Revisiting the growth-inflation nexus: a wavelet analysis

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Revisiting the Growth-Inflation Nexus: A Wavelet Analysis

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Abstract: Motivated by the concern that the recent surge in inflation could retard growth, the paper revisits the nexus between inflation and growth from the perspective of an emerging economy, India. Examining this relationship using a wavelet multi resolution analysis with varying time scale decomposition suggests a strong and persistent negative relationship between growth and inflation for a short time scale, while it is not significant for a longer time scale.

1. Introduction:

The relationship between inflation and long-run growth has of late, emerged as one of the most widely discussed issues since the resurgence of interest in economic growth. Urged by the concern that in many developing markets the surge in the inflation might eventually pose threat to the growth of the economy, many researchers have examined the problem and sought to establish a relationship between inflation and growth of the economy. However, despite these efforts the issue still remains controversial from the perspective of both the theory and empirical findings. The most important questions that arise in this context are: whether inflation and growth are inversely related or not? Is the empirical inflation growth relationship primarily a long-run relationship or a short-run relationship across time?

A plethora of research has extensively examined all the dimensions and aspects of the relationship between inflation and growth including the nature of their interaction and the direction of causality. A large body of literature among these has explored the issue using panel data based on cross- country regression. For example, Barro (1990) reports a negative, but weak relationship between inflation and growth rate of real GDP during

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1970-1985 in a cross-section of 117 countries. Fischer (1993) concluded that a surge in inflation is detrimental to the growth in output as it negatively impacts the investment and productivity as well.

Bruno and Easterly (1996) also found using different panels, that episodes of high inflation corresponded with negative growth in output. Ghosh and Phillips (1998) interestingly noticed that during low inflation period, there is a significant positive impact on growth, but beyond a certain limit (2 to 3% per year), inflation however negatively affects growth in output. Furthermore, they have found that decline is much sharper, at a higher level of inflation suggesting a convex relationship between the two variables.

Khan and Senhadji (2001), in their study using panel data, based on a cross-country regression (140 countries), over the period 1960-1998, concluded that the point beyond which inflation retards growth is between 1 and 3 percent for industrial countries, and between 7 and 11% for developing countries. Burdekin et al (2004) in their study using a panel of 72 countries, based on annual data suggested that for developing countries inflation retards growth beyond a low threshold of 3%.

However, though there is a consensus suggesting in the long run, high inflation is correlated with a lower level of economic growth, several other studies have examined this finding for a single country over time. Rangarajan (1997) analyzed data for India and established the range of 5-7% which has been further confirmed by Samantaraya and Prasad (2001) who suggested that 6.5% is the estimated threshold. Mubarik (2005) studied data for Pakistan for a wide sample period of 1973-2005 and concluded that beyond 9%, inflation affects growth adversely, while at a moderately low level of 5%, inflation positively influences growth.

Although, a few empirical studies have attempted to examine whether high inflation is inversely related with growth in the long run, a single country over time, a test on a time series data for a single country could be constraint driven. One of the main aspects of the problem could be choosing a suitable approach for defining the long-run and detecting long-run relationships. Keeping this issue in view, our study uses the methodology of wavelet analysis in order to examine the relationship from a non-structural low frequency point of view. The uniqueness of this technique lies in its ability to handle a variety of non-stationarity signals. Moreover, wavelets are localized in both time and scale as these are constructed over finite intervals of time and therefore these are not necessarily homogeneous over time. The most important property of wavelets in economic analysis is its time-scale decomposition. In empirical literature, wavelet analysis has previously been applied in examining foreign exchange data using waveform dictionaries (Ramsey and Zhang, 1997), decomposition of economic relationships of expenditure and income (Ramsey and Lampart,1998a,b), systematic risk in a capital asset pricing model (Gencay et al., 2003) and multiscale hedge ratio (Kim and In, 2005). For India, Biswal et al. (2004) analyzed the Bombay stock exchange index at various time scales, and beyond that the wavelet technique is not explored quite extensively for Indian data. The primary contribution of the paper is two-fold:

First, the paper aims at a rigorous exploration of the relationship between growth and inflation, both from the short-term as well as long-term perspective. Also in the current economic scenario with higher inflation and very volatile supermarket, it is highly imperative for a developing country like India, to comprehend the relationship between these two important macro-variables. Higher inflation, it is seen in the long- run deters growth as it can affect both investment and productivity growth. If higher inflation does reduce long-run growth, it can be addressed by known policies that may be easier to implement than promoting investment in human capital or the development of human technologies.

Second, the paper proposes a wavelet analysis, for investigating the relationship between growth and inflation over different time-scales. Wavelet multiscaling method decomposes a given time series on a scale by scale basis. Therefore, this proves to be a useful methodology to establish the short-run and long-run relationship, and provides us a holistic picture on the entire relationship.

