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Multiscale Analysis of the Liquidity Effect

Antonis Michis*

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Abstract

This study examines the existence of a liquidity effect in Mexico over different time scales. This analysis draws from the liquidity preference framework, an approach to interest rate determination, and uses wavelet multiscale analysis in the context of a standardised regression model. The results suggest that, in short-term cycles, interest rates are influenced primarily by changes in the money supply (i.e., the liquidity effect). In medium- and long-term cycles, the liquidity effect becomes less important and interest rates are found to be more sensitive to income and price effects.

Keywords: Interest rates, liquidity effect, money supply, wavelets.

JEL Classification: E43, E51.

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1. Introduction

The study of interest rate determinants is important to financial managers because changes in interest rates can greatly influence the profitability of investments. For this reason, many institutions use sophisticated forecasting methods in order to accurately predict changes in equilibrium rates (Mishkin and Eakins, 1998, p.128). The liquidity preference theory for the determination of interest rates suggests that changes in equilibrium rates result from changes in the demand for and supply of money. Increases in the money supply by monetary authorities lead to a reduction in interest rates (i.e., the liquidity effect). On the other hand, changes in demand result from income and price effects that are positively related to interest rates.

The liquidity effect generally has an immediate influence on interest rates, while income and price effects can involve substantial time lags. This is because increases in the money supply take time before they increase prices and income in the economy. Expectations of inflation also have an important influence on interest rates. It is important for monetary policy to identify the magnitude and speed of adjustment associated with each effect (Mishkin and Eakins, 1998, p.123).

Following an increase in the money supply, interest rates can rise or fall depending on the size of each effect, and results can vary by time scale or cycle (e.g., short-term, medium-term and long-term). This study uses wavelet analysis in the context of a linear regression model, as suggested by Ramsey and Lampart (1998a), in order to examine the liquidity, income and price effects on interest rates in Mexico by time scale.

Ramsey and Lampart's methodology is also extended by standardising the time scale regression models so that all of the variables in a given time scale are set on a common scale of measurement. This allows for a comparison of the three effects. Results for the Mexican economy suggest that the magnitude of the liquidity effect varies by time scale. When only short-term cycles are examined, the liquidity effect is higher than the income and price effects, but in the medium and long-term, the price and income effects become more important.

The rest of this article is organised as follows: section 2 reviews the main empirical evidence for the liquidity effect, and section 3 provides a short introduction to wavelets and presents the standardised time scale regression models. The data used in the analysis

are explained in section 4, and the results for the Mexican economy are presented in section 5. Section 6 summarises the main findings of the article.

2. Empirical evidence for the liquidity effect

Mishkin (1982) used a linear rational expectations model to study the liquidity effect in the United States (US) and found that increases in money supply are not correlated with declines in interest rates. A different conclusion was reached by Urich and Watchel (1984); they identified a liquidity effect using actual money supply announcements and survey data on expectations of the money supply and the producer price index. Cochrane (1989) used band-pass filters in the context of a regression model to isolate short-term movements in money growth and interest rates. His results suggest the existence of a short-term negative relationship between money growth and interest rates.

Subsequent studies by Leeper and Gordon (1992), Strongin (1995) and Serletis and Chwee (1997) used structural models to show that increased money growth can lower interest rates in the short-term, but the correlation often becomes positive and results are not as robust across sub-periods. Boyd and Caporale (1997) used the Kalman Filter to also demonstrate that monetary innovations do not always impact interest rates in the same direction.

Pagan and Robertson (1998) emphasise that the results from structural models are much less certain due to several econometric problems related to the choice of instrumental variables and the sample period used in the analysis. More recent studies have examined alternative explanations of the liquidity premium puzzle in the United States. For example, Thornton (2004) introduced the idea of interest rate smoothing, which suggests that the US Federal Reserve aims to smooth the transition of rates to new equilibrium levels following economic shocks. As a result, the relationship between interest rates and monetary aggregates can be positive. Another interesting aspect is discussed by Kelly et al. (2011), who showed that monetary aggregates are characterised by measurement errors that can distort estimates of the liquidity effect.

Kopchak (2011), building on earlier work by Hamilton (1997), found that deviations of the federal funds rate from its target level are frequently the result of demand-side shocks. In order to identify the liquidity effect, Kopchak modelled demand-

side forecast errors with a Kalman Filter model consisting of permanent and transitory components. Hamilton used a different identification approach by using forecast errors as an instrumental variable for exogenous changes in the supply of reserves. Kopchak found a considerably larger liquidity effect than Hamilton.

