Money growth, money velocity and inflation in the US, 1948-2021

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Abstract

Leading central banks did not anticipate the surge in inflation in 2021 and 2022. In our paper we assess whether changes in the velocity of money and monetary growth (broadly defined) explain long term inflation patterns in the US. We use a hundred-year sample to study the long term and the cyclical behaviour of money velocity. We find that *changes* in the velocity of money are short lived and revert to its mean. We also characterise the periods where changes in money velocity have kept closer to its mean as those of monetary equilibrium. We use a regime switching model to test for the impact of changes in the amount of money (broadly defined) and in money velocity in inflation over the medium and long term. Our model explains both the non-inflationary outcome of the Global Financial Crisis and the surge in inflation in the aftermath of the Covid-19 pandemic.

Keywords: money velocity, monetary equilibrium, money and inflation, quantity equation of money, regime switching model

JEL classification: E31, E41, E50, E52, E58

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1. Introduction: central banks and money during and in the aftermath of Covid 19 pandemic

The extraordinary response of leading central banks to the Covid-19 crisis with a full range of so-called unconventional monetary policies (see Haas et al. 2020) in 2020 led to a surge in both central bank balance sheets (thus, in the monetary base) and in a broader definition of money - namely one that includes most of the liabilities of the banking sector (i.e. bank deposits). This is in sharp contrast with the period of the Global Financial Crisis, when the monetary base soared but the amount of money broadly defined decelerated and even fell. In 2020 in the US, the rate of growth in the amount of money broadly defined (as measured by M3) reached the highest rate since the end of the Second World War, with the annual rate of growth hitting 25% in the spring of 2020. Monetary expansion continued at abnormally high rates in 2021 particularly in the US, and to a lesser extent in the UK and the Eurozone, although not reaching the same extraordinary levels as in 2020. In the US, the compound annual rate of growth of the broad monetary aggregate M3 in the three years before the end of 2021 (13.2%) was more than three times higher than it was in the three years before the end of 2018 (4%).

As stated by leading central bankers, and in particular by top US Fed officials (see Powell, 2021 a, b), central banks do not consider money growth when assessing the likely level of inflation. This has been confirmed by the US Fed's 2020 strategy review, which brought in 'average inflation targeting' strategy and disregarded any consideration of the likely effects of changes in the amount of money on the main macroeconomic outcomes. This revision to the US Fed's policy strategy provides further evidence that monetary aggregates have not been perceived as relevant to the policy decisions made by the US Fed for a long time. Similarly, in its 2021 strategy review, the ECB states that it can identify '(…) a weakening of the empirical link between monetary aggregates and inflation' (ECB 2022). Given these developments, it is not surprising that central bank statements back in 2020 did not mention nor discuss the potential effects of excessive money growth on inflation, nor foresee long term inflationary pressures. Indeed, they predicted disinflation (see Clarida, 2020, Schnabel, 2020).

The focus on money as a principal determinant of inflation has diminished in the last four decades in most central banks. With the exception of the European Central Bank (ECB) at least up to 2021, no other leading central bank assigned an explicit role to money in both the making of policy decisions and the communication of such decisions to the public. In explaining inflation over the medium term, the ECB formerly referred to the relevance of monetary and credit aggregates (i.e. the so-called 'monetary pillar') in its publications, but now it too has changed its stance. To support this approach to policy making, two main reasons are often given. Firstly, the instability of the velocity of money, which would make changes in the amount of money an unreliable metric for anticipating changes in prices. Secondly, the lack of inflation during the Global Financial Crisis years, when despite the implementation of a large range of unconventional monetary policies – including asset purchases – inflation persistently remained on average below the central bank targets. If anything, central banks have claimed that inflation has been too low since 2008. This is one of the reasons given by the US Federal Reserve in August 2020 for adopting an 'average inflation targeting' strategy (Federal Reserve Board of Governors, 2020), as this would be able to accommodate inflation rate higher than 2% for a period of time.

