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Money Growth and Inflation: A Wavelet Analysis for a Monetization Approach to COVID 19

This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

Published Version:

Focacci, A. (2023). Money Growth and Inflation: A Wavelet Analysis for a Monetization Approach to COVID 19. CHALLENGE, 66(1-2), 27-48 [10.1080/05775132.2023.2213103].

Availability:

This version is available at: <https://hdl.handle.net/11585/926015> since: 2023-06-10

Published:

DOI: <http://doi.org/10.1080/05775132.2023.2213103>

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(Article begins on next page)

This is the final peer-reviewed accepted manuscript of:

Focacci, A. (2023) MONEY-GROWTH AND INFLATION: A WAVELET ANALYSIS FOR A MONETIZATION APPROACH TO COVID-19 *CHALLENGE* on line version

The final published version is available online at:

[<https://doi.org/10.1080/05775132.2023.2213103>]

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Esempio citazione:

Focacci, A. (2023). Money-growth and inflation: a wavelet analysis for a monetization approach to covid-19 *Challenge*, DOI: 10.1080/05775132.2023.2213103

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MONEY GROWTH AND INFLATION: A WAVELET ANALYSIS FOR A MONETIZATION APPROACH TO COVID 19

Abstract

Covid 19 pandemic will cause a global economic contraction. The magnitude of shocks will impact the fiscal deficit and the public debt in all Countries. This paper provides an insight into the dynamic relationship between money growth and inflation for several Countries. The Morlet wavelet coherence model is employed since it allows the simultaneous examination of lead-lag effects and co-movements between the couple of variables in the different Countries. The overall results do not evidence a clear impact of the money growth on inflation. This outcome has relevant economic policy consequences considering that the monetization of the public debt can sustain the economic recovery. Thus, the pure monetary nature of the inflationary phenomenon can hardly be considered as a constraint in designing the measures to counteract the issue.

Keywords: Lead-lag effect, Wavelet analysis, Morlet wavelet analysis, Money growth, Inflation

JEL codes: C49, E31, E51, E58

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1. Introduction

The economic and social disruptions induced by present pandemic crisis are huge (Mohanty and Sharma, 2022). At the moment, the possible evolution of the COVID-19 both on the social and the economic development remain highly uncertain.

Currently, social consequences are heavy and harmful. Millions of lives lost, losses of employment, setbacks in the education of children, disruption to ordinary health services, increasing poverty and food deprivation are among the most important aspects to enumerate.

Under the mere economic perspective, the International Monetary Fund (IMF) reports that “The COVID-19 pandemic has not yet been brought under control, and recovery is not assured” (IMF, 2021). For the fiscal year 2020 the forecasts on real GDP decline are impressive for all Countries. For example, the gap with 2019 is estimated equal to: -8.1% for France, -8.9% for Italy, -9.8% for the UK, -4.8% for Japan, -3.5% for the USA and -3.4% for the World (EU, 2021). Expressed in percent of GDP, the 2020 figures and the projection to the fiscal year 2026 of Governments Overall Balance point to marked worsening both of deficits and of debt. More generally for advanced economies, the forecasts do not estimate that the values recorded in 2019 will be reached in the next 5 years (IMF, 2021). To find similar contractions for industrialized Countries in recent economic history, we have to go back to the World War II or to the Great Depression. Elaborating the data on GDP as presented in Bolt et al (2018), as mere illustrative cases: Italy experienced a yearly average decreasing rate equal to -7.16% between 1939 and 1945, Japan plunged of -10.7% between 1941 and 1945, and the UK fall was at a -3.6% rate between 1943 and 1947. Differently, the USA did not experience war damages on their territory, while the most significant drop can be found in the Great Depression time span (1929-1933) where the corresponding contraction rate of the economy

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was equal to -7.76%. The parallelism between the magnitudes of COVID induced economic slowdowns and those experienced in those critical periods is more than evident.

Given such a situation, the main concerns of Governments lie in how to deal with and manage the epidemic (Eichenbaum et al, 2020). Especially, with debts both at the private and the public level. Private debts affect the level of economic activity mainly through the business failures, the induced increasing unemployment and the financial stress of the whole system. The raising of the Government debt-GDP ratio can become a potentially lethal problem for the Countries belonging to monetary unions. As an example, within the Euro Zone (EZ), IMF forecasts predict that Italy will climb up to 157% in the 2021 starting from about 135% in 2019. A similar increase of 20% is expected for Spain reaching the threshold of 118% (IMF, 2021). By way of example only, the same holds for the debt and the financing risks in the Middle East Area, Afghanistan, Pakistan and North Africa (Menkulasi et al., 2021). Thus, broadening the perspective, the vulnerability of international debt is the direct result of this pandemic crisis, presenting itself as an urgent issue for the world whole economic system.

Summing up, the picture is rather complex. At the economic policy level, there are the potential instruments based on the fiscal policy, on the monetary policy and a balanced mix between them. Accordingly, the main concerns regard the alternatives to adopt in a concrete and practicable way to address this dramatic problem. Solutions that prefer the adoption of unconventional monetary policies are generally counteracted as they are held responsible for potential and uncontrollable inflationary pressures.

In this paper we propose a wavelet analysis (WA) to investigate the relationship between money growth and inflation in different Countries. WA has distinctive features when compared with most conventional econometric methods. In fact it allows us to expand time series into a time-frequency space in which both the local correlation and the lead-lag relationship can be read off in a highly

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intuitive way (Jiang et al., 2015). Differently from time-domain methods (correlation analysis, Granger-causality within a vector autoregressive framework, cross correlation function after the prewhitening of raw data, etc.) WA shows its advantage in identifying short-run and long-run relationships. While compared with frequency domain methods (like for example Fourier analysis), it can be useful in revealing the change over time of such a relationship (Roueff and Sachs, 2011). We are aware of the fact that empirical analysis could be considered as somewhat specific to the period covered by the dataset. For this reason, we try to build the longest time series to process with available public data. Moreover and intentionally, the paper extends the period of analysis including Countries having very different economic structures and financial regulatory frameworks.

Our results do not suggest the existence of meaningful and unequivocal relationship between the variables, and this fact should be considered as a distinctive trait for the adoption of appropriated policies.

The remainder of the paper is organized as follows. The next section briefly reviews and discusses the main aspects and empirical literature on the money-inflation relationship also considering some up-dated proposals on the subject. Section 3 and 4 provide the methodology and the data descriptions. Section 5 presents the empirical results and findings on lead-lag effects. Finally, Section 6 concludes.

2. Considerations and related literature about the money-inflation mechanism

Alternative phases of economic growth and depression have always been recorded throughout economic history. Many scholars have also theorized the existence of specific cycles. The identification of cycles has been conducted either via isolating turning points in the time series or by finding oscillations in them (Kulish and Pagan, 2021). We can find in literature a classification of such cycles following their average length (Reijnders, 2009):

- Kitchin cycles (3-5 years);

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- Juglar cycles (7-12 years);
- Kuznets cycles (15-25 years);
- Kondratieff cycles (40-60 years);
- Hegemonial cycles (over 60 years).

Not all economists agree on the genesis of the crises and their descriptions. Classical economic aspects have been complemented with financial factors (Minsky, 1992) to build a more coherent long-run theoretical framework (Bernard et al., 2014). However, even if the causes and the recipes for getting out of crises are often not shared, there is a widespread consensus between economists and historians in considering that capitalist systems are characterized by instability (Adelman, 1965). To review crisis narratives (including recent ones) a good paper to start is Miller (2021).