All of the above-mentioned studies concentrate on the US economy. Studies investigating the liquidity effect in other countries (mainly the G-7 group) include Sims (1992), Grilli and Roubini (1996), Cushman and Zha (1997), Fung and Kasumovic (1998), Lastrabes (1998), Kim (1999), Halabi and Lastrabes (2003) and Lastrabes and McMillin (2004). All of these studies report evidence of a short-term liquidity effect but do not provide any evidence for the Mexican economy.

3. Methodology

3.1. Wavelet analysis of macroeconomic data

Ramsey and Lampart (1998b) first proposed the use of wavelets in order to analyse the effect of monetary policy on income over different time scales. The authors identified four key properties of wavelet analysis that are useful for analysing macroeconomic and financial data: the ability to analyse non-stationary time series, localisation in time, orthogonal time-scale decomposition of the data and the fact that pre-filtering is not needed when analysing time series with wavelets. Using Granger causality tests, the authors concluded that, in short-term cycles (or high frequencies), income Granger-causes money; at business cycle frequencies, money Granger-causes income.

Ramsey and Lampart recognised that when examining relationships between macroeconomic variables, the value of the parameters involved may be different across time scales. Even if the direction of the relationship is the same, the intensity may be different. When the effects vary by time scale, important insights are lost by concentrating only on the observed sampling rate of the data that averages, and therefore masks, the individual time scale effects.

Aguiar-Conraria et al. (2008) extended the work of Ramsey and Lampart by using several cross-wavelet tools to show that the relationship between monetary policy variables (money supply and interest rates) and macroeconomic variables (industrial production and inflation) has changed over time and is not homogeneous across time

scales. However, their analysis is based only on bivariate correlation measures between the series and therefore does not have the *ceteris paribus* causal interpretation offered by regression analysis.

Cochrane (1989) also used a frequency domain framework to examine the liquidity effect but concentrated only on short-term movements in interest rates. By running a regression of filtered interest rates on filtered money growth, he was able to find a short-term negative relationship for periods of up to one year. In addition, his analysis is based on the assumption of stationary time-series. In this study, the liquidity effect is studied across a range of cyclical movements (i.e., frequencies) without the stationarity requirement because wavelet analysis can also handle nonstationary time series.

There are also many successful applications of wavelets in finance. For example, Gencay et al. (2003) estimated capital asset pricing models in several countries using time scale decompositions of excess returns and concluded that the models' predictions are more successful for medium-term cycles. With respect to interest rate dynamics that are also the subject of this paper, Shrestha and Hui Tan (2005) used wavelet analysis to identify the existence of long-term and short-term relationships among real interest rates in G-7 countries. A review of the main applications of wavelets in finance can be found in an article by Fernandez (2006).

3.2. Time scale decompositions

Wavelets are functions defined within the set of square integrable functions $L^2(R)$. They have compact local support but decay quickly to zero elsewhere. Any function of time can be represented by a sequence of projections onto a basis of orthonormal elements called the father (ϕ) and mother wavelets (ψ). They are defined as follows:

$$\phi_{j,k} = 2^{-j/2} \phi\left(\frac{t-2^j k}{2^j}\right) \quad \text{and} \quad \psi_{j,k} = 2^{-j/2} \psi\left(\frac{t-2^j k}{2^j}\right).$$

The mother wavelet can be dilated proportional to 2^j $\{j = 1, 2, 3, \dots, J\}$ and translated by changing the parameter $k = \{0, 1, 2, \dots\}$. A unit decrease in j packs the wavelet oscillations of $\psi_{j,k}$ closer (i.e., reduces their width and doubles their frequency). A unit increase in k

shifts the location of the wavelet by an amount proportional to its width. The father wavelet remains unaffected by changes in j but is also translated by changes in k .