The surge in the amount of money broadly defined has been a distintive issue of the reaction to the Covid-19 pandemic in leading economies in 2020-21. As detailed in the next section, this phenomenon has sparked renewed interest in the study of the relation between changes in the amount of money broaly defined and inflation, and thus in the potential consideration of the implications and prescriptions of the Quantity Theory of Money.

In light of the failure of leading central banks to anticipate the inflation episode in 2021 and 2022, this paper assesses whether changes in the velocity of money and monetary growth, as measured by a broad measure of money, can explain inflation patterns in the US from 1948. Our results (see section 4 below) are in line with recent research on the role played by changes in the amount of money on CPI inflation, and have policy implications as regards the variables used by leading central banks to assess inflation.

2. The Quantity Theory of Money revisited: on money growth, inflation and money velocity

There is a vast literature on the stability or instability of the velocity of money and whether monetary aggregates play any role in explaining inflation. Teles and Uhlig (2013) show that the relation between changes in money and inflation is only a feature of economies with high inflation. Among other studies, De Grauwe and Polan (2005) and Papadia and Cadamuro (2021) reach the same conclusion, the latter using a sample of US and Eurozone data up to June 2021. Similarly, Benati (2009) also identifies a closer correlation between money growth and inflation in the event of high inflation episodes, and a weaker correlation when money velocity shocks occur. This is in sharp contrast to the seminal results presented by Lucas (1980, 1996), where a strong relation between changes in money growth and in CPI prices holds in the long term for a variety of economies, with different rates of inflation. Likewise, Nelson (2008) argues that central banks are able to determine money growth in the long term and affect inflation.

Milas (2009), using a regime-switching model as we also do in our paper, shows that the relationship between inflation and M4 growth in the UK is not stable over time: M4 exerts inflationary pressures conditional on the annual M4 rate of growth exceeding a certain threshold. Milas (2009) concludes that, below this threshold broad monetary growth (as measured by M4) hardly affects inflation. Even though we use the same model and also a broad monetary growth measure, when applied to the US we find in our paper that the rate of growth of the M3 aggregate affects inflation whatever its rate, although not with the same intensity throughout the analysed period.

Teles and Uhlig (2013) use cross sectional OECD data to show that, once corrected for changes in output and in the opportunity cost of holding money, there is a clear relation between changes in the amount of money (measured either as M1, M2 or M3) and average inflation. In the same vein, De Santis (2012), using a broad money aggregate, shows that the Quantity Theory of Money is valid in the long term for both the Eurozone and the US. His conclusions only apply, however, once the volatility in money velocity has been corrected to allow for changes in domestic and particularly cross border portfolio adjustments. Dery and Serletis (2023) also provide empirical evidence to support that the US business cycle can be mainly driven via monetary policy shocks, as measured by changes in a broad monetary indicator. Hall, Swamy and Tavlas (2012) conclude that even sharp changes in M3 money velocity in the Eurozone, such as those experienced during the uncertainty of the Global Financial Crisis, are mean reverting. This result is very relevant for policy-making purposes, as it means that the Quantity Theory can still be used to explain changes in inflation though over the medium and long term, including periods when the velocity of money has returned to its mean. Anderson et al. (2017), comparing the Great Depression and the Great Recession, suggest an enhanced role of a broad, liquid money aggregate (M2) as a policy guide during crises and their unwinding. In the same vein, Gao et al. (2020) demonstrate the validity of the standard Quantity Theory models in OECD economies when explaining the relation between money and inflation over the long term. Hanke et al. (2022) also find very high correlation between changes in broad money growth and CPI using a sample of 147 countries covering a period of up to 30 years. Benati et al. (2019) show the stability of the demand for M1 in 38 economies; and Benati (2020) also finds a stable relation between (M1) money velocity and short-term interest rates in the UK after the Second World War.

In the aftermath of Covid19 pandemic, several authors have emphasised the neglect by major policy makers of changes in the amount of money as a signal of inflation (see King, 2021, Congdon 2021, Greenwood and Hanke, 2022). In this line, Borio et al. (2023) very recently show that those countries with a higher rate of growth of (broad) money during the Covid19 pandemic suffered from higher rates of consumer price inflation later on, suggesting that 'looking at money growth would have helped to improve post-pandemic inflation forecasts'.

