Olaolu Richard Olayeni, Aviral Kumar Tiwari, Reza Sherafatian-Jahromi, Olagbaju Ifeolu Oladiran, (2014). Inflation, Output Gap and Money in Malaysia: Evidence from Wavelet Coherence. International Journal of Computational Economics and Econometrics, *Vol. No. pp. (DOI:) (Forthcoming)*

Inflation, Output Gap and Money in Malaysia: Evidence from Wavelet Coherence

Abstract

This paper investigates the relationship among inflation, output gap and money not only in time, but also in the frequencies for Malaysia over the period 1986:2-2008:12. In so doing, we utilized the wavelet tools such as wavelet coherence and phase difference in continuous wavelet analysis and multiresolution in the discrete wavelet analysis. Application of such tools is helpful in answering particularly two important questions. First, we examined the question of strength, co-movement and synchronization in the relationship among inflation, output gap and money. Second, we studied whether the relationship is cyclical or anti-cyclical in nature. Wavelet coherence and phase difference show that money and output gap are coherent in low and middle frequencies. Moreover, most of the time, output gap could be considered as a leading variable. Furthermore, we noticed evidence for both cyclical and anti-cyclical relationship among the variables. Combining multiresolution with the Diebold-Yilmaz spillover index allows us to preview the extent of the interactions and dynamics among the variables not only over time but also over frequency.

Keywords: Inflation, Output Gap, Money, Wavelet Coherence, Spillover index

JEL No.: C49, E43, E52

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1. Introduction

How do nominal magnitudes like money and prices, on the one hand, and real output, on the other, co-move and on what frequency? Does the relationship move cyclically or anti-cyclically? To what extent do they influence one another? To be quite sure, the co-movement among these variables has been a subject of serious debate in both the empirical and the theoretical literature. In order to unravel the nature of this relation, most studies have indulged mainly in time-domain analysis. The time-domain analysis collapses all the frequencies driving the series and thus all the frequency-dependent oscillations unintelligibly into a single layer of frequency. This means we lose information on frequency domain that may be useful in classifying the horizons of the relationship. To see why pure time-domain analysis might not be appealing in the relationship under investigation, readers are invited to understand that CPI on which the measure of inflation is based is a conflation of many commodity prices each carrying a gene peculiar to its own frequency of activity. The same is true of GDP, which is a monetary summary value of activities taking place on different scales. This is a fact even though many studies have only paid scant attention to this material issue. The position of this paper is that the two domains are important for policy purposes and a method that infuses the two domains will be clearly useful. Indeed, in policy formulation short-run fluctuations and long-run trend movement suggest different policy implication, and the kind of analysis carried out here clearly shows how the classifications along various horizons can be achieved. To this end, we study the Malaysian data in view of the fact that no known study has decomposed the co-movement among these variables for Malaysia into frequencies. We focus on Malaysia for a couple of reasons. The first reason is that Malaysia has pursued over the years, various policies with implications for short-run fluctuation and long-run trend. The second reason has to do with the way the variables are estimated. Poon (2008), for instance, stated that the three topmost listings in the Malaysian CPI basket are on food and non-alcoholic beverages (31.4 %), housing, water, electricity, gas, and other fuels (21.4 %) and transportation (15.9 %). As argued above, these commodities and their prices carry their respective genes at different frequencies that will flaw the analysis if they are not systematically taken into account. In this study, we take this view more seriously for Malaysia.

Nevertheless, exploring the frequency domain is not wholly a new proposition as there have been attempts to extract the variations in frequency for some countries. Our approach also avails us the opportunity to analyze the cyclicality of these variables and show how cyclicality has evolved in frequency. Indeed, different theoretical perspectives have differing predictions regarding the short and long-term tradeoffs between money, output, and prices and for the nature of cyclical relationship. Hence, decomposing the causal relationships over time and frequency and analyzing the cycles and spillovers among the variables are extremely important in understanding the underlying macroeconomic processes and, consequently, in conducting monetary policy. For this purpose, we use both the discrete and the continuous wavelet tools such as wavelet coherency, phase differences and multiresolution to study the co-movement in the time-frequency space, the lead-lag relationship between any two time series and the extent of spillover among the variables. We also use a trivariate specification to overcome limitation of the bivariate model analyzed in most of studies applying continuous wavelet approach. Our findings show that results and thus conclusions from those studies that basically look at the bivariate relationship between money and inflation (see, Rua, 2012, Huag and Dewald, 2004, and Bruggeman, 2005), between money and output (see, Caraiani, 2012) or between inflation and output might simply have been misleading.

For this purpose, the rest of this paper is structured as follows. Section 2discusses the Malaysian experience and provides a brief review of the related literature. In Section 3, we highlight the methodology. It is followed by the discussions of results in section 4. Section 5 presents the conclusion.

2. Malaysian experience and the literature in brief

2.1 Growth and inflation in Malaysia

Since the 1980s, South Asian countries, including Malaysia have experienced a series of financial crises. However, two of them were very damaging. The Asian Financial Crisis sparked by the collapse of the Thai currency in 1997 caused the financial collapse throughout the region. The influence of this crisis in Malaysia could be seen in Figure 1. During this period, inflation increased sharply and GDP growth decreased drastically. By 1999, economies of Asia recovered. Second crisis is the unwinding global financial crisis that started in 2007. Again, large financial institutions collapsed following the worse financial crisis since the 1930s. This crisis also affected the Malaysian economy, with inflation increasing and growth reducing. It must be noticed that the impact of this crisis on GDP started from the second half of 2008 with noticeable reduction in export value. Although many studies have looked at the implications of these crises for the Asian economies, including the Malaysian economy, the evidence is not yet overwhelming.