At this point, also this pandemic economic downturn from a macroeconomic perspective can be traced back to the various shocks afflicting the system. Interventions to tackle resulting consequences through traditional economic and fiscal policy instruments raise several issues.

As far as the fiscal policy is concerned, it must be pointed out that even if the level of public debt cannot be considerate as a decisive factor in limiting the economic growth of an advanced Country (Panizza and Presbitero, 2014), a strong and traditional public fiscal stimulus following the current rules is very complicated to pursue. Under current conditions, an increase of government deficit jointly with the forced contraction of GDP would determine a lethal combination for debt/GDP ratios. Countries belonging to currency unions and having high public debt would be under excessive (and probably unsustainable) financial stress (Afonso et. al, 2019). The potential responses by Central Bank (CB) would be forcedly asymmetric determining the increasing of the interest spreads among the different sovereign debts issued by the various Countries (as already happened in the recent 2010-2011 period). The resulting trade-off between public debt stabilization and household welfare is well depicted by Jesus et al., (2020). On the private side, the effects on

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corporate bankruptcies of conventional monetary policy have been recently highlighted by Sarikov and Kuprianov (2020), and support the hypothesis that the increase of monetary base reduce the rate of failures not having distortionary effects on the relative prices (and yields) between eligible corporate bonds and not eligible ones (Mäkinen et al., 2022). In a currency union this would determine a great differentiate shock among the economic structures of the various Countries. The risks of low (also negative) interest rates on debt management policies inducing a short-term excessive leverage ratio is empirically pointed out by Hodula and Melecký (2020). Also too much private indebtedness is toxic for the growth of the whole economy, and the threshold identified by Arcaud et al. (2015) is close to the 100% of GDP.

For what concerns the adoption of traditional monetary policies, even they were successful in maintaining price stability or reducing unemployment in some circumstances (El Alaoui et al., 2019), they showed several shortcomings in supporting economic recovery considering that the interest “zero lower bound” is the rule since the 2008-2011 crisis (Sims and Wu, 2021). The result is that both fiscal and conventional monetary policies seem unfitted in their role (El-Shagi and Turcu, 2021), and this is even more so in an exceptional case such as that determined by the Covid-19.

Within such a context, the possibility to recur to unconventional monetary measures has been authoritatively introduced and discussed in contributions by Blanchard and Pisani-Ferry (2020) or also Giavazzi and Tabellini (2020). Moreover, the role of the CB is discussed by literature because current goals oriented towards price stabilization appear not fully adequate (Seccareccia and Khan, 2019). A discussion of the effects of the ECB's efforts in the EZ is, for example, proposed by Benigno et al. (2022). Given the exceptional nature of the current crisis, the “forgotten” role of a direct monetization of public debt regain its appeal as a useful instrument for financing fiscal policy. A monetization consists in the purchase on the primary market by CB of Government Bonds

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issued to finance Government public spending. The purpose is to sustain the whole economy through the fiscal/investment (Keynesian) multiplier which is significantly exceeding the unity when interest rates are persistently low as recent estimates have found (see Bonam et al., 2020) and more effective during recession times than in expansion ones (Auerbach and Gorodnichenko, 2012). The excessive increase in inequalities due to the economic crisis can be a crucial factor that worsens the sustainability conditions of public debts (Maebayashi and Konishi, 2021).

This option is not a novelty for all those Countries having their own currency and CBs (IMF, 2022, De Grauwe and Ji, 2022 and Wray, 1997). A sovereign debt does not face legal consequences of default (Yue and Wei, 2019). At the moment, the EZ is a very different case, because the European Treaty rules (art. 123 TFEU) do not allow such a possibility. The application of the European Stability Mechanism (ESM) in the Greek crisis raised several criticism for effects on the whole socio-economic Hellenic structure and people standard living conditions. A discussion of the for a new role of the ESM is proposed by De Angelis (2022). Some, albeit shy, signs of acceptance of the proposal of the monetary financing of deficits for the EZ have nevertheless appeared in the literature (De Grauwe and Diessner, 2020). The atavic prejudice versus this option founds its roots in the well-known Quantity Theory of Money (QTM). The Nobel Prize Winner Milton Friedman is associated with such a theory also called “Monetarism” (1963a,b). In its dynamical form (expressed as percentage change over time), the QTM can be expressed as:

$$m + v = \pi + y, \quad (1)$$

wherein:

- m is the money growth;

- v is the change in the velocity of money (average number of times that money moves from one economic entity to another one over the course of a year);

- π is the inflation rate;

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-y is the output growth.

The more traditional and rigid QTM interpretation considers the existence of a unitary relationship between money growth and inflation ($m = \pi$), while v and y are negligible terms (Fisher and Brown, 1911). This assumption is at the root of inflationary fears, because the inflation expectations emphasize the focus of monetary policies on stabilizing interests rates to promote savings and investment (Abel and Lehmann, 2019). A modern interpretation of QTM argues that money growth impacts both output and inflation in the short-term but would be totally reflected on inflation in the long-term (Friedman, 1956). The relationship between the output fluctuations driven by shocks to supply and money growth has been discussed by Ireland (1996). Additionally, Lucas (1980) considered that also the frequency level must be included in this interaction. An overview of the great wealth of recent literature contributions investigating money growth and inflation empirical relationship within the time-domain is resumed within subsequent Table 1.

The well-known Friedman's (1963a) statement: "Inflation is always and everywhere a monetary phenomenon" (Davidson, 2015) represented the empirical beacon (and the nightmare) for generation of students in economics and central bankers (Cukierman, 2017).

Table 1-Main empirical literature on the money-growth inflation relationship

| Literature findings | Authors |
|---|--|
| <i>Unidirectional or bidirectional causal relationship between money growth and inflation</i> | Assenmacher-Wesche et al. (2008), Basco et al. (2009), Chang et al. (2009), Ellington and Milas (2019), Falck et al (2021), Guncor and Berk (2006), Hall et al. (2009),Haug and Dewald (2004), Hossain, (2005), Jiang et al. (2015), Liu (2002), Makin et al. (2017) and Sola and Peter (2013) |
| <i>Money growth has a positive impact on inflation in the short-term</i> | Assenmacher-Wesche and Gerlach (2008), Xie (2004), Roffia and Zaghini (2007), Zhang (2012) and Zhang et al. (2012) |
| <i>Money growth has a positive impact on inflation in the long-term</i> | Benati (2008), Mccandless and Weber (1995), Crowder (1998), Christensen, (2001), Doan Van (2020), Grauwe and Poland (2005) and Zhang (2008, 2012) |
| <i>Money growth and inflation related one-for-one in the long term</i> | Mccandless and Weber. (1995) and Grauwe and Poland (2005) |
| <i>No particular evidence of a money-growth inflation positive correlation</i> | Cukierman (2017), Focacci (2022), Gerlach and Svensson (2003), Liu and Chen (2012), Müller and Watson (2018) and Nicoletti Altimari (2001) |
| <i>Money growth and inflation linked by a negative relationship</i> | Shuai (2002) and Wu (2002) |

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3 .Methodology

The wavelet analysis (WA) is a powerful mathematical tool for signal processing in the time-frequency domain able to overcome main drawbacks of harmonic (also labeled as Fourier) analysis (HA or FA) (Kaiser, 2011). Wavelets are functions with zero mean localized in frequency and time. In simpler terms, they are small waves (or wave packets) representing the varying duration of the components of a time series (Walker, 2008). This allows to obtain an alternative representation in the timescale domain of an original time domain represented function. The HA is a filtering approach of decomposition of a time-series $y(t)$ into a sum of sinusoidal different frequency components (Bloomfield, 2000). Such a procedure discards the time-localized information allowing to investigate how relations vary across frequencies by using spectral techniques. However, this approach is not efficient, because the resolution is the same across the whole spectrum of frequencies (Anguiar-Conraria et al., 2008). Differently, the WA transform is localized both in time and in its functional components in the frequency domain because the estimation of spectral characteristics of a time series is conducted as a function of time (Rhif et al., 2019 and Li et al., 2015). Additionally, the WA has meaningful advantages over basic HA when the object of investigation is locally stationary and not homogeneous (Roueff and Von Sachs, 2011). Being the approximations generated by the WA procedure robust to small variations, WA is an efficient way to deal with variables lasting for a finite time, or showing markedly different behavior in their time-sequence (Crowley, 2007). This flexibility advises its adoption in many disciplines. Among the others, astronomy, climatology, engineering, medicine. While, the very first contributions in economics have been proposed by Goffe (1994) and Ramsey and Lampard (1998a,b).