In our paper, we use the Quantity Theory of Money (Friedman, 1956) as the framework for assessing whether changes in the amount of money broadly defined explain inflation in the US in the medium to the long term. However, rather than focusing on the *level* of the velocity of money, we study the properties of its *changes* in the US since 1919 both in the long term and across the business cycle. This is a key element in our paper. If changes in the velocity of money are mean reverting, then periods of abnormally low or high money velocity will eventually be followed by an acceleration or deceleration in the future.

Following Castañeda and Congdon (2020) and Reynard (2023), we use a broad monetary aggregate to model the relation between changes in the amount of money and inflation in the US. In Section 3, we assess the stability of changes in the velocity of money in a long-term perspective, from 1919 to 2021 in the US,[1] along with its behaviour throughout the business cycle. We found a slow but significant reduction in velocity over time, but also the presence of oscillations of different degree associated with the business cycle. The amplitude of these oscillations will help us to define and identify periods both close to 'monetary equilibrium' and further removed from it. These latter times are characterised as periods of 'monetary disequilibrium' or greater monetary imbalances. This classification, obtained by means of a regime switching model, fits well with the monetary history of the US in the period under consideration. In Section 4 we address the relationship between broad money and inflation through a regression analysis in which, as an additional explanatory variable, we include changes in the velocity of circulation. We found that both changes in broad money growth and the presence of monetary imbalances (i.e. monetary disequilibrium) have had a significant impact on inflation. In this relationship, the parameters (elasticities) that link broad money growth and inflation have not remained constant throughout the period. From 1970 onwards, the models show that when a greater monetary imbalance has taken place, a more powerful transmission of money growth to inflation has occurred. We summarise and draw policy conclusions in Section 5.

3. Variations of the velocity of circulation as an indicator of monetary disequilibrium: an application to the US (1919-2021)

In this section we model and analyse the variations in the velocity of circulation of broad money in the US from 1919 to 2021. In the long term, we find a slow reduction of velocity. However, it is more interesting to analyse its oscillations, which feature a succession of periods of monetary disequilibrium closely linked to changes in the business cycle. To capture this behaviour, we model money velocity variations using a regime switching model. We start by considering the rate of change of the velocity of money. This is equal to the difference between the growth rates of nominal GDP and of

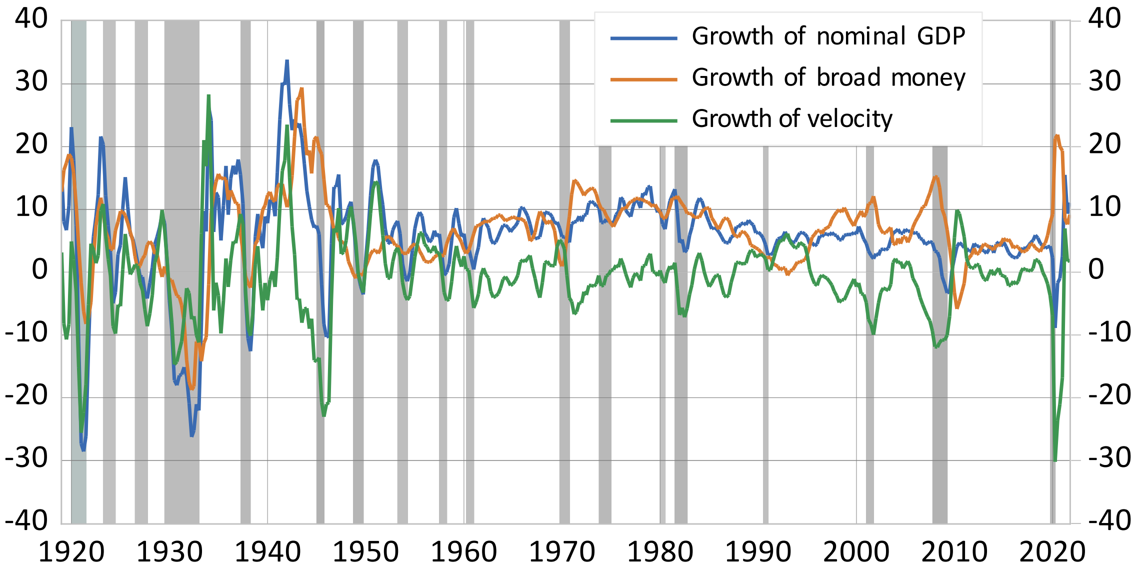
[1] The relationship between money growth, inflation and money velocity has been modelled for the period 1948-2021 due to the availability of comparable data series since 1948. In section 3 we cover a broader time period, from 1919 to 2021, as it is available for money growth and nominal GDP (on the contrary, for CPI inflation we have data since 1948).