Figure (1)- Inflation and GDP growth in Malaysia

2.2 Related literature

Inflation and output relationship is an old subject in economics. Philips, in the 1950s, studied the relationship between inflation and unemployment, specifically investigating the trade-off between inflation and economic activity. He found that inflation and output gap were positively related. Since this pioneering effort, many authors have reconsidered this relationship for different economies. It has also engendered theoretical interests and modifications. For instance, Friedman and Phelps criticized Philips for his unstable curve, and developed the expectations-augmented Phillips curve. Galí and Gertler (1999) indicated that dynamics of inflation could be extracted by New Keynesian Phillips curve. Baghli et al. (2007) used nonparametric framework to investigate the sensitiveness of inflation on output in Euro area. The non-linear Phillips curve was obtained in Laxton et al. (1994) while Dwyer et al. (2010) documented that the output gap is an important variable that explains inflation. Clark et al. (1996) examined the asymmetric Philips curve in the case of the United States and indicated that asymmetric relationships exist between output and inflation. Dupasquier and Ricketts (1998) investigated the relationship between output and inflation in Canada using five different nonlinear models. Their findings indicated that the time variation in the trade-off is significant, but they could not distinguish between the five non-linear models examined. Filardo (1998) estimated Philips curve and found that the relationship between inflation and output is not linear as it depends on the prevailing economic operation: when operated below the trend, Philips curve is concave; however, when operated above the trend, Philip curve is convex.

In case of the relationship between money and inflation, "quantity theory of money" suggests that positive unitary relation exists between these variables. Brown and Crowney (2007) applied vector auto regressive model and indicated that there is a short-run as well as long-run relation between consumer price, commodity price and money using US data. Furthermore, their findings showed that monetary development has a causal role in changing the commodity price, which in turn spills over to consumer price. Bodina et al. (2006) examined the relationship between money, inflation and output for Romania and their findings revealed that inflation is highly related to monetary factors. Such a relationship was also revealed for Malaysia by Tan and Cheng (1995). Basco et al. (2009) examined the relationship for Argentina over the period 1977-2006 for different inflation regimes. They found that money velocity and money growth correlate, but this correlation is positive in high inflation and negative under low inflation period. They also considered short-run dynamics, in which inflation expectation plays an important role both in high and low inflation regimes. However, this role is more colourful in high inflation regime. Oomes and Ohnsorge (2005) proved that the broad money growth has a significant influence on short-run inflation. Whether this is true in the long run is still open to an empirical investigation. Price volatility also affects money; however, this impact could be positive or negative. Klein (1977) found that price uncertainty is related to money demand positively. A positive relationship has also been found in the Khan (1982) for Pakistan. Blejer (1979) revealed that there is a negative relation between inflation and demand for money. More recently, Arize et al. (2005) showed that the volatility of inflation rate affects negatively the money demand in eight less developed countries not only in the short run but also in the long run.

What the review of literature above reveals is that there are overwhelming studies investigating the time-domain relationship among money, inflation and output. Not only are the studies investigating the frequency-domain relationship among these variables missing, the studies venturing into understanding both the time and frequency domains are equally absent in the literature. In view of this gap in the literature, this paper examines the relationship, both in time and in frequency, using two approaches, namely the continuous and the discrete wavelet transforms and studying (partial) coherence and phase difference as well as multiresolution-based spillover among the variables. We investigate the Malaysian data in the present study.

3. Methodology

3.1 The continuous wavelet transform (CWT)

The objective of the wavelet analysis is to determine the frequency content of a variable with a view to extracting the temporal variation of this frequency content (Heil and Walnut 1989; Labat 2005). A wavelet is a function with zero mean localized in both time and frequency. It grows quickly and decays within a limited period (Fan and Gançey 2010) thereby obeying the conditions that $\int \psi(\eta) d\eta = 0$ and $\int |\psi(\eta)|^2 d\eta = 1$. We can characterize a wavelet by its localization in time (Δt) and frequency ($\Delta\omega$ or the bandwidth).

Thus, for a CWT of series $x(t)$

$$W_x(s,\tau) = \langle x(t), \psi(t) \rangle \equiv \int_{-\infty}^{\infty} x(t) \circ \frac{1}{\sqrt{s}} \psi\left(\frac{t-\tau}{s}\right) dt \qquad (1)$$

where s and τ are the scale and location parameters and $\psi((t-\tau)/s)$ is known as the mother wavelet function that is possibly complex-valued. The symbol $\circ$ is the convolution operator. A complex wavelet function is of valuable utility in economic analysis as it gives information on local phase. One such function having this property is the Morlet wavelet function. Besides, the Morlet wavelet function can be shown to achieve an optimal localization between the resolution in time and in frequency due to its Gaussian envelop. This property is guaranteed by Heisenberg's uncertainty theorem stating that there is a lower limit to the product of time and frequency resolution. Also implying a trade off between the resolution in time and in frequency, the theorem ensures that any improvement in time degrades the frequency resolution and any improvement in frequency degrades the time resolution. Thus, to achieve optimal balance, we employ the Morlet wavelet function given by

$$\psi_0(\eta) = \pi^{-1/4} e^{i\omega_0\eta} e^{-\frac{1}{2}\eta^2} \qquad (2)$$

where ω_0 is dimensionless frequency and η is dimensionless time. For optimal balance, we set $\omega_0 = 6$ as suggested by Torrence and Compo (1998). Since the idea behind the CWT is to apply the wavelet as a band pass filter to the time series, the wavelet is stretched in time by varying its scale s, so that $\eta = s \cdot t$ and normalizing it to have unit energy. For the Morlet wavelet, the Fourier period (λ_{wt}) is almost equal to the scale $(\lambda_{wt} = 1.03)$ s. The wavelet transform also inherits this property.

The discretized version of Equation (1) for time series $\{x_n : n = 1,\ldots,N\}$ is given by

$$W_m^x(s) = \frac{\delta t}{\sqrt{s}} \sum_{n=0}^{N-1} x_n \cdot \psi^*\left((m-n)\frac{\delta t}{s}\right), \quad m = 1,2,\ldots,N-1 \qquad (3)$$

where δt is the uniform step size. From the expression above, the wavelet power that measures the variability in the time series, both in time and in frequency is defined as $|W_m^x(s)|^2$. For this discretized version, the complex argument of $W_m^x(s)$ can be interpreted as the local phase. Specifically, if $W_m^x(s)$ is complex-valued, then it can be separated into real $\Re\{W_m^x(s)\}$ and imaginary $\Im\{W_m^x(s)\}$ parts, allowing for the calculation of the phase angle, $\varpi_x = \tan^{-1}\left(\Im\{W_m^x(s)\}/\Re\{W_m^x(s)\}\right)$ parameterized in radians ranging from $-\pi$ to π. The CWT suffers from edge effects caused by a discontinuity at the edge because wavelet is not completely localized in time. To cope with this challenge, the cone of influence (COI) has been introduced. The COI earmarks the area where edge effects cannot be ignored and determines the set of CWT coefficients influenced by the value of the signal at a specified position. Outside COI, edge effects are predominant and can distort the result. Here we take the COI as the area in which the wavelet power drops to e^{-2} of the value at the edge.