3.1 Discrete and continuous wavelet transforms

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The wavelet transforms can be seen in their continuous version (*CWT*) and in their discrete one as well (*DWT*). Even if the main drawback in applying the *CWT* is computational time, the positive consequence lies in the possibility to select the most appropriate mother wavelet to draw conclusions from the data. Basically, the *DWT* is suitable for de-noising and decomposing processes. Instead, the *CWT* appears more useful for extracting information and detecting data self-similarity. For these reasons, in order to investigate a potential lead-lag effect between variables, we adopt the *CWT*. Different types of wavelet functions exist with proper characteristics: *Daubechies*, *Haar*, *Mexican Hat* and *Morlet* among the most widespread. As a mother wavelet, we use the *Morlet* one for a couple of reasons. Firstly, its transform coherent analysis is able to propose useful indicators to investigate the relationship between the variables (like for example the amplitude and the phase). Secondly, it has a good balance of time and frequency to identifying and separating time series with periodic variation (Sun and Xu, 2018). A simplified formal expression of the *Morlet* is the following:

$$\varphi(t) = \pi^{-1/4} e^{-i\omega_0 t} e^{-0.5t^2}, \quad (2)$$

wherein $\pi^{-1/4}$ ensures the unity energy of the mother wavelet, ω_0 is the parameter of the central frequency of the wavelet and the angular frequency (rotation rate in radians per time unit). The angular frequency ω_0 is set to 6, following the most common practice in economic applications (Rösch and Schmidbauer, 2018 and Rua and Nunes, 2009). This facilitates the interpretation of the relationship between the scale s and the Fourier frequency f , in fact the Fourier frequency is given by $f(s) = \frac{\omega_0}{2\pi s}$ and for the specific selection of $\omega_0 = 6$ the corresponding conversion from s to f is obtained as:

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$$f = \frac{6}{2\pi s} \approx 1/s . \quad (3)$$

This means that the wavelet scale approximates a reciprocal of the Fourier frequency. At this point, the $y(t)$ is decomposed into a joint frequency-time plane where the longer (shorter) wavelet scale corresponds to the lower (higher) frequency.

The *CWT* of a given series $y(t) \in L^2(\mathcal{R})$ has a relation with its mother wavelet $\varphi(t)$ through the inner product of $y(t)$ with the group $\varphi_{\tau,s}(t)$ of “daughters” as depicted by:

$$W_y(\tau,s) = \langle y(t), \varphi_{\tau,s}(t) \rangle = \int_{-\infty}^{+\infty} y(t) \varphi_{\tau,s}^*(t) dt, \quad (4)$$

wherein the asterisk $*$ represents the complex conjugation, τ the localized time and s the wavelet scale. The “daughter wavelet” functions $\varphi_{\tau,s}(t)$ are obtained from the mother function $\varphi(t)$ in the decomposition given that $\varphi_{\tau,s}(t) = |s|^{-0.5} \varphi\left(\frac{t-\tau}{s}\right)$, with $\tau, s \in \mathcal{R}$ varying continuously and $s \neq 0$. The variation of the scale s determines the compression (with $|s| < 1$) or the stretching (with $|s| > 1$) of the mother wavelet $\varphi(t)$ across the various frequencies. The shifting of the position of the mother wavelet $\varphi(t)$ in time domain is defined by τ values. This combination produces the picture both of the amplitude of any features of $\varphi(t)$ versus the scale and any variation in amplitude in time. There are indispensable requirements that a mother wavelet must satisfy. The first is that it must be a square-integrable function or in more formal terms: $\varphi(t) \in L^2(\mathcal{R})$. The second is the “admissibility condition” expressed as:

$$0 < C_\varphi = \int_0^{+\infty} \frac{|\varphi(f)|^2}{|f|} df < +\infty, \quad (5)$$

wherein, C_φ is the “admissibility constant” (a constant for each mother wavelet), $\varphi(f)$ is the Fourier transform of the mother $\varphi(t)$ and f its corresponding Fourier frequency. This “admissibility

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condition” provides the opportunity of recovering a time series $y(t)$ from the CWT , $W_y(\tau, s)$ following:

$$y(t) = \frac{1}{C_\varphi} \int_{-\infty}^{+\infty} \left[\int_{-\infty}^{+\infty} W_y(\tau, s) \varphi_{\tau, s} d\tau \right] \frac{ds}{s^2}, s \neq 0. \quad (6)$$

This allows to move from $y(t)$ to the CWT and viceversa given that they are the same mathematical entity expressed under two different representations.

The original energy of $y(t)$ can be denoted as $|y|^2$ and preserved by:

$$|y|^2 = \int_{-\infty}^{+\infty} |y(t)|^2 dt = \frac{1}{C_\varphi} \int_{-\infty}^{+\infty} \left[\int_{-\infty}^{+\infty} |W_y(\tau, s)|^2 d\tau \right] \frac{ds}{s^2}. \quad (7)$$

However, considering that our aim is to test the supposed connection between two time series (a potential lead-lag effect between money growth and inflation) and their dynamic relationship, we have to apply an appropriate econometric tool able to measure the size of the local correlation between a pair of series. This is the wavelet coherence.

3.2 Wavelet coherency

Considering two time series $y(t)$ and $x(t)$ -as introduced by Hudgins et al. (1993) and following Torrence and Compo (1998)- the corresponding Cross Wavelet Transform (XWT) or Cross Wavelet Power (XWP) is:

$$XWT = W_{x,y}(\tau, s) = W_x(\tau, s) W_y^*(\tau, s) \quad (8)$$

wherein $W_x(\tau, s)$ and $W_y(\tau, s)$ are the CWT of $x(t)$ and $y(t)$, the asterisk (*) denotes the complex conjugation, τ is a position index and s is the scale. To correct for biases, the original version is rectified by normalizing scales as proposed by Veleda et al. (2012):

$$XWT_s = W_{x,y}(\tau, s) = \frac{1}{s} \cdot W_x(\tau, s) W_y^*(\tau, s) \quad (9)$$

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From the *XWT* it is possible to compute the cross wavelet power able to reveal areas in the time-frequency space where the time series present a high common power (local covariance between the series at each scale). This wavelet coherency allows for a three-dimensional investigation including: time, frequency and the strength of correlation between the time series components. It will show the regions in which the variables have local correlation in time-scale space even if they may not have high power. This concept is particularly useful, because there is no need to sub-divide the data into different sub-samples during different regimes. Standard time series econometric methods analyze the time and the frequency components separately. The Torrence and Webster's approach (1999) is followed to calculate the wavelet coherency (*WC*) by using the cross-wavelet and auto-wavelet power spectrum:

$$WC = R_{xy}^2(\tau, s) = \frac{\left| S\left(s^{-1} W_{xy}(\tau, s)\right) \right|^2}{S\left(s^{-1} |W_x(\tau, s)|^2\right) \cdot S\left(s^{-1} |W_y(\tau, s)|^2\right)}, \quad (10)$$

wherein:

- $W_{x,y}(\tau, s)$ is the cross-wavelet power as defined in the (9) (it uncovers the region in time-scale space in which the data show high common power);
- S is the smoothing operator and is achieved by convolution in time and scale without smoothing coherency will be equal to 1 at all scales and time (Grinsted et al, 2004).