The wavelet series approximation of a time series can be represented as follows:

$$f(t) \approx \sum_k s_{J,k} \phi_{J,k}(t) + \sum_k d_{J,k} \psi_{J,k}(t) + \sum_k d_{J-1,k} \psi_{J-1,k}(t) + \dots + \sum_k d_{1,k} \psi_{1,k}(t).$$

The coefficients associated with the father and mother wavelets are, respectively:

$$s_{J,k} = \int f(t) \phi_{J,k}(t) dt \quad \text{and} \quad d_{j,k} = \int f(t) \psi_{j,k}(t) dt.$$

The father wavelet coefficients capture the low-frequency trend behaviour in the data, and the mother wavelet coefficients capture all deviations from the trend. The wavelet series approximation can be written more compactly as

$$f(t) = S_J + D_J + D_{J-1} + \dots + D_j + \dots + D_1$$

with the following orthogonal components that are also termed “wavelet crystals”:

$$S_J = \sum_k s_{J,k} \phi_{J,k}(t) \quad \text{and} \quad D_j = \sum_k d_{j,k} \psi_{j,k}(t).$$

Large values of j refer to low-frequency variation (in long-term cycles) of the time series $f(t)$, and small values refer to high frequency variation (in short-term cycles). Consequently, wavelets provide an orthogonal decomposition of the data into J time scales, with each component providing a resolution of the data at scale 2^j . In the next section, monthly interest rate time series with a length of $2^7 = 128$ are decomposed into 7 time scales. The coefficients of the first time scale component (D_1) capture frequency variation over durations of 2-4 months, and the coefficients of the second component (D_2) capture frequency variation over durations of 4-8 months. Accordingly, the coefficients of the seventh component (D_7) capture frequency variation over durations of 64-128 months.

3.3. Standardisation of time scale regressions

Instead of looking at the relationship between money and income averaged over all time scales, Ramsey and Lampart (1998b) examined the relationship at each time scale by estimating separate regression models using the wavelet crystals as variables. In section 5, the same method is adopted in order to examine the effects of the money supply (M),

inflation (I) and the industrial production index (P) on short-term interest rates (R) in Mexico. The industrial production index is used as a proxy for real income. These variables are commonly used in Keynesian liquidity preference models of interest rate determination (see, for example, Mishkin, 1982). Using the wavelet crystals, the following regression models are estimated:

$$\begin{aligned} R[S_j]_t &= a + \beta_1 M[S_j]_t + \beta_2 I[S_j]_t + \beta_3 P[S_j]_t \\ R[D_j]_t &= a + \beta_1 M[D_j]_t + \beta_2 I[D_j]_t + \beta_3 P[D_j]_t, \quad j = 1, 2, \dots, J-1. \end{aligned} \quad (1)$$

In the first regression equation, the low-frequency (trend) behaviour of short-term interest rates ($R[S_j]_t$) is a function of the low-frequency behaviour of the money supply ($M[S_j]_t$), inflation ($I[S_j]_t$) and industrial production ($P[S_j]_t$). In the second regression equation, the same relationships are estimated for $J-1$ time scales, with each scale covering a different short-term frequency band of the data as described in subsection 3.2.

This second step in the analysis extends the time scale regression framework developed by Ramsey and Lampart (1998b) by standardising the coefficients in each time scale. The usefulness of this step derives from the complex data transformations generated by wavelets, as a result of which the variables are difficult to interpret within each time scale. By subtracting off their mean and dividing by their standard deviation, all the variables in a particular time scale are standardised so that they are measured on a common scale. The corresponding coefficients are called standardised coefficients (see Wooldridge, 2003, p. 186). It is therefore possible to examine whether the income and price effects are more important than the liquidity effect within a specific time scale.

Standardisation of the regression equation at time scale j proceeds as follows:

$$\frac{R[D_j]_t - \bar{R}}{\hat{\sigma}_R} = \beta_1 \frac{M[D_j]_t - \bar{M}}{\hat{\sigma}_M} + \beta_2 \frac{I[D_j]_t - \bar{I}}{\hat{\sigma}_I} + \beta_3 \frac{P[D_j]_t - \bar{P}}{\hat{\sigma}_P}, \quad j = 1, 2, \dots, J-1 \quad (2)$$

where \bar{R} and $\hat{\sigma}_R$ are the sample mean and standard deviation, respectively, of the time series $R[D_j]_t$, and the intercept of the regression model (a) is eliminated from the transformation. The notation for the other variables is similar. The standardised regression can also be written more compactly as:

$$Z_R = b_1 Z_M + b_2 Z_I + b_3 Z_P$$

where the standardised coefficients are

$$b_1 = \frac{\hat{\sigma}_M}{\hat{\sigma}_R} \beta_1, \quad b_2 = \frac{\hat{\sigma}_I}{\hat{\sigma}_R} \beta_2 \quad \text{and} \quad b_3 = \frac{\hat{\sigma}_P}{\hat{\sigma}_R} \beta_3.$$

These coefficients are measured in terms of standard deviations (e.g., a one standard deviation increase in the money supply changes interest rates by b_1 standard deviations), and their magnitudes can be compared in order to identify which has the biggest effect on interest rates at the specific time scale j .