3.2 Wavelet coherence (WTC)

Since our intention is to measure the extent of synchronization between two given time series, it is informative to use coherence between them. Wavelet coherence is a time-frequency counterpart of the time-domain coefficient of determination and shares property with traditional correlation coefficient. Aguiar-Conraria et al. (2008, p. 2872) defines wavelet coherence as "the ratio of the cross-spectrum to the product of the spectrum of each series, and can be thought of as the local (both in time and frequency) correlation between two time-series". Following Torrence and Webster (1999), we define the wavelet coherence between two time series as

$$R_m^2(s) = \frac{\left|S\left(s^{-1}W_m^{xy}(s)\right)\right|}{S\left(s^{-1}\left|W_m^x\right|^{\frac{1}{2}}\right)\cdot S\left(s^{-1}\left|W_m^y\right|^{\frac{1}{2}}\right)}, (4)$$

where S is a smoothing operator and $W_m^{xy} = E[W_m^x \tilde{W}_m^y]$ is the cross-spectrum, with $\tilde{W}_m^y$ as the complex conjugate of W_m^y. Notice that $0 \le R_m(s) \le 1$ while for the traditional correlation coefficient (ρ) $0 \le \rho \le 1$. Without smoothing coherency is identically 1 at all scales and times. We may further write the smoothing operator S as a convolution in time and scale:

$$S(W) = S_{scale}(S_{time}(W_m(s))), (5)$$

where S_{scale} denotes smoothing along the wavelet scale axis and S_{time} denotes smoothing in time. The time convolution is done with a Gaussian and the scale convolution is performed with a rectangular window (see, for more details, Torrence and Compo 1998). For partial continuous wavelet transform, Aguiar-Conraria, and Soares (2011) define coherence as

$$R_m^2(s)_{X,Y|Z} = \frac{\left|Q_{XY}^M\right|^2}{Q_{XX}^M Q_{YY}^M}, \qquad (6)$$

where Q_{XY}^M, Q_{XX}^M and Q_{YY}^M are the minors associated with the smoothed cross wavelet transforms $\left|S\left(s^{-1}W_m^{XY}(s)\right)\right|^2$, $S\left(s^{-1}\left|W_m^X(s)\right|^2\right)$ and $S\left(s^{-1}\left|W_m^Y(s)\right|^2\right)$ respectively in a 3×3 matrix Q. This trivariate model was used in Ng and Chan (2012) and is a specific form of the multivariate case, where the effects of all other variables are removed from the coherence between x and y.

It is important to conceptualize the lead-lag relationship between two time series. This is achieved by computing the phase difference given by

$$\phi_{x,y} = \tan^{-1}\frac{\Im\{W_m^{xy}\}}{\Re\{W_m^{xy}\}}, \qquad \phi_{x,y} \in [-\pi, \pi] \quad (7)$$

where $\Im$ and $\Re$ are the imaginary and real parts of the smooth power spectrum respectively. Phase differences are useful to characterize the phase relationship between any two time series. A phase difference of zero indicates that the time series move together at the specified frequency. If $\phi_{x,y} \in [0, \pi/2]$, then the series move in-phase, with the time-series y leading x. On the other hand, if $\phi_{x,y} \in [-\pi/2, 0]$ then x is leading. We have an anti-phase relation (analogous to negative covariance) if we have a phase difference of π (or $-\pi$) meaning $\phi_{x,y} \in [-\pi/2, \pi] \cup [-\pi, \pi/2]$. If $\phi_{x,y} \in [\pi/2, \pi]$ then x is leading, and the time series y is leading if $\phi_{x,y} \in [-\pi, -\pi/2]$.

3.3 Discrete Wavelet Transform (DWT)

The idea that the relationship can be cast in continuous form is fantastic, but in some specific cases, most relationships are better handled in discrete forms. Indeed, discrete wavelet transform allows us to provide answers to some specific questions regarding the spillover on scale-by-scale bases as earlier raised in the introductory section. Both the continuous and discrete wavelet transforms are based on Equation (1). In the case of discrete wavelet transform, however, the analysis relies on Mallat's pyramid algorithm to discretize Equation (1) into levels or scales using details. More practically, the discrete wavelet transform (DWT) involves sampling the CWT at the dyadic points. This dyadic sampling is achieved by letting the scale and location parameters be $s = 2^j$ and $u = k2^j$ respectively. By translating and dilating the mother wavelet – involving changing the values of k and j respectively – the daughter wavelets are obtained. Although the father wavelet function can be translated, it is unaffected by the process of dilatation. This property ensures that one can use the father wavelet function to construct the associated father wavelet coefficient that measures the long-term movement in the series. On the other hand, we can use the daughter wavelet functions to construct the associated wavelet coefficients, which capture the short-term movements in the series. The daughter wavelet coefficients and the father wavelet coefficients are respectively given by

$$\omega_{j,k} = \int x(t) \circ \phi_{j,k}(t)dt \text{ and } s_{J,k} = \int x(t) \circ \psi_{J,k}(t)dt$$

where $j = 1,2,\ldots,J$ and $J = \log_2(T)$. More formally, the time series and the wavelet functions are convolved to construct these wavelet coefficients.

3.2 Multiresolution analysis

A major utility of the discrete wavelet analysis is the multiresolution decomposition (MRD) of time series, which involves the process of reconstructing the original time-series. The application of Mallat's (1989) pyramid algorithm ensures that the multiresolution decomposition of $x(t)$ is given by

$$x(t) = \sum_k s_{J,k}\psi_{J,k}(t) + \sum_{j=1}^{J}\sum_k d_{j,k}\phi_{j,k}(t) \qquad (8)$$

This equation makes it clear that we can decompose any series into its constituent details. We will apply Equation (8) on all the series in our study to decompose the data into scales.