Calculating the smoothed *WC* by adopting the squared expression generates a value in the range between 0 and 1 within the time-frequency window. Values close to 0 mean weak correlation, while values close to one indicate strong correlation. Thus, the *WC* measures the local linear correlation between two stationary series at each scale similarly to a squared correlation coefficient in linear regression.

3.3 Phase

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The *WC* is more powerful than the *XWT* both because it is normalized by the power spectrum of the two time series and because it provides lower peaks avoiding the problems of spurious regressions (Anguier-Conraria and Soares, 2011). Since the *WC* squares all terms, it is not able to distinguish between positive and negative co-movements. This advises us to use phase difference to provide further information about co-movements and lead-lag dynamic relationship. Both the *Morlet* and the *CWT* are complex representations having real and imaginary parts and, through the *WC* phase differences, we can investigate the lead-lag relationship between the data. The phase difference characterizes phase relationship between $x(t)$ and $y(t)$. Following Torrence and Webster (1999), it is defined as:

$$\phi_{xy} = \tan^{-1} \left(\frac{\mathcal{I}\{S(s^{-1}W_{xy}(\tau, s))\}}{\mathcal{R}\{S(s^{-1}W_{xy}(\tau, s))\}} \right) \text{ with } \phi_{xy} \in [-\pi, \pi], \quad (11)$$

wherein \Re and \mathcal{I} are the real and imaginary parts, respectively, of the smooth power spectrum. To interpret outcomes, it must be pointed out that if $\phi_{xy} = 0$ the two underlying series move together while if ϕ_{xy} is $\pi(-\pi)$ they move in the opposite direction. In the diagram representing the *WC*. Within *WC* plots the information regarding the in-phase (anti-phase) are depicted by arrows. Specifically, the arrows pointing to the right (left) represent an in-phase (anti-phase) condition. This means that they are positively (negatively) correlated. When arrows point up, the first series leads the second one by π , the very opposite when arrows point down. Summing up, four cases are possible (Rösch and Schmidbauer, 2018):

- if $\phi_{xy} \in [0, \pi/2]$ the series positively co-move and are in-phase with $x(t)$ leading $y(t)$,
- if $\phi_{xy} \in [\pi/2, \pi]$ the series negatively co-move and are out of phase with $x(t)$ lagging $y(t)$,
- if $\phi_{xy} \in [-\pi, -\pi/2]$ the series are out of phase with $x(t)$ leading $y(t)$,
- if $\phi_{xy} \in [-\pi/2, 0]$ the series are in phase with $x(t)$ lagging $y(t)$.

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To our research aim, it is the phase difference that represents causality between variables. In empirical analysis a mixture of positions can be detected. An arrow pointing up and right contemporarily indicates that the time series are in phase, with the first variable leading the second one.

4. Data description

For what concerns the dataset, we gathered money growth and inflation data for the following Countries: Italy, Japan, United Kingdom and United States. The cases of Italy and Japan are very meaningful. Italy has a total public debt as a percentage of GDP that in the broad perception of commentators is a potential concern for the whole EZ. On the contrary, Japan (even with an even higher GDP-public debt ratio) has been pursuing an accommodative monetary policy for decades. The United Kingdom and the USA are among the most advanced financial Countries.

As additional examples, we analyze also Argentina and Bolivia that have experienced hyperinflation periods. Considering that overall, there are difficulties in gathering sufficiently long historical series (for example for other important EU Countries), our selection is also driven by the availability of suitable datasets to process. To the present research aim, thus, different sources are adopted given that a unique international database collecting the required homogeneous values is not available.

To be coherent in the need of investigate a long-run relationship between the money supply and the inflation, we use yearly frequencies data. The adoption of higher frequency observations, like for example in the case of monthly and/or quarterly figures, increases the likelihood of finding (spurious) causal relationship (Schwarz and Szakmary, 1994). Additionally, infra-annual frequency is meaningful (only) in terms of increased volatility (Mutascu, 2018), but volatility is neither our

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focus nor is relevant to our purpose. Our choice looks like a reasonable trade-off between more extreme positions. In detail, our dataset includes:

- Italy with M1 and M2 growth (respectively labeled as ITA_M1 and ITA_M2) (Barbiellini Amidei et al, 2016) and Consumer Price Index (labeled as ITA_INFL) (IMF, 2020a and it.inflation.eu, 2020) from 1956 to 2014;

- Japan with M1 and M2 growth labeled as JPN_M1 (OECD, 2020) and JPN_M2 (World Bank, 2020a) coupled with Consumer Price Index (labeled as JPN_INFL) (World Bank, 2020a and it.inflation.eu, 2020) from 1960 to 2019 (M1 vs Inflation) and from 1961 to 2016 (M2 vs Inflation§);

- United Kingdom with M1 and M4 growth labeled as UK_M1 (Bank of England, 2020a) and UK_M4 (Bank of England, 2020b) the Consumer Price Inflation labeled as UK_INFL (Bank of England, 2020c) from 1923 to 2016 (M1 vs Inflation) and from 1881 to 2016 (M4 vs Inflation§);

- USA with M1 and M2 growth labeled as USA_M1 (IMF, 2020b) and USA_M2 (Board of Governors, 2020) combined with Consumer Price Index (labeled as USA_INFL) (World Bank, 2020b) from 1961 to 2017 (M1 vs Inflation) and from 1961 to 2019 (M2 vs Inflation§);

- Argentina with M2 growth labeled as ARG_M2 (World Bank, 2020a) paired with Inflation Consumer Prices labeled as ARG_INFL from 1970 to 2013 (World Bank, 2020c);

- Bolivia with M2 growth labeled as BOL_M2 (World Bank, 2020a) coupled with Inflation Consumer Prices for the Plurinational State of Bolivia labeled as BOL_INFL from 1970-2019 (World Bank, 2020d).

Even if the stationarity is not a prerequisite in WA (Anguier-Conraria et al., 2008), “the assumption of stationary statistics provides a standard by which any non-stationarity can be detected” (Torrence and Compo, 1998).

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In Table 2, we report four among the most widespread and well-known unit root tests (Augmented Dickey-Fuller: ADF, Augmented Dickey-Fuller Generalized Least Squares Regression: ADF-GLS, Kwiatkowski-Phillips-Schmidt-Shin: KPSS and Phillips-Perron: PP) to investigate the stationarity properties of the time series. Except that in the cases of UK_M4, UK_INFL\$, ARG_M2, ARG_INFL, BOL_M2 and BOL_INFL all remaining series are not stationary at levels.