4. Data description

Monthly data for interest rates, the M2 monetary aggregate (MXN billion), inflation and the industrial (manufacturing) production index in Mexico were used in the analysis covering the period from May 2000 until December 2010. The interest rate and industrial production data were obtained from the OECD statistical database, and the M2 and inflation data were obtained from the statistical database of the Bank of Mexico. Based on the OECD definition, short-term interest rates in Mexico refer to the 91-day interbank equilibrium rate. The M2 monetary aggregate was preferred over M1 because it is less subject to measurement errors (see Kelly et al. 2011). Following Mishkin (1982), the industrial production index was used as a proxy for real income, which is not available with monthly regularity for Mexico.

Charts of the variables are included in Figure 1. Each variable exhibits different characteristics and cyclical behaviour. For example, inflation is characterised by strong short-term and seasonal variability, while M2 is characterised by an upward trend with sporadic short-term changes. Interest rates and industrial production exhibit different cyclical movements, structural changes and trend characteristics.

Wavelet decompositions of all the time series were performed using the Daubechies least asymmetric family of wavelets with a filter length of 8 in the context of the maximal overlap discrete wavelet transform (MODWT). Because the time series consist of 128 observations, seven time scales were generated from the MODWT ($2^7 = 128$). This wavelet family was also used by Gencay et al. (2002, p. 159) to analyse the money supply in Mexico and by Shrestha and Tan (2005) to analyse real interest rates in G-7 countries. It was also found to provide good resolutions for the data used in this

study. Although it does not provide an exactly orthogonal decomposition, the MODWT provides efficiency gains and generates wavelet coefficient vectors of equal length with the original time series that can be used in a time scale regression analysis.