4. Results and discussion

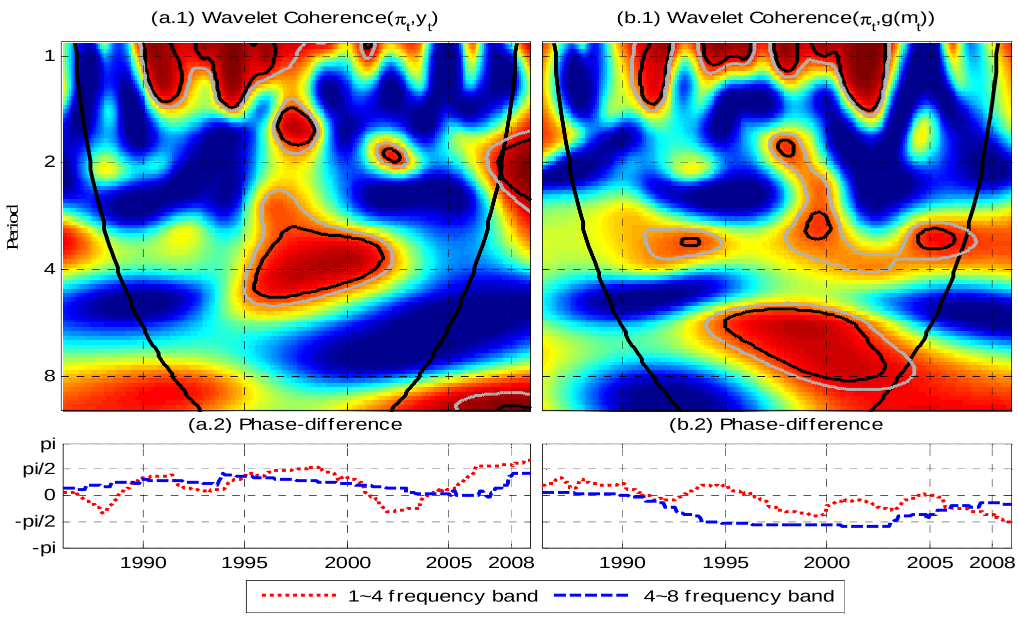
Our aim in this paper is to examine the relationship between output gap, money and inflation in Malaysia. For this purpose, monthly data of inflation, output gap, derived using the Hodrick-Prescott (HP), and money growth, measured by M3 log-first difference multiplied by 100, is considered during 1986:2-2008:12. All data are obtained from IMF-IFS (2010) dataset.

Figure 2 gives the wavelet coherence and phase difference (Panel (a.1)) between the output gap and inflation and between inflation and money growth (Panel (b.1)). As can be seen in the figure, inflation and output were significantly synchronized in low frequencies during the period 2003-2008 at both 5 and 10 percent levels of significance. It should also be noted that this significant coherence occurs below the cone of influence during this period, and appears to suggest that the coherence is dubious due to zero padding. However, we remark that the impact of zero padding on the coherence will only downplay rather than inflate the coherence. Thus, it seems that without zero padding the coherence would have appeared even much more significant. Synchronization was huge in high frequencies during the period 1990-1996 perhaps on account of the doubling per capita income during this time. The period 1990-1996 had followed the era of a shift from agriculture to manufacturing of exports especially microchips and semiconductors. The increased purchasing power probably puts greater pressure on spiral movements in prices as Malaysians began to express this power through purchases of goods and services. We also notice high and significant coherence at 5 and 10 percent levels of significance in middle frequencies during the periods 1996-2001 and 2007-2008 and around 2-year and 4-year bands respectively. We observe that the late 1990s were spectacular in the Malaysian history due to the speculative attack on the Ringgit following which event the country moved to peg its currency to major international currencies. It is also of interest that the regime of subsidizing a wide range of products that kept price level low had been institutionalized by the National Development Policy (NDP) that further extended objectives of the National Economic Policy (NEP). The desire to break with subsidizing actually removed the lid on inflation rate in Malaysia.

Focusing on Panel (b.1), we found that the coherence between inflation and money growth was high and significant in high frequencies during 1991-2003. This short-term correlation between inflation and money growth was significantly picking up High and significant coherence also existed from 1995 to 2007 in low frequencies, especially during 1995-2004. Our variables were tenuously coherent in middle frequencies at the end of the period under investigation. No occurrence of significant coherence below the cone of influence on the relationship between inflation and money growth was found and thus the area of significant coherence does not suffer from edge effects that were noted for the relationship between inflation and output gap.

Phase-differences between our variables are shown in this figure in two frequency bands. On the high frequency band depicted by the 1-4 years frequency band in Panel (a.2), inflation and output gap moved in phase until 2006. Thereafter, they started to move out of phase. While inflation was a leading variable during 1987-1988 and 2001-2004, in all other times, output gap could be considered as a leading variable. Looking at the low frequency band, depicted by the 4-8 years frequency band, we observe that inflation and output gap moved in phase and output gap was the leading variable all the time. In Panel (b.2), inflation and money growth also moved in phase in the high frequency band. In this frequency and save the short spell of leading role for inflation around 1993, money growth was the leading variable until 1996. Thereafter, inflation played the leading role. However, this situation was changed for the low frequency band, that is, on the 4-8 years frequency band. At this frequency, money has been the leading variable just until 1990, while inflation was leading, for the rest of the time. We observe here however that between 1995 and 2003, our variables marginally moved out of phase, but continued to move in phase again from 2003. This finding supports the fact that in 1995, monetary strategy in Malaysia was changed in terms of intermediate targets from monetary aggregates to interest rates to ensure price stability. Malaysia had experienced large capital inflows in 1992-1993, which not only ceased, but also led to capital reversal in 1994, thereby typifying the instability of targeting the monetary aggregates. Hence the change in policy intermediate target. The market rate changes occasioned affected aggregate demand and inflation through consumption, saving and investment by influencing the financial system and, most importantly, the asset prices.