broad money.[2] From $v_t = \frac{P_t Y_t}{M_t}$, taking logarithms and subtracting in $t-4$ (given that we use quarterly data) we have the following equation for the annual rates of change:

$$\Delta \log(v_t) = \Delta \log(P_t Y_t) - \Delta \log(M_t) \qquad (1)$$

The absence of a trend behaviour in v_t would imply that the mean value of $\Delta \log(v_t)$ is of no significance. Figure 1 represents the annual growth rates of $P_t Y_t$, M_t, and v_t for the period 1919.I-2021.IV for the US. Recessive periods according to the National Bureau for Economic Research (NBER) dating committee are shaded.[3]

Figure 1. Annual growth rates of nominal GDP, broad money and velocity of circulation in the US. Period: 1919.I -2021.IV.



The mean value of $\Delta \log(v_t)$ for the entire sample period was -0.82% per year, with a standard deviation of 6.59%. Assuming a Gaussian distribution in $\Delta \log(v_t)$, the hypothesis of a mean equal to 0 is not rejected for a significance level of 1% (

[2] By broad money, we mean a monetary aggregate that includes not just cash in circulation but the majority of bank deposits in the US. In this regard, we have made use of the monetary aggregate M3 calculated by Shadow Government Statistics (http://www.shadowstats.com), following the same method and data which the US Federal Reserve used to publish M3 up to 2006. For nominal GDP: Gross Domestic Product, Billions of Dollars, Quarterly (https://fred.stlouisfed.org).

[3] https://www.nber.org/research/data/us-business-cycle-expansions-and-contractions

$t = \frac{-0.82}{0.32} = -2.53$) but rejected at 5%. Thus, we can state that the velocity of circulation has been decreasing at an approximate rate of 0.8% per year. If we just consider the sample until 2019.IV, to avoid the distorting effects of Covid-19 crisis, the average growth rate was -0.62%, with a standard deviation of 6.23%, and the t-statistic of the null mean test ($t = \frac{-0.62}{0.31} = -1.99$) also implies the acceptance of the hypothesis of null mean at a 1%, but its rejection at a 5%. Therefore, the average reduction of the velocity was around 0.6% per year. As a result of these calculations a slow long-term reduction in the velocity of circulation may not be rejected, whether we consider the Covid-19 crisis years or not. However, this average behaviour is not the result of a homogeneous reduction in velocity throughout the entire period. The velocity of money has varied in association with changes in the business cycle, as we analyse below.

Figure 1 shows how the variations in v_t, $\Delta \log(v_t)$, do not show a tendency to increase or decrease consistently throughout the period, but rather a stationary behaviour around its average rate. This is because the values of $\Delta \log(P_t Y_t)$ and $\Delta \log(M_t)$ do not follow divergent paths for excessively long periods of time. This "attraction" between nominal GDP and broad money can be interpreted as a tendency towards monetary equilibrium in spite of variations in the rate of growth. Thus, this feature can be interpreted as the long-term fulfilment of a weak version of the Quantity Theory of Money, one where *changes* in the amount of money and in money velocity are accompanied by proportional *changes* in nominal income. Taking into account that the velocity of money has been reducing at a non-zero average rate, μ_v, we can define monetary equilibrium as a scenario where the difference between nominal GDP growth and monetary growth is close to μ_v. Consequently, we can define monetary disequilibrium as a situation where nominal GDP and money grow at rates significantly far removed from μ_v. Therefore, the deviations of money velocity from its average (μ_v) would give us an indicator of how near or far we are from a monetary equilibrium scenario. Through appropriate modelling, later we proceed to specify what we mean by "near" and "far".