Table 2-Unit root test for the data (to be continued)

| Series | ITA_M1 | ITA_M2 | ITA_INFL | JPN_M1 | JPN_INFL | JPN_M2 | JPN_INFL\$ |
|------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| Time interval | 1956-2014 | 1956-2014 | 1956-2014 | 1960-2019 | 1960-2019 | 1961-2016 | 1961-2016 |
| ADF with const | -3.49 | -2.19 | -1.49 | -3.02 | -2.71 | -3.71 | -2.73 |
| p-value ($\alpha = 0.05$) | 0.01* | 0.21 | 0.53 | 0.04* | 0.08 | 0.00* | 0.08 |
| ADF with const and trend | -4.66 | -5.11 | -1.73 | -3.85 | -3.88 | -4.89 | -3.58 |
| p-value ($\alpha = 0.05$) | 0.00* | 0.01* | 0.72 | 0.02* | 0.03* | 0.00* | 0.04 |
| ADF_GLS τ | -1.33 | -2.34 | -1.62 | -2.23 | -2.43 | -5.12* | -3.63* |
| Critical value ($\alpha = 0.05$) | -3.03 | -3.03 | -3.03 | -3.03 | -3.03 | -3.03 | -3.03 |
| KPSS test | 0.85 | 0.87 | 0.37* | 0.89 | 0.98 | 1.16 | 0.96 |
| Critical value ($\alpha = 0.05$) | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| PP Test Z τ | -3.40 | -3.74 | -1.65 | -2.83 | -2.53 | -3.94 | -2.62 |
| p-value ($\alpha = 0.05$) | 0.01* | 0.01* | 0.45 | 0.06 | 0.11 | 0.00* | 0.10 |

Notes: This Tables summarizes the formal unit-root tests: Augmented Dickey-Fuller (ADF), Augmented Dickey-Fuller Generalized Least Squares Regression (ADF-GLS) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. For each test the corresponding statistic and p-value are proposed. * Indicates stationarity at 5% level ($\alpha = 0.05$). Source: Personal elaboration on dataset as cited within the Section Data description

Table 2-Unit root test for the data (to be continued)

| Series | UK_M1 | UK_INFL | UK_M4 | UK_INFL\$ | USA_M1 | USA_INFL | USA_M2 |
|------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Time interval | 1923-2016 | 1923-2016 | 1881-2016 | 1881-2016 | 1961-2017 | 1961-2017 | 1961-2019 |
| ADF with const | -4.76 | -3.53 | -4.21 | -4.15 | -4.44 | -2.01 | -4.29 |
| p-value ($\alpha = 0.05$) | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.28 | 0.00* |
| ADF with const and trend | -4.92 | -3.42 | -4.56 | -4.19 | -4.44 | -3.56 | -4.67 |
| p-value ($\alpha = 0.05$) | 0.00* | 0.06 | 0.00* | 0.01* | 0.00* | 0.03* | 0.00* |
| ADF_GLS τ | -3.07* | -1.54 | -4.56* | -4.15* | -1.48 | -1.46 | -1.94 |
| Critical value ($\alpha = 0.05$) | -3.03 | -3.03 | -2.93 | -2.93 | -3.19 | -3.03 | -3.03 |
| KPSS test | 0.48 | 0.36 | 0.79 | 0.39* | 0.14* | 0.47 | 0.49 |
| Critical value ($\alpha = 0.05$) | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| PP Test Z τ | -4.66 | -3.43 | -4.20 | -4.25 | -4.44 | -2.38 | -4.18 |
| p-value ($\alpha = 0.05$) | 0.00* | 0.01* | 0.00* | 0.00* | 0.00* | 0.15 | 0.00* |

Notes: This Tables summarizes the formal unit-root tests: Augmented Dickey-Fuller (ADF), Augmented Dickey-Fuller Generalized Least Squares Regression (ADF-GLS) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. For each test the corresponding statistic and p-value are proposed. * Indicates stationarity at 5% level ($\alpha = 0.05$).

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Table 2-Unit root test for the data

| Series | USA_INFL§ | ARG_M2 | ARG_INFL | BOL_M2 | BOL_INFL |
|------------------------------------|-----------|-----------|-----------|-----------|-----------|
| Time interval | 1961-2019 | 1970-2013 | 1970-2013 | 1970-2019 | 1970-2019 |
| ADF with const | -2.04 | -3.58 | -4.38 | -5.62 | -6.15 |
| p-value ($\alpha = 0.05$) | 0.27 | 0.01* | 0.00* | 0.00* | 0.00* |
| ADF with const and trend | -3.63 | -3.68 | -4.48 | -5.66 | -6.18 |
| p-value ($\alpha = 0.05$) | 0.03* | 0.03* | 0.00* | 0.00* | 0.00* |
| ADF_GLS τ | -1.48 | -3.67* | -3.62* | -5.73* | -6.26* |
| Critical value ($\alpha = 0.05$) | -3.03 | -3.19 | -3.19 | -3.19 | -3.19 |
| KPSS test | 0.49 | 0.23* | 0.19* | -0.15 | 0.14* |
| Critical value ($\alpha = 0.05$) | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| PP Test Z τ | -2.39 | -3.48 | -3.45 | -5.61 | -6.15 |
| p-value ($\alpha = 0.05$) | 0.15 | 0.01* | 0.01* | 0.00* | 0.00* |

Notes: This Tables summarizes the formal unit-root tests: Augmented Dickey-Fuller (ADF), Augmented Dickey-Fuller Generalized Least Squares Regression (ADF-GLS) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. For each test the corresponding statistic and p-value are proposed. * Indicates stationarity at 5% level ($\alpha = 0.05$).

Source: Personal elaboration on dataset as cited within the Section Data Description

Thus, we proceed with first differencing to detrend series having unit roots. Results are summarized in subsequent Table 3.

Table 3-Unit root test for the detrended series (*to be continued*)

| Series | ITA_M1 | ITA_M2 | ITA_INFL | JPN_M1 | JPN_INFL | JPN_M2 | JPN_INFL§ |
|------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Time interval | 1956-2014 | 1956-2014 | 1956-2014 | 1960-2019 | 1960-2019 | 1961-2016 | 1961-2016 |
| Unit root test | | | | | | | |
| ADF with const | -10.63 | -8.56 | -7.00 | -7.91 | -7.52 | -13.63 | -7.22 |
| p-value ($\alpha = 0.05$) | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* |
| ADF with const and trend | -10.57 | -8.51 | -7.07 | -7.86 | -7.44 | -13.65 | -7.15 |
| p-value ($\alpha = 0.05$) | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* |
| ADF_GLS τ | -10.42* | -12.60* | -3.47* | -9.35* | -7.14* | -2.58 | -7.38* |
| Critical value ($\alpha = 0.05$) | -3.03 | -3.03 | -3.03 | -3.03 | -3.03 | -3.03 | -3.03 |
| KPSS test | 0.07* | 0.06* | 0.13 | 0.06* | 0.06* | 0.04* | 0.05* |
| Critical value ($\alpha = 0.05$) | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| PP Test Z τ | -11.65 | -14.56 | -7.00 | -11.04 | -9.68 | -14.79 | -8.74 |
| p-value ($\alpha = 0.05$) | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* |

Notes: This Tables summarizes the formal unit-root tests: Augmented Dickey-Fuller (ADF), Augmented Dickey-Fuller Generalized Least Squares Regression (ADF-GLS) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. For each test the corresponding statistic and p-value are proposed. * Indicates stationarity at 5% level ($\alpha = 0.05$).