Figure (2)- Left hand side figures are wavelet coherence and phase difference of inflation and output gap and right hand side shows wavelet coherence and phase difference of inflation and money growth

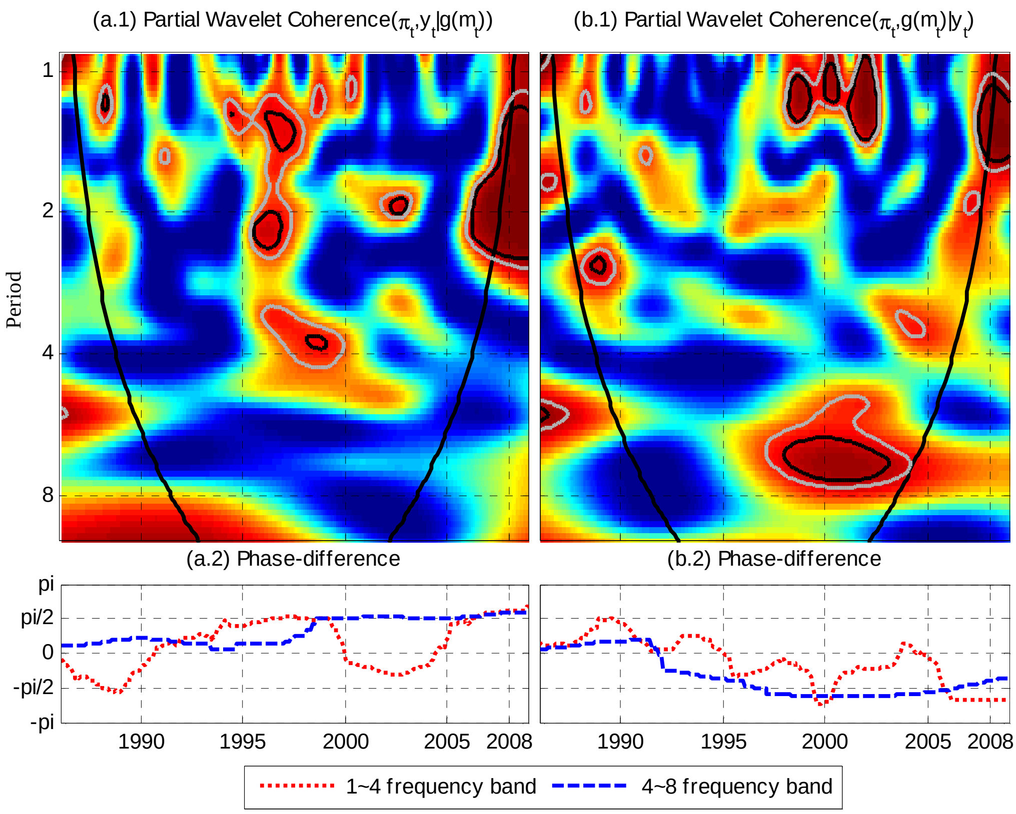


Having considered coherence in bivariate setup, we now consider the influencing roles of the output gap and money growth in modulating coherences previously discussed. To this end, we consider partial wavelet coherences of the corresponding relationships above. Figure 3 presents the partial wavelet coherence and phase difference between the output gap and inflation, while controlling for money growth in Panel (a.1) and between inflation and money growth while controlling for output gap in Panel (b.1). As can be seen from Panel (a.1), significant coherence between inflation and output gap is confined to between 1995 and 2000 and between 2006 and 2008. In other words, after removing the contribution of money growth to inflation and output, coherence noted in Figure 2 considerably diminishes, especially in the middle frequencies, while in the high frequencies coherence seems to have vanished. This suggests that money growth played a crucial role in the "Philips curve" relation in the short and medium terms for Malaysia during 1995-2000. This result reflects the interventionist monetary policy in 1995. We remark also that coherence in the high frequency region during 2006-2008 was in part below the cone of influence and thus suffered from the edge effects. Nevertheless, this coherence could have been downplayed rather than inflated due to zero padding. Hence, we believe that the region could even be more significantly coherent.

Turning to the relationship between inflation and money growth in Panel (b.1), we found that after accounting for the influence of the output gap, coherence between them diminished in high frequencies, especially between 1990 and 1997 and virtually in middle frequencies compared to Panel (b.1) of Figure 2. While coherence observed at low frequencies in Panel (b.1) of Figure 2 remains, it is more diminutive than in partial wavelet coherence reported in Panel (b.1) of Figure 3 even at 10 the percent level of significance.

Panels (a.2) and (b.2) show phase-difference between the variables for low and high frequency bands. In the high frequency band corresponding to 1-4 years frequency band, inflation and output gap moved in phase between 1986-2006, with transient drift out of phase in 1988 and 1997. These findings clearly reflect the episodic changes in the fundamental relationship between inflation and output gap in Malaysia. During the Asian Financial Crisis exchange rate depreciated heavily in Malaysia, which caused higher inflation in 1997. Under this situation, output gap and inflation moved anti-cyclically. At the same time, output gap was negative while inflation was high. The same situation could be observed during the global financial crisis because of the increase in global commodity prices. From 2006, the variables were out of phase. During 1986-1991 and 2000-2004, inflation was a leading variable and as the variables moved out of phase in 2006, this leading role for inflation continued. During the rests of the period under investigation, output gap turned out to be a leading variable. Looking at 4-8 years frequency band, we observed that inflation and output gap were consistently in phase until 1997, when they started to drift out of phase until the end of the study period. In this frequency band, output gap was leading robustly until 1998. However, the leading role of output gap became waned between 1998 and 2006 and finally, inflation became the leading variable until the end of the study period. Concerning inflation and money growth, these variables were in phase in the 1-4 years frequency band except for transient drift out of phase in 2000 and significant drift out of phase in 2006. The changing lead-lag relationship certainly encodes the mood of the economy during this time. For instance, while the BNM changed its intermediate target in 1997 from monetary aggregates to interest rates, the new target was soon perceived as a potential source of instability. In particular, the ability of the bank to influence the domestic interest rates based on domestic factors was corroded considerably by such factors as the volatile short term capital flows and the volatility of the Ringgit occasioned by the Asian Crisis. Thus, by September 1998, selective controls were used which supposedly allowed the BNM to efficiently manage Ringgit without having to use more resources for the purpose. Amidst these policy changes, the lead-lag relationship also changed accordingly. Until 1995, money growth was a leading variable. Between 1995 and 1999, inflation was a leading variable with money growth re-emerging temporarily as the leading variable around 2000. Following this period and until 2004, inflation was leading until 2006 except for 2004 when money growth led again. As the variables were moving out of phase in 2006, money growth once again was leading. In the 4-8 years frequency band, inflation and money growth were consistently in phase until 1996. Between 1996 and 2006, they were out of phase. From 2006 to 2008, the variables were in phase again. Regarding the lead-lag relationship, money growth played a leading role during 1986-1992 and 1997-2006 while inflation was leading otherwise during the study period.

