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Using wavelets to decompose the time–frequency effects of monetary policy[☆]

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Abstract

Central banks have different objectives in the short and long run. Governments operate simultaneously at different timescales. Many economic processes are the result of the actions of several agents, who have different term objectives. Therefore, a macroeconomic time series is a combination of components operating on different frequencies. Several questions about economic time series are connected to the understanding of the behavior of key variables at different frequencies over time, but this type of information is difficult to uncover using pure time-domain or pure frequency-domain methods.

To our knowledge, for the first time in an economic setup, we use cross-wavelet tools to show that the relation between monetary policy variables and macroeconomic variables has changed and evolved with time. These changes are not homogeneous across the different frequencies.
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Keywords: Monetary policy; Time–frequency analysis; Non-stationary time series; Wavelets; Cross-wavelets; Wavelet coherency

1. Introduction

Central banks have different objectives in the short and long run and they operate simultaneously at different timescales — see Ref. [40]. Moreover, many economic processes are the result of the actions of several agents, who have different term objectives, with some agents focusing on daily movements and co-movements, while other agents are concerned about longer horizons. Therefore, a macroeconomic time series is a combination of components operating on different frequencies. On top of this, some interesting relations may exist between two macroeconomic time series at different frequencies. For example, it is possible that monetary policies have different impacts in the short or long run, therefore affecting the economy in different ways at different frequencies. Or, it is possible that monetary

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authorities react to inflation news in the short run, while, in the long run, the price level is essentially determined by the money supply. Finally, it is possible that the effects of a certain policy evolve with time, as institutions and policymakers change. While several questions about time series economic data are connected to the understanding of the behavior of key variables at different frequencies over time, this type of information is difficult to uncover using pure time-domain or pure frequency-domain methods.

We use wavelets to analyze the impact of interest rate price changes on some macroeconomic variables: industrial production, inflation and the monetary aggregates M1 and M2.[1] Specifically, we utilize the continuous wavelet power spectrum and three cross-wavelet tools: the cross-wavelet power spectrum, the wavelet coherency and the wavelet phase difference. With these instruments we are able to unravel some economic time–frequency relations that have remained hidden so far.

With the wavelet power spectrum, we show that the "great moderation" is not a recent phenomenon and that the observed reduction in the volatility of production happened in the 1950s and not in the 1980s as has been erroneously assumed in the economic literature. The volatility was temporarily revived during the oil crisis of the 1970s and 1980s, mostly at business cycle frequencies. This is specifically one of the advantages of the wavelet analysis: the possibility of uncovering transient relations. The same conclusion is reached about inflation. The volatility of inflation decreased at the same time. Therefore, the great moderation is not just a real phenomenon but also a nominal phenomenon.

With the cross-wavelet tools we show that the relation between monetary policy variables (money aggregates and interest rates) and macroeconomic variables (industrial production and inflation) has changed and evolved with time and is not homogeneous across the different frequencies. For example, in the 1970s and 1980s we observe that interest rates reacted procyclically with inflation at the business cycle frequencies, and that at lower frequencies this helped to control inflation. We also find evidence that in the 1950s interest rates were reacting to industrial production, in the 2–4 year period, but that in the 1970s and 1980s, especially in the 4–12 year period, we observe an anti-phase relation with interest rates leading, meaning that increases in the interest rates had contractionary effects, supporting the conclusions of some authors [1,30] who argued that monetary policy reinforced the recessionary effects of the oil shocks. We also find evidence of a structural break in the relation between the interest rates and the monetary aggregates. In the late 1970s, early 1980s, at the business cycle frequency, the broader definition of money, M2, stopped lagging the interest rates. At lower frequencies, corresponding to 15–20 year period oscillations, M1 started leading the interest rates. This suggest that the Fed has been following a monetary targeting type of policy, even if they are not explicit about it (except between the mid-1970s and mid-1980s).

The paper proceeds as follows. In Section 2, we discuss the main advantages of wavelet analysis, its applications to economics and some of the typical difficulties in applying it to study economic relations. We present the continuous wavelet transform, and discuss its localization properties and the optimal characteristics of the Morlet wavelet. Section 3 describes the wavelet power spectrum, the cross-wavelet power spectrum, the wavelet coherency, and the phase difference. In Section 4, we apply these tools to study the effects and the effectiveness of monetary policy. Section 5 concludes.

2. Wavelets: The dynamical decomposition of time

In the economic literature it is common to utilize Fourier analysis to uncover relations at different frequencies. For example, spectral techniques can be used to identify some stylized business cycle facts [21,28], and seasonal components [37,50], or to highlight different relations among economic variables at distinct frequencies, such as the paradoxical relations between production and inventories [51]. In spite of its utility, under the Fourier transform, the time information of a time series is completely lost. Because of this loss of information, it is hard to distinguish transient relations or to identify structural changes. Moreover, these techniques are only appropriate for time series with stable statistical properties, i.e. stationary time series. Unfortunately, typical economic time series are noisy, complex and strongly non-stationary.

To overcome the problems of analyzing non-stationary data, Gabor [13] introduced the short time Fourier transform. The basic idea is to break a time series into smaller sub-samples and apply the Fourier transform to each sub-sample. However, as Raihan et al. [42] pointed out, this approach is inefficient because the frequency resolution is the same across all different frequencies. As an alternative, wavelet analysis has been proposed.

[1] The total stock of money in the economy consists primarily of currency in circulation, checking accounts and savings accounts. M1, also known as narrow money, includes currency in circulation and checking accounts. M2, also known as broad money, includes M1 and the savings accounts.

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