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Table 3-Unit root test for the detrended series (to be continued)

| Series | UK_M1 | UK_INFL | USA_M1 | USA_INFL | USA_M2 | USA_INFL§ |
|------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| Time period | 1923-2016 | 1923-2016 | 1961-2017 | 1961-2017 | 1961-2019 | 1961-2019 |
| Unit root test | | | | | | |
| ADF with const | -14.22 | -9.01 | -9.46 | -7.09 | -9.96 | -7.24 |
| p-value ($\alpha = 0.05$) | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* |
| ADF with const and trend | -14.16 | -9.02 | -9.40 | -7.13 | -9.86 | -7.27 |
| p-value ($\alpha = 0.05$) | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* |
| ADF_GLS τ | -12.63* | -7.73* | -9.37* | -6.26* | -8.89* | -6.41* |
| Critical value ($\alpha = 0.05$) | -3.03 | -3.03 | -3.03 | -3.03 | -3.03 | -3.03 |
| KPSS test | 0.07* | 0.13* | 0.04* | 0.11* | 0.05* | 0.11* |
| Critical value ($\alpha = 0.05$) | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
| PP Test Z τ | -15.21 | -10.07 | -10.18 | -6.09 | -10.88 | -6.22 |
| p-value ($\alpha = 0.05$) | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* | 0.00* |

Notes: This Tables summarizes the formal unit-root tests: Augmented Dickey-Fuller (ADF), Augmented Dickey-Fuller Generalized Least Squares Regression (ADF-GLS) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. For each test the corresponding statistic and p-value are proposed. * Indicates stationarity at 5% level ($\alpha = 0.05$).

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Considering that all detrended series now are stationary, so they are integrated of order I(1). Overall findings do not suggest that all series share a stationary long-run relationship (cointegration). At this point, it is not useful to propose a cointegration procedure only for I(1) series, because applying different methodologies would appear as not homogeneous (and to skepticals as an artifact).

5. Empirical results

In this section, we plot of the *Morlet* wavelet transform coherency WC and ϕ_x (phase differences) between money-growth and inflation to examine and measure the co-movement and the lead-lag effect between the variables for the different Countries. A Monte Carlo simulation with $n = 100$ and phase randomized series are used to estimate the 99% confidence intervals (1% significance) depicted by a white solid contour in Figures. Let us mention that, in WC graphs the region below the brilliant area represent the cone of influence (COI). It moves into shade and excludes areas of

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edge effects. The area outside the COI (lighter shade) shows no statistical influence. The horizontal axis shows time (years) and the left vertical axis represents the wavelet transform period (years). On the left vertical axis the color code for power ranges from blue (low power) to red (high power). The WC finds the regions in time-frequency space where the series co-vary. Regions inside the brilliant area plotted in warmer colors represent regions with statistical significant dependence. The warmer the color, the higher the degree of dependence between the couple. Cold colors depict areas where limited or no dependence exists.

To keep this Section of the paper short, we propose the plots representing the money-growth as independent variable and inflation as the dependent one (as reported in the specific head title) in Figures 1 and 2. Without saying that, on request, also the diagrams resulting from the reverse relationship are available to interested readers (the outcomes are confirmed). Testing the variables in both direction is a common procedure followed in classical Granger-causality analysis too. The only exceptions presented are for Argentina and Bolivia. In these two cases, we propose also the INFL vs M2 graphs. In this circumstance, changing the order of the variables we can note the existence of the same lead-lag mechanism. This fact does not allow conclusions to be drawn on the dynamic nature of the behavior of the variables (Fig. 3). On this aspect, while the direction of the money-inflation mechanism can be directly derived from Friedman's theory (too much money is chasing too few goods), an interpretation of the reverse direction (inflation leads money) is less intuitive. The latter occurrence is plausible when tax revenues sharply decline and the drop is accompanied by negative supply shocks as occurs, for example, in times of war or following exogenous events (such as oil shocks in the 1970s). In these cases, Governments' possibilities to finance public spending are limited and increasing costs force new money issuances coherently with the hypothesis of the endogenous nature of money.

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Additionally, we gather findings in two dedicated Tables (4 and 5) wherein both details about periodicities of significant lead-lag relationships and time dates are explicated. Let us mention that arrows directions must be interpreted as explained in the sub-section 3.3.

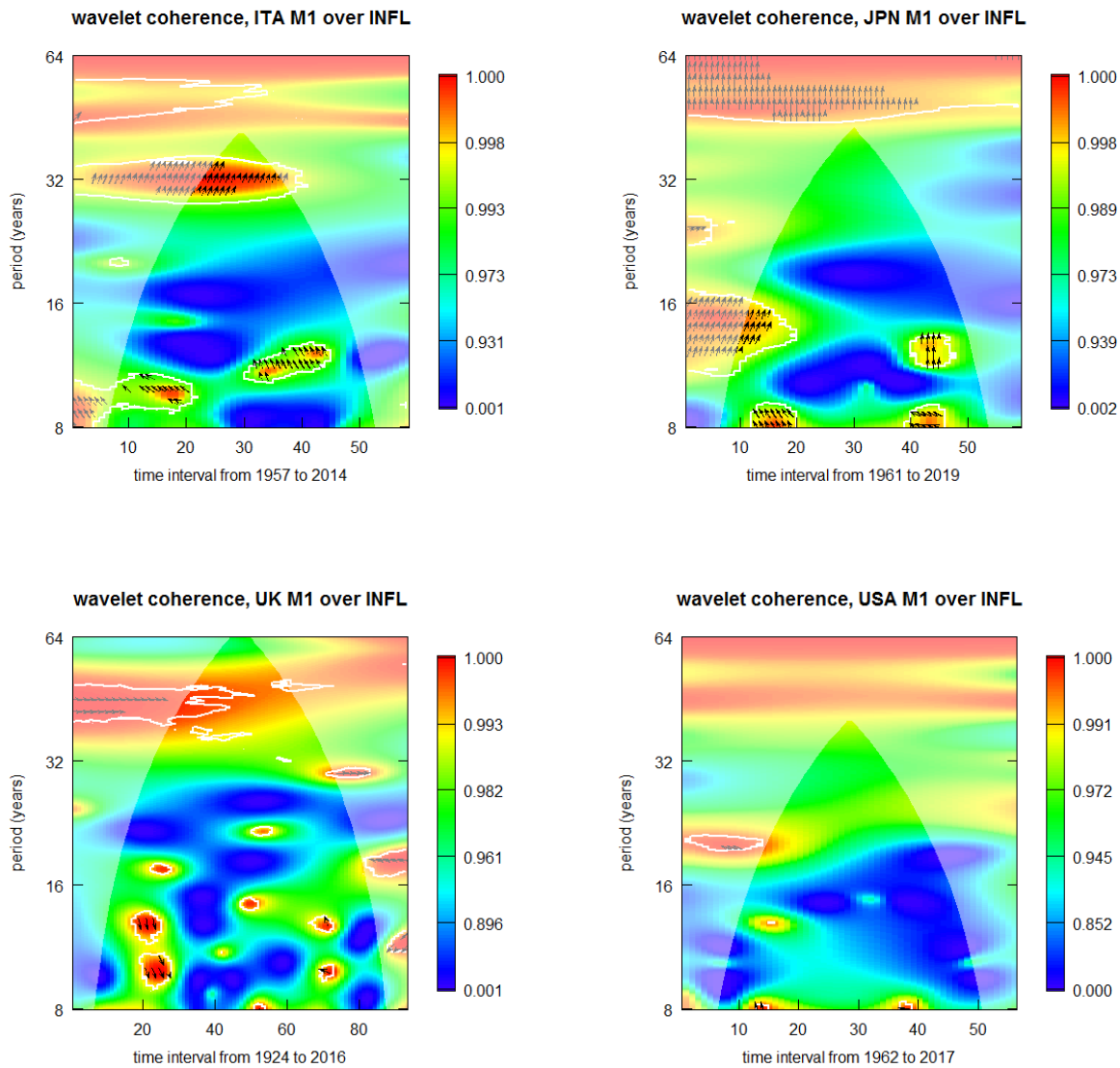
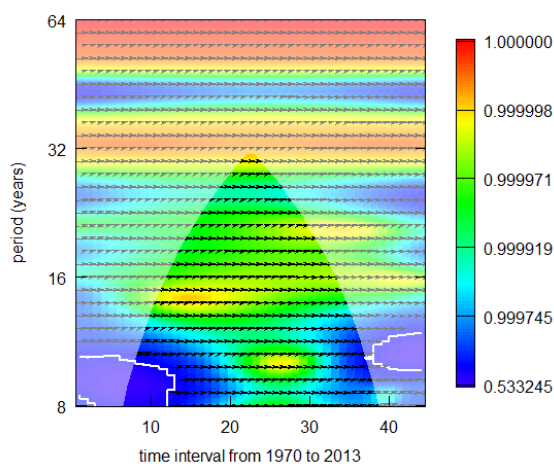