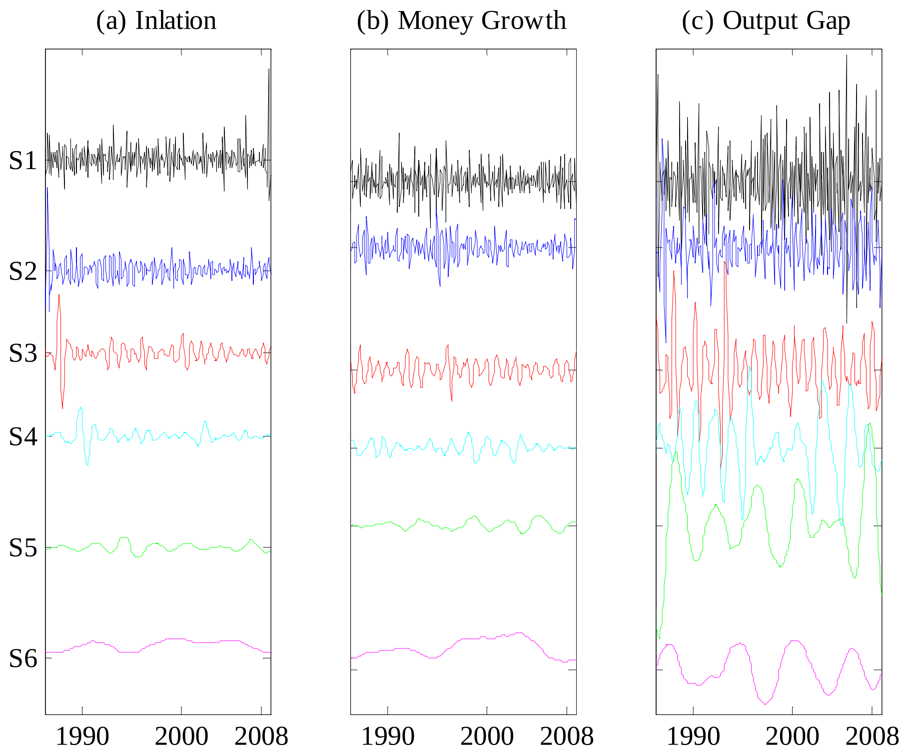
Figure (3)- Left hand side figures are partial wavelet coherence and phase difference of inflation and output gap and right hand side shows wavelet coherence and phase difference of inflation and money growth



4.2. Examining scale-by-scale spillover among the variables

In Figure 4, we report the decomposed series for inflation (in Panel (a)), money growth (in Panel (b)) and output gap (in Panel (c)) using the Mallat pyramid algorithm. Our goal at this point is to examine how and to what extent these variables interact on each scale. To achieve this, we compute the Diebold-Yilmaz (2012) spillover index to measure percentage of variations in a variable accounted for by the variations in another variable. In a sense this analysis is similar to variance decomposition. The intuition is that we should expect a high level of synchronization among these variables if the spillover among them is high. In order to achieve this, we compute a time-varying spillover index using a 50-month moving window. The main reason for the time-varying analysis is to see the evolution of the interactions over time. The DY spillover index is based on a vector autoregressive (VAR) model, and the focus is to compute the forecast error variance decompositions. We employ ordering-invariant generalized variance decomposition

Figure (4) - Decomposed series for inflation, money growth and output



rather than the Cholesky decomposition that is sensitive to the ordering of the endogenous variables. The DY spillover index can be understood as follows. Let $\mathbf{X}_t$ be a 3x1 vector of variables used in this study. A VAR (p) model depicting the dynamics in this relationship is given by

$$\mathbf{X}_t = \sum_{i=1}^{p} \Theta_i \mathbf{X}_{t-i} + \boldsymbol{\varepsilon}_t,\ \boldsymbol{\varepsilon}_t \sim \mathbf{N}(\mathbf{0}, \boldsymbol{\Sigma}) \tag{9}$$

where $\boldsymbol{\varepsilon}_t$ is the error vector and $\boldsymbol{\Sigma}$ is the associated 3x3 variance-covariance matrix. For this VAR(p) model, the moving average (MA) representation is $\mathbf{X}_t = \sum_{i=0}^{\infty} \mathbf{A}_i \boldsymbol{\varepsilon}_{t-i}$ where $\mathbf{A}_i$ is recursively computed as

$$\mathbf{A}_i = \mathbf{\Theta}_1 \mathbf{A}_{i-1} + \mathbf{\Theta}_2 \mathbf{A}_{i-2} + \cdots + \mathbf{\Theta}_p \mathbf{A}_{i-p} \tag{10}$$

The formula for the H-step-ahead generalized forecast error variance decompositions therefore is given by

$$\theta_{ij}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} (s_i' \mathbf{A}_h \mathbf{\Sigma} s_j)^2}{\sum_{h=0}^{H-1} (s_i' \mathbf{A}_h \mathbf{\Sigma} \mathbf{A}_h' s_i)} \tag{11}$$

where σ_{ii} is the i element on the principal diagonal of $\mathbf{\Sigma}$. As each row of $\theta_{ij}(H)$ does not generally sum to 1, it is important to normalize as

$$\tilde{\theta}_{ij}(H) = \frac{\theta_{ij}(H)}{\sum_{j=1}^{N} \theta_{ij}(H)} \text{ so that } \sum_{j=1}^{N} \tilde{\theta}_{ij}(H) = 1 \text{ and } \sum_{i,j=1}^{N} \tilde{\theta}_{ij}(H) = N$$