The rest of the paper is organized as follows: Section 2 briefly discusses about the wavelet technique and the methodology used in the paper. Section 3 describes the empirical results and Section 4 concludes the study.

2. Methodology:

2.1 Empirical Model.

In this paper we revisit the issue of relation between inflation and GDP growth, for an emerging economy, India, covering the period of (1976-2007), over different time horizon using the discrete wavelet decomposition analysis. We decompose the yearly data into different time-scale component using non-decimated discrete wavelet transformation and then estimating the time-scale relationship between inflation and GDP growth. The basic model used in the paper closely follows Khan and Senhadji (2001) where the explanatory variable is inflation. It is well- known that a wide variety of external environment policy variable could influence the growth rate of economy by changing its long run income and its rate of productivity growth. Consistent with the growth, a large set of variable could be mentioned as an important determinant of long-term GDP growth: the stock of physical capital, the stock of human capital, investment to GDP ratio, movements in the terms of trade, measures of political stability etc. However, based on the availability of the data, and previous empirical evidence, we have selected a set of explanatory variable which includes the ratio of GDP, population growth, the rate of change in the terms of trade and the variability in the terms of trade.

Yearly data for the period (1976-2007) has been used to estimate the empirical model. The selection of the sample period is governed by the fact that the wavelet analysis warrants the data point in 2^j where J is the level of decomposition. The availability of the data is therefore limited to 32 data points. The wholesale price index, WPI and GDP at constant prices are considered to derive the inflation rate and output growth. All the growth rates are calculated as the first difference of the logarithmic transformation of the concerned variables. All the variables are collected from the handbook of statistics on the Indian economy 2010 published by The Reserve Bank of India.

2.2. Wavelet Analysis:

This section discusses the idea of wavelet analysis, and thereafter presents the method for calculating the wavelet variance and covariance from the data decomposed by the non-decimated discrete wavelet transform. In this context, it is important to present a comparison of wavelet tool with Fourier approach. Both the approach decomposes a given series in orthogonal components. But, while the former decomposes according to the scale, the latter approach considers frequencies as the basis of decomposition. Therefore, since wavelet analysis act locally in time, it does not need stationary frequencies in order to decompose the series. In place of stationary frequencies, of late, a windowing Fourier decomposition method has been developed that essentially uses a time-period M as a window for frequency estimation, event less than the number of observations T. The major difficulty with this approach is the correct selection of the window and most significant, its constancy over time.

Next, let us consider the mathematical details of the basic wavelet functions: the father and the mother wavelets, $\Phi(t)$ and $\Psi(t)$, respectively. The formal definition of the father wavelets is the function

$$\Phi_{jk} = 2^{-j/2}\Phi\left(\frac{t-2^j k}{2^j}\right) \qquad (1)$$

defined as non-zero over a finite time length support that corresponds to given mother wavelets

$$\Psi_{jk} = 2^{-j/2}\Psi\left(\frac{t-2^j k}{2^j}\right) \qquad (2)$$

with j=1,….,J in a J-level wavelets decomposition. The former integrates to 1 and reconstructs the longest time-scale component of the series (trend), while the latter integrates to 0 (similarly to sine and cosine) and is used to describe all derivations from trend. The mother wavelets, as said above, play a role similar to sines and cosines in the Fourier decomposition. They are compressed or dilated, in time domain, to generate cycles fitting actual data.

To compute the decomposition we need to calculate wavelet coefficients at all scales representing the projections of the time series onto the basis generated by the chosen family of wavelets, that is

$$d_{jk} = \int f(t)\Psi_{jk} \quad and \quad s_{jk} = \int f(t)\Phi_{jk}$$

where the coefficients d_{jk} and s_{jk} are the wavelet transform coefficients representing, respectively, the projections onto mother and father wavelets.

The orthogonal wavelet series approximation to a signal or function f (t) in $L^2(R)$ is given by

$$f(t) = \sum_k s_{jk}\Phi_{jk}(t) + \sum_k d_{jk}\Psi_{jk}(t) + \ldots + \sum_k d_{jk}\Psi_{jk}(t) + \ldots + \sum_k d_{i,k}\Psi_{1k}(t) \qquad (3)$$

where J is the number of multiresolution components or scales, and K ranges from 1 to the number of coefficients in the specified components. The multiresolution decomposition of the original signal f(t) is given by the sum of the smooth signal Sj and the detail signals D_J, D_{j-1}, ….., D_1,

$$f(t) = S_j + D_j + D_{j-1} + \ldots + D_j + \ldots + D_1 \qquad (4)$$

$$where \quad S_j = \sum_k s_{jk}\Phi_{jk}(t) \quad and \quad D_j = \sum_k d_{jk}\Psi_{jk}(t) \quad with\ j = 1\ldots J$$

The sequence of terms S_J, D_J, …Dj,….,D1 in (4) represent a set of signals components that provide representations of the signal at the different resolution levels 1 to J, and the detail signals Dj provide the increments at each individual scale, or resolution, level.