Fig. 1 Cross-wavelet coherency (or squared wavelet coherence) plots between M1 and Inflation for Italy, Japan, UK and the USA

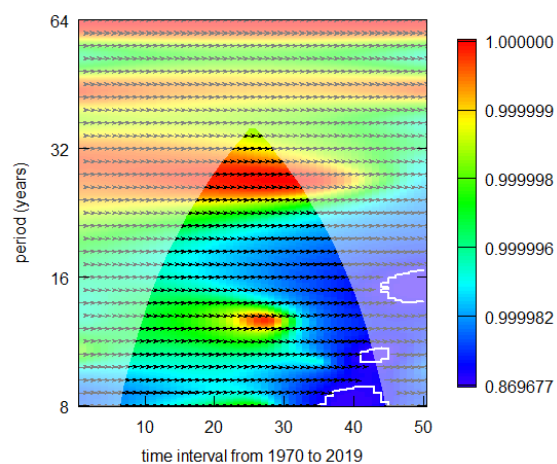
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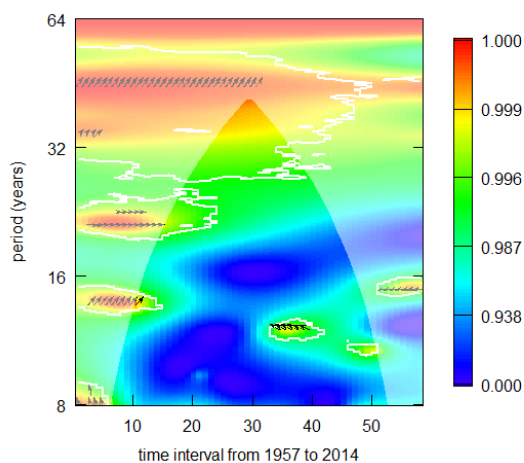
wavelet coherence, ARG M2 over INFL



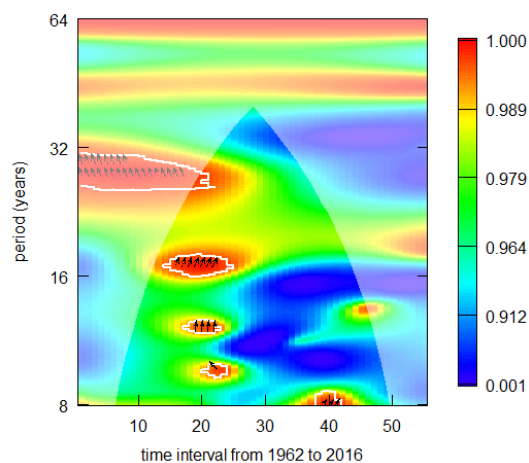
wavelet coherence, BOL M2 over INFL



wavelet coherence, ITA M2 over INFL



wavelet coherence, JPN M2 over INFL



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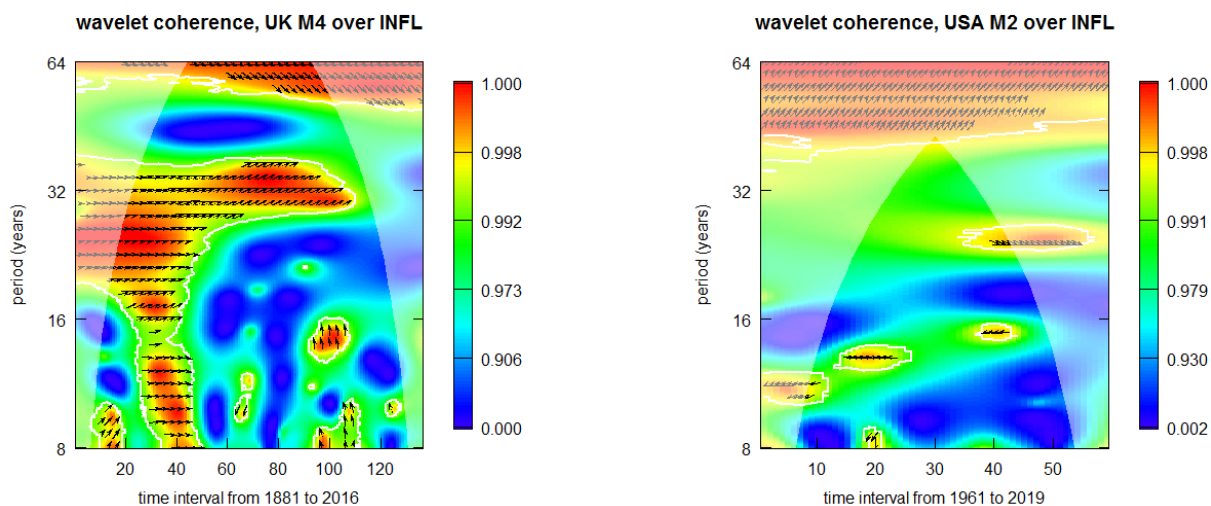


Fig. 2 Cross-wavelet coherency (or squared wavelet coherence) plots between M2 and Inflation for Argentina, Bolivia, Italy, Japan, UK (M4 in this case) and the USA.