Diebold and Yilmaz (2012) recommend measuring the total spillover by

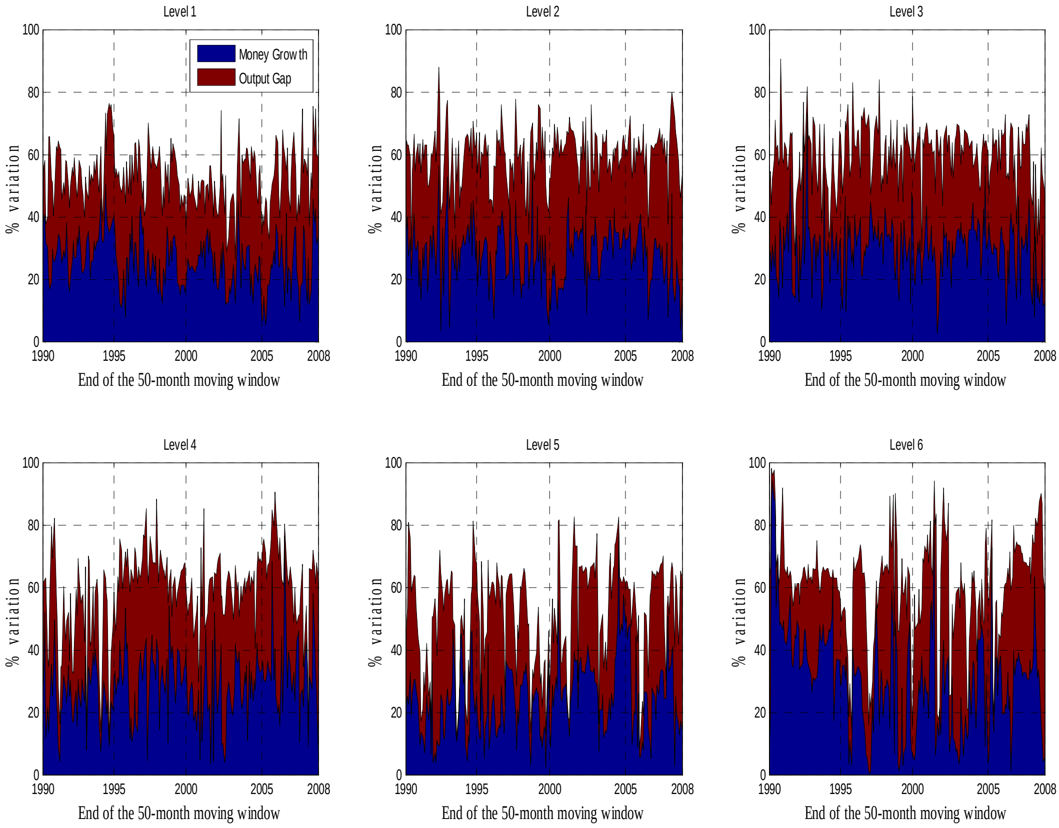
$$S(H) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}(H)}{N} \cdot 100 \tag{12}$$

In our case, we are interested in the directional spillover received by variable i from all other variables. This is given by

$$S_{i,\circ}(H) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}(H)}{\sum_{j=1}^{N} \tilde{\theta}_{ij}(H)} \cdot 100 \tag{13}$$

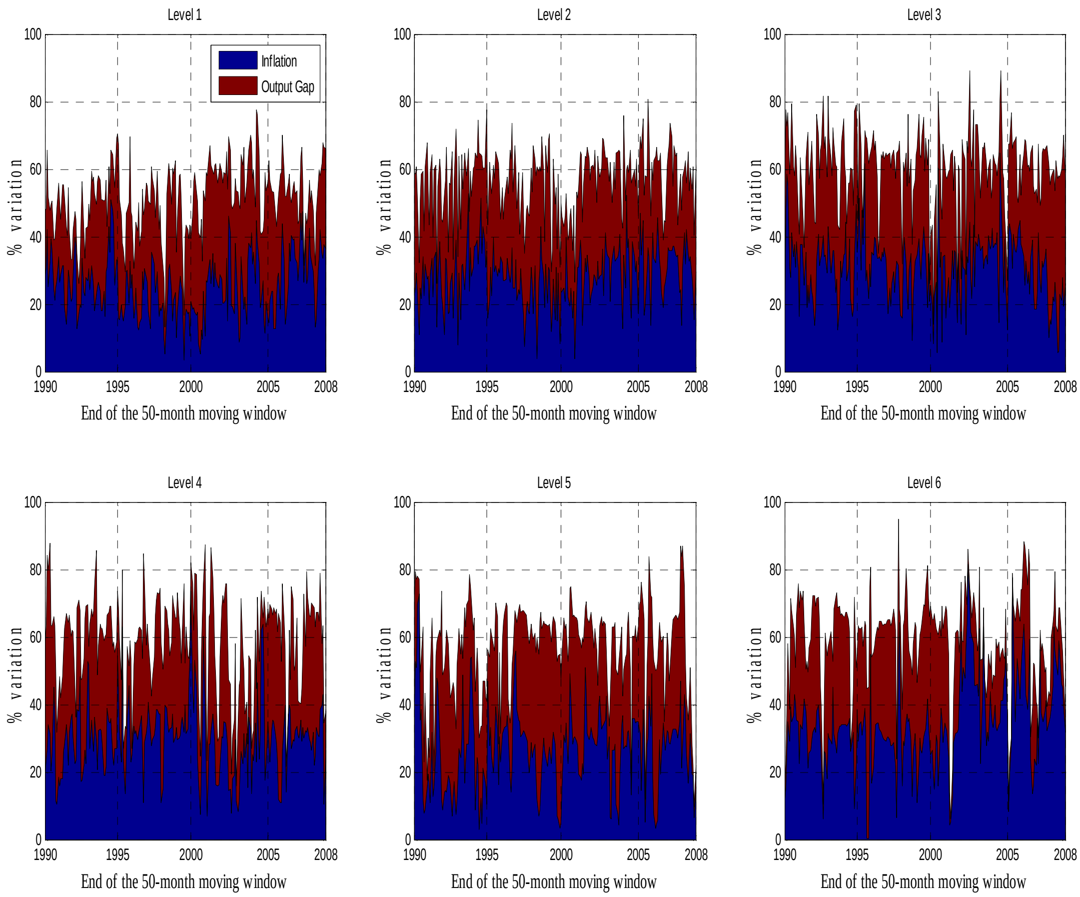
This formula is applied scale-by-scale to the DWT-decomposed series. The plots of these spillovers among the variables of interest are reported in Figures-5-7. Figure-5 reports the spillover of money growth and the output gap in inflation on a scale-by-scale bases. In the case of the variation in inflation, both money growth and output gap explain a reasonable proportion of the changes in inflation. We found that on the first scale inflation on average explains almost 55% of its own variance over the whole sample period, money growth on average explains almost 30% of variance in the inflation while the rest is explained by the output gap. However, on the second and the third scales, money growth and the output gap jointly explain about 60% (where money growth explains about 35%) of total variance in the inflation. On the higher scales, i.e. on the fourth and the fifth scales, and during 1991, 1994, 1999, and 2006, inflation explains about 65% of own variation. On the highest scale (i.e., at sixth level) and during 1995 and after 2006 money growth explains about 42% of variation in the inflation followed by inflation which explains about 40% of own variation.