3. Empirical Results:

The estimation of our empirical model proceeds in three district steps; first, we ascertain the direction of causality between our two key empirical variables i.e inflation and growth. Second, we establish the nature of relationship by testing our null hypothesis of linearity between inflation and growth against the alternative of a variety of non-linear models, such as TAR, LSTAR. Third, we explore the relationship over different time horizon applying discrete wavelet decomposition analysis. After ensuring that all the variables under consideration are stationary using an Augmented Dickey-Fuller test, we explore the direction of the causality using a pair wise Granger causality test for inflation and growth. The results reported in Table 1 clearly establish a unidirectional causality running from inflation to growth for the sample period.

Table1: The result of Pair wise Granger Causality Tests with optimum lags of 2.

Null Hypothesis:	F-Statistic	Prob.
INFLATION does not Granger Cause GROWTH	3.89956	0.0291
GROWTH does not Granger Cause INFLATION	1.28213	0.2895

Next, we examine the nature of the causality by proposing a linear relationship between inflation of TAR as well as LSTAR models and the specification test results are reported in Table 2[2]. Hansen LR test (1999) convincingly rejects the TAR and accepts the linear model. Similarly, the F test for LSTAR based on the third order Taylor series expansion of the logistic function around the null hypothesis also accepts the linear model. However, it is important to note that though both these tests consistently argue for linear model, they have identified a threshold inflation of about 8% for our sample.

Table2: The result of specification test for linearity.

Null Hypothesis: Liner Model	F-Statistic	Prob
Hansen LR Test for TAR	2.65	0.45
F test for LSTR	2.3	0.56

Note: F test for LSTR is based on the third-order Taylor series expansion of the logistic function around the null hypothesis

Therefore, based on these findings we propose a linear model and the results are reported in Table 3. The estimates clearly show that there exists a significant negative relation between inflation and growth. While population growth and investment to GDP ratio are significant and have positive influence on growth, the change in terms of trade and the variability in it do not show any influence and hence are dropped from the model.

Since our interest is to explore the relationship between inflation and growth over different time horizon, therefore we examine this strong negative relationship using a wavelet analysis. We estimate the similar linear model after decomposing the variables through wavelet techniques. We apply the non-decimated discrete wavelet transformation to the variables using the Daubechies wavelet filter of length four, with periodic boundary condition. The application of the translation invariant wavelet transformation, with number of scales J=5, produces five vectors of wavelet filter coefficients, that is D5,D4,D3,D2,D1 and one vector of scaling coefficients, S. Since we use annual data, the wavelet filter coefficients, D5, D4…D1, represent progressively finer scale of the series in an ascending order where D1 is the shortest time scale with frequency resolution of 1 to 2 year, while D5 is the longest one with resolution of 16-32 years. Further, for the decomposed series we define the short term and the long term as D1+D2 and D3+D4+D5+S respectively. For each level classified, the linear model is estimated and coefficients are reported in Table3. The appropriate model for each level is determined by the Akaike information criterion and the

[2] The LSTR specification used in the paper is : $Y_t = \phi' z_t + \phi' z_t G(\gamma, c, S_t)$

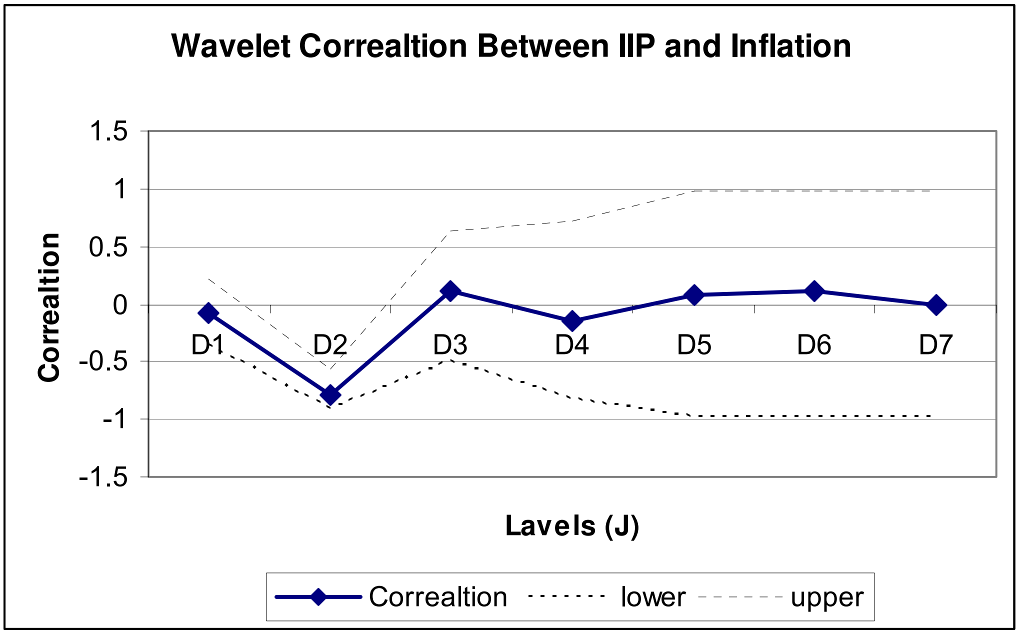
$$G(\gamma, c, S_t) = (1 + \exp\{-\gamma(S_t - c)\})^{-1}, \gamma > 0$$

