = \sum_{t=1}^{N} \hat{\hat{\xi}}_{1t}$. Let m is the number of free parameters in the M-G model and k is number of parameters set to zero when estimating the constrained model, then the test statistic is defined as

$$S_F = \frac{(S_c - S_u)/k}{S_u/(N-m-1)} \approx F_{k,N-m-1}$$

If the calculated statistics is greater than a specified critical value, then someone rejects the null hypothesis that Y does not nonlinearly causes X.

Monthly data over the span from 1991 to 2008 is used to explore the causal linkages between interest rate, capital inflows and inflation rate. The main source of data is the IMF's International Financial Statistics (CD-ROM). Our basic model consists of nine variables. These variable are the log of market interest rate (line 60b and denoted by LMMR), the log of nominal exchange rate (line ae and denoted by LNER), the log of consumer price index (line 64 and denoted by LCPI), the ratio of net foreign assets to GDP (line 31n divided by line 90b and denoted by FAR), the ratio of abroad money supply to GDP (lines 34 plus 35 divided by line 90b and denoted by MSR), and the log value domestic credit growth (line 32 and denoted by LDC)[2].

3. Empirical Results

The first step involved in applying cointegration to explore the long-run association is to determine the order of integration of each variable/series. More specially, the study tested whether all the said variables are integrated of order one, $I(1)$.

[2] Here, the domestic debt includes claims on general government (net), claims on non-financial public enterprises, claims on private sector, and claims on nonblank financial institutions.

This was achieved by estimating the KPSS unit root test. The estimated statistics of the KPSS tests for level and first-difference series are presented in Table 1.

Table 1: The KPSS Unit Root Test Results for Level Series (Jan. 1990 to Dec. 2008)

Variables	Levels		First-Difference	
	$LM_{KPSS(c)}$	$LM_{KPSS(c+t)}$	$LM_{KPSS(c)}$	$LM_{KPSS(c+t)}$
Ratio Form Variables				
FAR	1.496	0.287	0.195	0.082
MSR	0.672	0.166	0.114	0.092
Log Form Variables				
LCPI	1.838	0.421	0.945	0.284
LMMR	0.440	0.161	0.061	0.060
LNER	1.792	0.413	0.522	0.093
LDC	1.828	0.239	0.289	0.292

Notes: $t_{ADF(c)}$ and $t_{ADF(c+t)}$ are the standard ADF test statistics for the null of nonstationary of the variable in the study without and with a trend, respectively, in the model for testing. $LM_{KPSS(c)}$ and $LM_{KPSS(c+t)}$ are the KPSS test statistics for the null of stationary of the variable in the study without and with a trend, respectively in the model for testing. The 10% and 5% asymptotic critical values are -2.57 and -2.86 for $t_{ADF(c)}$ respectively, and are -3.12 and -3.41 for $t_{ADF(c+t)}$ respectively. The 10% and 5% asymptotic critical values are 0.347 and 0.463 for $LM_{KPSS(c)}$ respectively, and 0.119 and 0.146 for $LM_{KPSS(c+t)}$ respectively. * and ** denote rejection of the null hypothesis at the 10% and 5% significant levels, respectively.

Since the estimated test statistic, η_u , is greater than the critical values for all the said series expect for the log change in manufacturing output, therefore, we reject the null of stationarity in favor of the alternative of unit roots, that is, all the series have unit roots. However, if the deterministic trends are present in the series then the rejections of the hypothesis of level stationarity are not considered reliable. The study therefore proceeds to test the null hypothesis of stationarity around a deterministic linear trend. The estimated statistics are significantly greater than critical values. Consequently, the null hypothesis of trend stationarity is rejected at any usual level of significance. However, the first-difference of the series appears stationary.

The traditional cointegration (says Johansen' technique, 1990) and Granger causality (says Granger procedure, 1986) tests are unable to find nonlinear causal relations. We apply nonlinear cointegration test developed by Lin and Granger (2004) to explore the nonlinear long-run relations between the variables. To test the pairwise nonlinear cointegration between domestic price level and capital inflows, domestic debt, money supply-to-GDP ratio, market interest rate and nominal exchange rate, we run a bi-variate regression of LCPI on constant and BOX-COX transform of the said explanatory variables. Specifically, the function is expressed as follows:

$$LCPI_t = \frac{\left((|X_t|)^{\theta} - 1\right)}{\theta} \tag{3}$$

where X_t denotes explanatory variable. We run the nonlinear least squares (NLS) method to estimate the underlying parameters ($\hat{\theta}$), and then apply the KPSS test to the residual to test the null hypothesis of nonlinear cointegration against an alternative hypothesis of no nonlinear cointegration. The estimates are given in Table 2.