Figure-(5) Scale-by-scale variations in inflation



The contributions of both output gap and money growth on the higher scales show that the trend movements in inflation are induced by these variables to a sizeable degree. However, it appears that these long-run trend movements in inflation are more influenced by money growth. The short-run fluctuations in inflation are almost equally explained by both money growth and output gap, although the bulk of the short-run fluctuations are due to the movement in inflation itself.

Figure-(6) Scale-by-scale variations in money growth



We found from Figure-6 that for the first three scales results obtained are almost similar to those obtained in the Figure-5. The only difference is that money growth explains relatively more of own variance than explained by inflation. On the fourth and the fifth scales, we found that around 1991, 1994, 2004, and 2008 explanatory power of money growth increases. However, money growth explains about 40% of own variation on average. Until 2002, inflation accounts for about 37% of variation in money growth and the rest is accounted for by output gap. However, after 2002 the explanatory power of inflation in money growth accounts for about 60% of the total variation. The proportion of variation in money growth attributable to variations in the output gap tapers off on the sixth scale and around 2002. This shows that the role of output gap in influencing the trend behaviour of money growth has been reducing in Malaysia. Before 2002, the influence of the output gap in moderating the money growth trend was substantial. For inflation, the impact it has not only on the long-run trend behaviour of money growth, but also on the short-run fluctuations throughout the study period is phenomenal as can be checked out from all the plots in Figure 6. In fact, the contribution of inflation is as important as the contribution of money growth itself.

Figure-(7) Scale-by-scale variations in the output gap

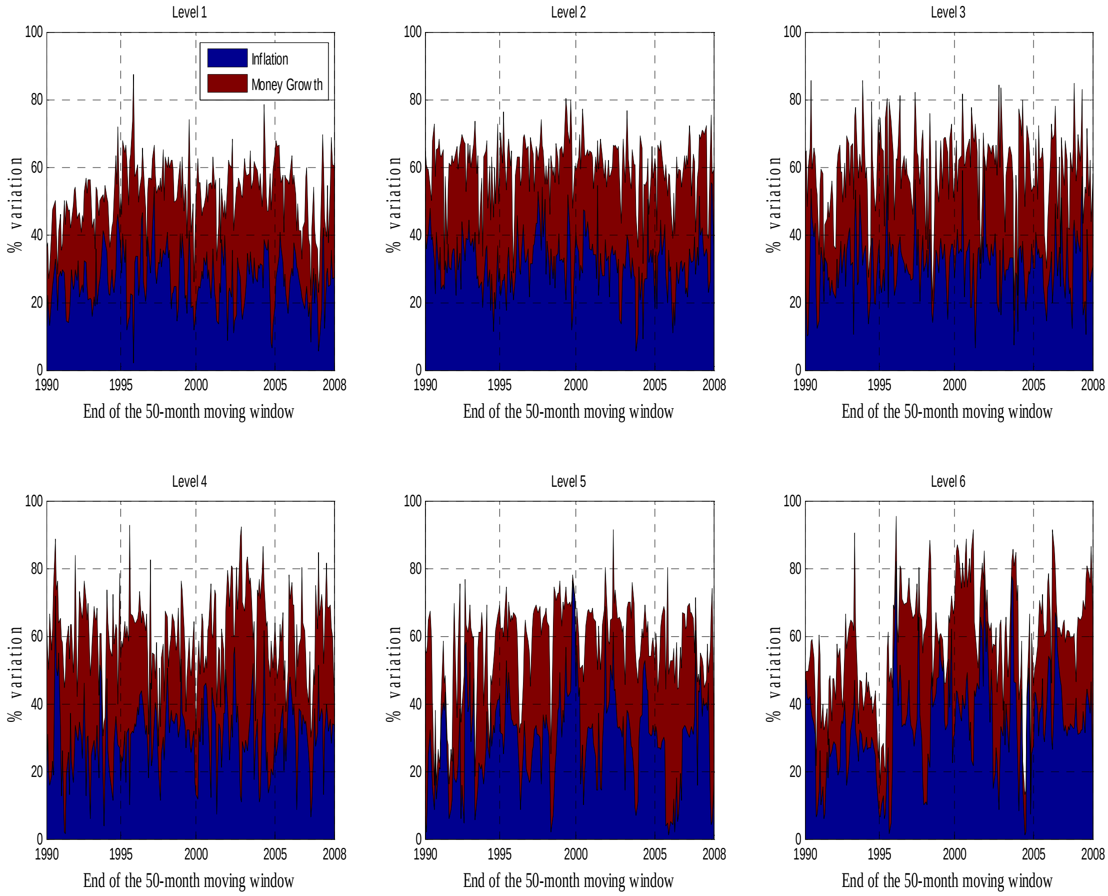


Figure-7 shows that for the first scale output gap accounts on average for about 65% of its own variation followed by inflation and money growth around 1995 and after 2006. The second, the third and the fourth scales show that most of the variation is accounted for by output gap (about

40%) followed by inflation (about 35%) and money growth. Similar results are found at higher scales, i.e., at scales five and six where up to 1995 output gap accounts for on average 50% own variation followed by inflation (about 45%) and money growth. This implies not only that these variables are important for short-run fluctuations, but also for long-run trend movements in the output gap.

5. Conclusion

In this study, the relationship between inflation, output gap and money has been examined using both discrete and continuous wavelet transforms. We also employed partial wavelet analysis based on the CWT. Wavelet coherence reveals that inflation and the output gap are more coherent in low and middle frequencies, while inflation and money are more coherent in low and high frequencies. According to phase-difference results, inflation and output gap move in phase and output gap could be considered as a leading variable, almost all the time. Inflation and money also move in phase, but in this case, at first money plays a role of leading variable and after 1995 for 1-4 years frequency band and 1990 for 4-8 years frequency band, inflation leads money. Accounting for the influencing role of either money growth or output gap in the relationship between inflation and output gap and between inflation and money growth revealed that money growth or output gap matters for the pattern of coherence in the relationship. This accounting also affects the lead-lag relationship. Our spillover analysis, which combines DWT with the Diebold-Yilmazspillover index formula, indicated that there are short-run fluctuations and long-run trend movements induced by the interactions among the variables. These imply the exigency of paying attention to the way monetary policy should be formulated in influencing both the short-run and the long-run co-movement among the variables studied.

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