Figure 1: Mexico Data

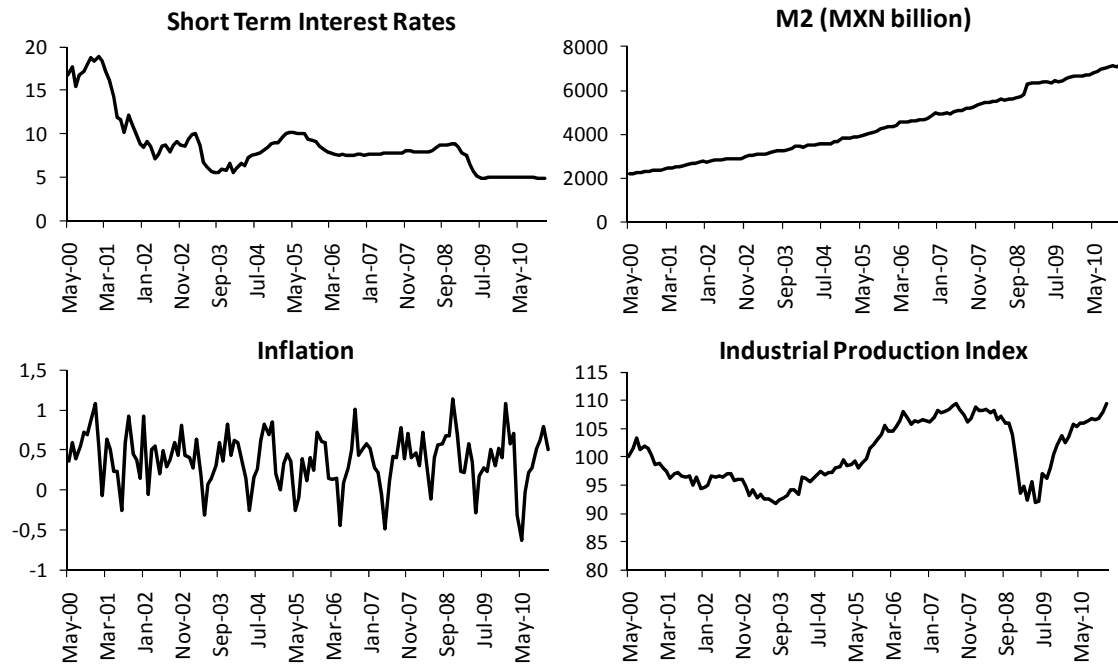
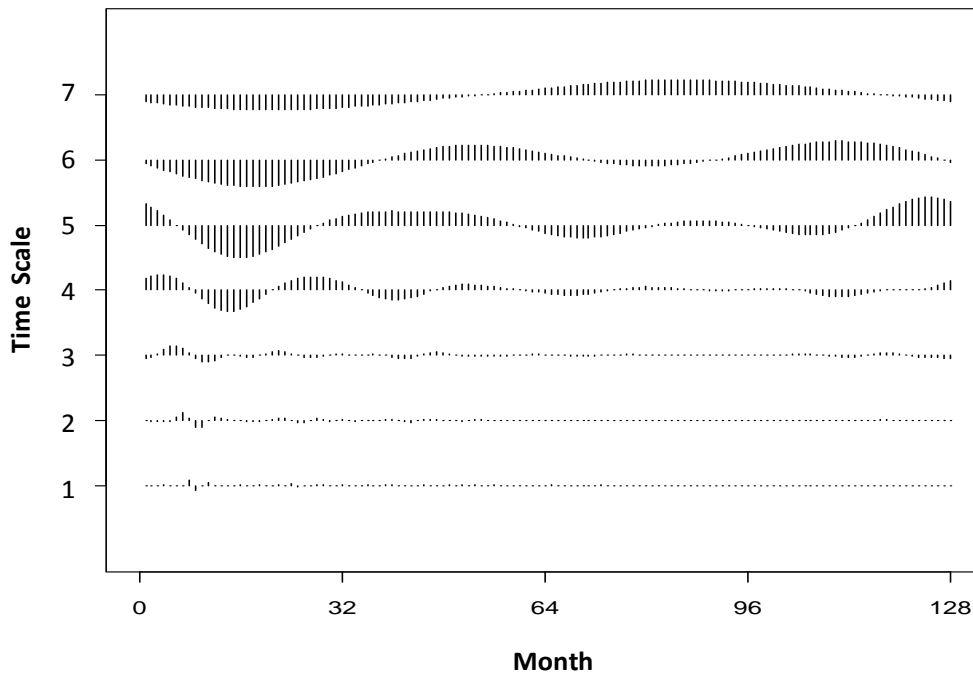


Figure 2 shows the wavelet coefficients for interest rates generated by the MODWT. Time scale 1 corresponds to cyclical movements of 2-4 months, and time-scale 7 corresponds to cyclical movements of 64-128 months. It can be observed that interest rates exhibit variation at all time scales, particularly in time scales 4 to 7. Furthermore, the cyclical variation in each time scale differs according to the time location (i.e., month). Unlike the Fourier transform, wavelets are flexible enough to provide a frequency decomposition of a time series while also preserving the time location dimension of the data. For example, although there is considerable variability during the first 32 months of the analysis at all time scales, the situation is different during the last 20 months of the sample period when variability is high at time scales 5 and 6. Also, the long-term trend of the series exhibits variability between months 64 and 96, a period when variability in other time scales is not high.

Because variability differs by time scale, it is interesting to examine how the liquidity, income and price effects differ (and their relative importance changes) by time scale. This difference is the subject of section 5.

Figure 2 : Interest Rates Wavelet Coefficients



5. Results and discussion

In order to examine the existence of a liquidity effect by time scale, separate regression models were estimated using the wavelet crystals of the variables. OLS estimates of the coefficients, together with their standard errors, are included in Table 1. The first part of the table includes estimates of the model (1) coefficients, and the second part (standardised coefficients) includes estimates of the model (2) coefficients.

The first column, $f(t)$, includes coefficient estimates from a regression using the original data for each variable (without the application of a wavelet transform) and is included for comparison with the time scale regressions. The three coefficients in this column have the expected sign according to the liquidity preference framework for interest rate determination. The coefficients for M2 and industrial production are

statistically significant at the 95% significance level, and the coefficient for inflation is significant at the 90% level. The standardised coefficient estimates in the second part of Table 1 show that M2 has the biggest effect on interest rates, and this effect is greater than the sum of the income and price effects. This finding points to the existence of a liquidity effect in Mexico.