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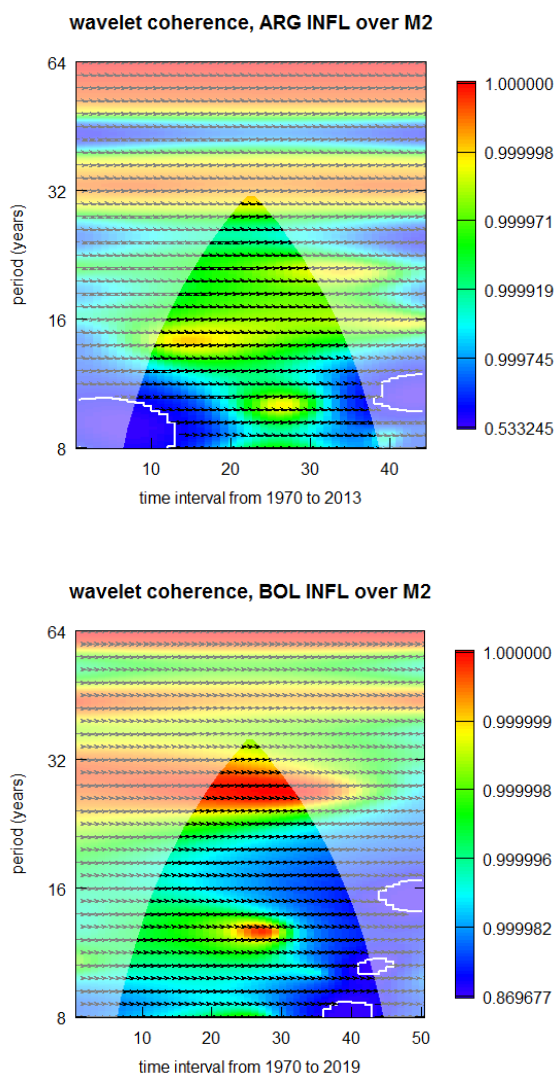


Fig. 3 Cross-wavelet coherency (or squared wavelet coherence) plots between Inflation and M2 for Argentina and Bolivia.

Table 4- Summary of cross-wavelet coherencies and phase-differences for M1 vs INFL

| Variables | Period (years) | M vs INFL relationship | Date |
|----------------|----------------|------------------------|--------------------------|
| ITA_M1 vs INFL | 32 | M1 leads INFL | 1977-1997 |
| | 12 | M1 lags INFL | 1977-1992 |
| | 10 | M1 lags INFL | 1972-1977 |
| JPN_M1 vs INFL | 12-16 | M1 leads INFL | About 1975 and 2005 |
| | 8-10 | M1 lags INFL | 1972-1980 and 2001-2005 |
| UK_M1 vs INFL | 10-14 | M1 lags INFL | About 1944-1950 and 1996 |
| USA_M1 vs INFL | - | No evidence | - |

Source: Personal elaboration on data

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Taking a closer look at the results reported in Table 4 regarding the monetary aggregate M1, we note that there is no evidence of a clear direction in the relationship between the variables in all the analyzed cases. More in detail, the findings point out that for the USA_M1 no inflationary effect due to money growth is detected. Interestingly, overall for a mid-long period of about 10-14 years inflation is not led by money growth. Only for Japan -and with a little longer frequency of about 12-16 years- the phase difference highlights a reverse direction in the causal mechanism between variables is evidenced. Also the results for Italy are not decisive. The period of 32 years confirms that money growth has a positive impact on a long-term as already observed for other Countries by a strand of the empirical literature, while the very opposite holds for a shorter period about 10-12 years long.

Table 5- Summary of cross-wavelet coherencies and phase-differencies for M2 (M4) vs INFL

| Variables | Period (years) | M vs INFL relationship | Date |
|----------------|-------------------|------------------------|-----------------|
| ARG_M2 vs INFL | - | Bidirectional | - |
| BOL_M2 vs INFL | - | Bidirectional | - |
| ITA_M2 vs INFL | 12 | M2 lags INFL | About 1988-1997 |
| JPN_M2 vs INFL | About 18 | M2 leads INFL | About 1975-1982 |
| | About 13 | M2 leads INFL | About 1978-1982 |
| | About 9 | M2 lags INFL | About 1982 |
| | About 8 | M2 lags INFL | About 2002 |
| UK_M4 vs INFL | About 60 | M4 lags INFL | About 1921-1981 |
| | About 16-36 | M4 leads INFL | About 1901-1981 |
| | About 8-16 | M4 leads INFL | About 1896-1943 |
| | About 14 | M4 lags INFL | About 1971-1986 |
| | About 8-10 | M4 leads INFL | About 1891-1901 |
| | | M4 lags INFL | About 1978-1991 |
| | About 10 | M4 leads INFL | About 1941-1946 |
| USA_M2 vs INFL | About 25 | M2 lags INFL | About 2001 |
| | About 15 | M2 leads INFL | About 2001 |
| | About 14 | M2 leads INFL | About 1976-1988 |
| | About 11 | M2 leads INFL | About 1971 |
| | About 9 | M2 leads INFL | About 1978-1981 |

Source: Personal elaboration on data

For what concerns the findings resumed within Table 5 for the aggregates M2 and M4, firstly we have to point out for the Arg_M2 and BOL_M2 cases, that money growth leads inflation, but -at the

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same time- the inverse relationship holds. In fact, as shown in diagrams depicted in Fig 2 and 3, the phase differences detect a bidirectional relationship between variables. Thus, for these Countries, several times evoked as archetypes of the monetary origin of the inflation explosion, a clear outcome cannot be drawn. For ITA_M2 the money growth lags inflation at the period of 12 years. The situation for Japan_M2 confirms the positive impact on inflation of money-growth for the 13-18 years period, while the opposite holds at the shorter frequencies. The case of UK is certainly very interesting. First of all, because we have the longest dataset to process among those available and here analyzed. The results seem to foster the hypothesis that in the long-run money and inflation have a negative relationship. In fact, the 60 year period calculations consider that money-growth lags inflation and not viceversa. Such an outcome is totally opposed to the common and widespread belief of a monetary nature of the inflation phenomenon especially in the long-term. The same negative correlation is present also at the 14 years period. All the other cases evidence a positive causal relationship of the inflation subsequent to a money-growth. A quite similar result can be observed from the case of the USA. In fact, only in the longer period (25 years) the phase difference explains that a causal dependence of inflation from money-growth is lacking. All the remaining cases are coherent with the TQM.

Overall our results seem not support the strictly hypothesis of a monetary origin of the inflation phenomenon as the orthodox monetary theory affirms.

5. Conclusions

The economic crisis deriving from Covid 19 pandemic will severely affect living standard and economic conditions for people all over the World. Thus, the need and the urgency to adopt suitable actions to alleviate the negative consequences of the resulting shocks becomes a priority. Traditional fiscal policies and conventional monetary instruments show all their shortcomings

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(Mehlum and Torvik, 2021). Too many Countries have no “fiscal space” to intervene with dedicated measures without raising their own debt/GDP ratio. The monetization of fiscal deficit to finance Government measures able to stimulate the economic recovery policies appear among the real and effective solutions until full employment is not reached. At the specific national level, the Governments can accelerate the world recovery and growth through the public investments (infrastructures, education and research and development) and through credit crunch counteracting measures (Salvatore, 2021). These are areas of action in which monetization can be strategic and decisive. The surge of potential inflationary pressure ignited by excessive aggregate demand could be offset by tightening fiscal and monetary policies (Stiglitz, 2021). The Countries issuing their sovereign currency and having a proper CB have an indisputable advantage to put into practice their negative shock counteracting policies (Wray, 2015). Such an alternative seems the only effective action to implement without having to unjustly further affect the condition of the populations. The main obstacles to this possibility find their roots in the idea of the monetary pure nature of the inflationary phenomenon. The problem is exacerbated for currency unions that show a lot of problems in tackling with external shocks (Krugman, 2013). Without any pretension to be exhaustive, the current WA causal analysis does not confirm that money can (always) generate inflation in a direct transmission mechanism also within a long time span. The whole interaction among all the factors considered by the TQM are involved in the excessive growing price paths. The influence of change over time of the real output (through employment level) cannot be neglected for example. In the Covid-19 pandemic, generalized and prolonged lockdowns can heavily affect on the supply-side and inflation dynamic.

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The author declares that he has no known conflict of interest or personal relationships that could have appeared to influence the work reported in this paper

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