acceptable auto-correlation structure of the residual. The results reported in Table3 shows that the significant negative relationship between inflation and growth as depicted by the short term model is similar to the findings of the actual series. However, it is important to note that the adverse impact of the inflation on growth is much more acute and persistent for the short term model than for the actual series. On the contrary, for the models capturing longer time horizon, the negative relationship between inflation and growth becomes insignificant. Further, we check the robustness of our findings by trying various permutation and combination of aggregation of wavelet coefficients (D1, D2… D5) and our findings remain invariant to the alternative specifications. Therefore, from the result presented in this paper we can infer that the adverse effect of high inflation on growth is limited to a relatively short-run of 2-4 years of time scale, while the effect seem to dissipate over a longer time horizon.

3.1 High Frequency Data Analysis:

In order to check the robustness of our findings we have further carried out a similar analysis using a high frequency monthly data. However, as many of the explanatory variables used in our earlier analysis are available only in yearly frequency, we have confined our analysis to a bivariate model using Inflation and IIP of manufacturing sector. In contrast to our earlier analysis, note that we only consider the inflation of manufacturing sector as it is often considered as a measure of core inflation in India.

Further, as the pair wise Granger causality test for inflation and IIP indicates a unidirectional causality from inflation to IIP we have used the wavelet correlation between these variables as measures of association. The data used for this analysis ranges from January 2000 to August 2010 (128 months) enabling us to use a 7th level wavelet decomposition. The following graph shows the nature of tradeoff between Inflation and IIP using a non-decimated discrete wavelet transformation to the variables using the Daubechies wavelet filter of length seven, with periodic boundary condition. The figure clearly depicts that the correlation is only significant at D2 suggesting a resolution of a quarter. Therefore, the result from the high frequency data further validates our earlier findings that the adverse effect of high inflation on growth is limited to a relatively short-run of 2-4 months of time scale, while the effect seem to dissipate over a longer time horizon.



4. Conclusions:

Motivated by the recent global and domestic inflation episode, this paper revisits the nexus between inflation and growth, for India. The basic proposition that the growth rate of the economy and the level of inflation are correlated is examined, at various time scales, using the wavelet decomposition technique. For the sample considered, the negative correlation between the inflation and growth for India, the original series is small and weak. However, after decomposing the data and extracting the long run and short run components, a stronger and persistent negative relationship emerges between the growth and inflation while it is insignificant for the longer term.

Table 3: Estimates of the liner models at various time resolutions.

Variable	Model 1 Original Series (Dependent Variable: GDP Growth)	Model 2 Low Resolution (D1+D2) (Dependent Variable: GDP Growth)	Model 3: High Resolution (D3+D4+D5+S) (Dependent Variable: GDP Growth)
C	-6.503109 (0.0198)	0.031304 (0.8721)	-1.952589 (0.2045)
WPI	-0.171993 (0.0374)	-0.219704 (0.0163)	-0.009667 (0.5903)
POP	8.769937 (0.0095)	8.801751 (0.0006)	2.248766 (0.2831)
INV	40.07873 (0.0003)	50.54535 (0.0003)	10.65174 (0.0169)
WPI(-1)		-0.261407 (0.0029)	
WPI(-2)		0.184974 (0.0448)	
GROWTH (-1)	0.1000785 (0.5125)		1.881961 (0.0001)
GROWTH (-2)			-1.711688 (0.0001)
GROWTH (-3)			0.592218 (0.0001)
R-squared	0.622334	0.720645	0.985995
Adjusted R-squared	0.564232	0.662446	0.982176
F-statistic	10.71099	12.38243	258.1471
Prob(F-statistic)	0.000029	0.000005	0
Durbin-Watson stat	2.081936	2.417001	2.038111

Note: P values are reported in the parenthesis.

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