Table 1: Time Scale Regressions

	f(t)	D1	D2	D3	D4	D5	D6	D7
Intercept	-4.159 (4.234)	-12.887 (13.982)	61.266* (7.228)	-2.159 (4.020)	-7.837** (4.082)	8.542* (3.107)	-2.922 (2.481)	-4.868* (1.806)
M2	-1.838* (0.165)	-0.749* (0.061)	-1.530* (0.098)	-1.019* (0.131)	-0.653* (0.140)	-1.790* (0.139)	-2.499* (0.174)	-2.441* (0.1881)
Production	0.203* (0.046)	0.051* (0.018)	0.406* (0.026)	0.026 (0.028)	-0.025 (0.040)	0.255* (0.038)	0.138* (0.043)	0.072 (0.045)
Inflation	1.111** (0.637)	21.920* (0.406)	1.791 (3.000)	23.906* (1.336)	19.278* (1.243)	3.055* (1.185)	1.740* (0.693)	0.695 (0.491)
F-test	45.1*	330200*	218.6*	335.1*	146*	66.74*	75.48*	70*
R-square	0.522	0.990	0.841	0.890	0.779	0.618	0.646	0.629
Standardized Coefficients								
M2	-0.823	-0.784	-0.610	-0.364	-0.394	-0.781	-0.813	-0.794
Production	0.328	0.179	0.578	0.035	-0.054	0.397	0.180	0.093
Inflation	0.109	0.854	0.023	0.698	0.683	0.146	0.135	0.080

* Significant at the 95% level, ** Significant at the 90% level

Standard errors in parenthesis

The regression results for the seven time scales are included under columns D1-D7. All the coefficients have the expected sign except for the coefficient for production in time scale D4, which is negative but close to zero. All the coefficients for M2 are statistically significant at the 95% significance level. Most of the other coefficients are statistically significant at the 95% significance level, except for the coefficients for inflation in time scales D2 and D7, the coefficients for production in time scales D3, D4 and D7 and the estimates for the intercept in time scales D1, D3 and D6. However, these were included in the models based on the values of the F-test for the joint significance of the coefficients in each time scale. The R-square values are higher for time scales D1-D4, which capture the low-frequency, long-term cyclical movements in the data.

The coefficient for the money supply (M2) is higher in time scales D6-D7 (higher frequencies), while the coefficients for industrial production and inflation vary by time scale. Accordingly, interest rates can rise or fall when examined within a specific time scale, depending on whether the income and price effects are higher than the liquidity effect.

To be able to compare the three effects within each time scale, it is necessary to standardise the coefficients as described in subsection 3.3. When only time scales D5-D7 are examined, the standardised coefficient of the liquidity effect is higher than the standardised coefficients of the income and price effects. It should therefore be expected that interest rates will decrease in the short-term following an increase in the money supply. When considered together, the total income and price effects are higher than the liquidity effect in time scales D3, D4 and D1 and are equal to the liquidity effect in time scale D2. Time scale D1 captures the long-term trend in the data, and the coefficients at this scale suggest that, in the long-term, the income and price effects become more important than the liquidity effect. Therefore, interest rates rise as suggested by Milton Friedman (1968).

The short-term liquidity effect identified in time scales D5-D7 is consistent with the work of Cochrane (1982), who estimated a negative relationship between money growth and interest rates in the US when only the high-frequency data are considered. Also, the results suggest that the inflation effect becomes more important than the liquidity effect at time scale D4, which covers cyclical movements with a duration of 16-32 months. The same is observed for time scales D1 and D3. This result is consistent with the empirical studies of Mishkin (1982), Lepper and Gordon (1992) and Strongin (1995), who reported a positive relationship between money supply and interest rates in the long-term in the US.

6. Conclusions

Wavelets can decompose time series into different time scales, which allows us to identify how the money supply, inflation and income influence interest rates throughout the cycle. This influence is not evident when only the observed sampling rate of the data is studied because sampling provides a mixture of the different frequencies and masks

differences between short-term and long-term relationships. This is an important distinction in the examination of the liquidity effect because both theoretical and empirical studies suggest that different factors influence interest rates in the short-term than in the long-term. Using data for the Mexican economy, this study examined the liquidity, income and price effects on short-term interest rates over different time scales. The results suggest that the impact of each effect varies by time scale: in the short-term, interest rates are influenced primarily by the liquidity effect, but in the medium and long terms, income and price effects become more important.

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