The results provide strong evidence of the existing of nonlinear cointegration between domestic price level and net foreign assets-to-GDP ratio, money supply-to-GDP ratio and domestic debt in both the examined period. On the other hand, the estimation shows that there is no significant nonlinear dynamic association between domestic price level and both market interest rate and nominal exchange rate.

Table 2: Pairwise Nonlinear Cointegration Tests

Variables included in Cointegration Equation	Sample Period: January 1990 to December 2000		Sample Period: January 2001 to December 2008	
	$LM_{KPSS(c)}$	$LM_{KPSS(c+t)}$	$LM_{KPSS(c)}$	$LM_{KPSS(c+t)}$
LCPI and FAR	1.286	0.102*	1.119	0.212*
LCPI and LDC	0.107**	0.098*	0.193**	0.171*
LCPI and MSR	1.261	0.137**	0.657*	0.222*
LCPI and LMMR	1.412	0.238	1.172	0.236
LCPI and LNER	1.167	0.546	1.146	0.289

$LM_{KPSS(c)}$ and $LM_{KPSS(c+t)}$ are the KPSS test statistics for the null of cointegration without and with a trend, respectively in the model for testing. The 1% and 5% asymptotic critical values are 0.737 and 0.463 for $LM_{KPSS(c)}$ respectively, and 0.216 and 0.146 for $LM_{KPSS(c+t)}$ respectively. * and ** denote rejection of the null hypothesis at the 1% and 5% significant levels, respectively.

To examine the nonlinear short-run causality, we use the Hristu-Varsakkeis and Kyrtsou (2006) nonlinear Granger causality test – know as the bi-varaite noisy Mackey-Glass model. In first step, since the variables are nonlinearly cointegrated, the nonlinear VEC model is estimated using the first differences of the variables and error correction term by ordinary least squares, in a specification ($\tau_1 = \tau_2 = 4$ and $c_1 = c_2 = 2$) selected by Log Likelihood procedure without and with restriction on lagged parameters of explanatory variable. Then we obtain the residual to calculate the test statistics (says S_F) for testing nonlinear Granger causality between the variables. The estimated S_F are reported in Table 3.

The table clearly shows the nonlinear dynamic association between domestic price level and capital inflows for the second sub-period and between inflation and domestic debt level and money supply to GDP ratio for both the sub-periods. The change in domestic price level (inflation) is statistically significantly nonlinearly caused by the change in net foreign assets-to-GDP ratio during the second sub-period. For the first sub-period, however, the estimates provide evidence to reject the null hypothesis that the change in net foreign assets nonlinearly causes inflation.

For money supply-to-GDP ratio and domestic debt, the analysis indicates that they have significant nonlinear impact on inflation during both the examined periods. Finally, for market interest rate and nominal exchange rate, the table reveals that they do not have any nonlinear causal link with inflation in either period.

Table 3: Pairwise Nonlinear Granger Causality Tests

Direction of Nonlinear Causality	**Sample Period: January 1990 to December 2000**		**Sample Period: January 2001 to December 2008**	
	$S_F - statistic$	**Decision** (at the 5% level)	$S_F - statistic$	**Decision** (at the 5% level)
FAR $\rightarrow$ LCPI	0.364	Reject	8.446	Do not reject
LDC $\rightarrow$ LCPI	3.283	Do not reject	3.749	Do not reject
MSR $\rightarrow$ LCPI	4.247	Do not reject	11.305	Do not reject
LNER $\rightarrow$ LCPI	1.446	Reject	0.003	Reject
LMMR $\rightarrow$ LCPI	1.318	Reject	0.159	Reject

where the arrow points to the direction of nonlinear causality.

3. Conclusion

The intention in this paper is to investigate the long-run and short-run nonlinear dynamic interactions between domestic price level and capital inflows, money supply, domestic debt, manufacturing output, market interest and exchange rates. The estimation indicates that there is highly significant nonlinear integration between domestic price level and capital inflows and domestic debt in both the periods. However, the domestic price level and market interest rate and nominal exchange rate are not cointegrated in either period.

The estimates on the nonlinear Granger causality tests provide evidence of significant nonlinear Granger causality from capital inflows, domestic debt and money supply to domestic price level, whereas, interest rate and exchange rate do not have significant nonlinear causal links with domestic price level.

The analysis suggests that there is a need to manage the capital inflows in such a way they should neither create an inflationary pressure in the economy nor fuel the exchange rate volatility. “Sterilization” may be an effective instrument to limit the impact of foreign capital inflows upon domestic monetary base. In addition, the SBP should put some restriction on credit to both government and private sector, especially on non-productive borrowing. The analysis may establish useful base for future empirical work in this field and suggests that researchers should also consider nonlinearity in modeling for inflationary dynamics.

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