To confirm the results from an exploratory analysis of Figure 1, we performed a unit root test in $\Delta\log(v_t)$. An augmented Dickey-Fuller test[4] unambiguously rejects the non-stationarity hypothesis in $\Delta\log(v_t)$ both for the entire sample and also when restricting the sample period until 2019.IV. The respective t-statistic values of the test are of -6.15 and -6.39, significantly below the 1% critical value of -3.45. This result carries significant policy implications as we can expect that a period characterised by a notable fall in money velocity during a crisis (i.e. 'monetary disequilibrium) would probably be followed by a period of an increase in velocity and a return to pre-crisis levels (i.e. 'monetary equilibrium').

It is observed in Figure 1 that, during recessive periods in the business cycle, the velocity of money tends to slow down, although not always. It also does so in expansionary periods immediately before or after recessions. To identify the periods both of increase and decrease in velocity while simultaneously considering the recessive or expansive business cycle phase, we proceed by modelling variations in velocity by means of a regime switching model (Hamilton, 1989, and Kim and Nelson 1999). So, the model estimated in Equation (2) simultaneously considers the effects that the business cycle phase has on changes in the velocity of money, as well as the variations in money velocity that may be due to other explanatory factors. In order to consider the effects of the business cycle on changes in money velocity, a dummy variable has been added, adopting the value 1 during recessive periods according the NBER business cycle classification. Its significance indicates that during recessions velocity reduces mainly due to a lower nominal GDP growth (the opposite during expansionary phases). However, as there is no one-to-one correspondence between the business cycle phase and the sign of velocity changes, a state variable has been estimated using a regime switching model; this variable varies endogenously according to changes in velocity.

Therefore, we estimate the following model:

$$\Delta\log v_t = -0.82 - \underset{(0.81)}{6.51} d\_recession - \underset{(0.46)}{1.30}(1-S_t^v) + \underset{(0.86)}{7.11} S_t^v + a_t^v \qquad (2)$$

[4] We include an intercept in the test coherently with the non-zero value of the mean growth of the velocity, μ_v, and select automatically the number of lags of the test by means of a Schwarz information criterion.

In Equation (2) we confirm that during recessions ($d\_recession = 1$), velocity decreases by an average annual rate of 6.5%. In addition to this business cycle effect, two other regimes have been identified in the behaviour of money velocity. The first regime (when the state variable $S_t^v = 0$) occurs when velocity decreases at an average annual rate of -1.3%; while the second regime ($S_t^v = 1$) occurs when velocity increases at an average annual rate of 7.1% (in both cases in addition to its average behaviour, $\mu_v = -0.82$). The probabilities of permanence in each of these two regimes are $p_{00}^v = \underset{(0.02)}{0.94}$ for the regime of reducing velocity and $p_{11}^v = \underset{(0.04)}{0.88}$ for the regime of increasing velocity.

Following Equation (2), four scenarios can be identified according to both the business cycle phase and the velocity regime. These are shown in Table 1. We use growth rates in money velocity and consider the highest values, either with a positive (6.3%) or a negative sign (-8.6%), as periods of high monetary disequilibrium (and thus of greater deviation between changes in nominal income and changes in the amount of money). The lower values, however, would imply oscillations of velocity growth closer to its mean value - in other words, periods closer to a monetary equilibrium scenario. Table 2 shows the percentage of quarters, the average duration and the standard deviation for the four scenarios of business cycle phases and regimes of money velocity. The cut off probability value to infer the regime of money velocity has been 0.5. As shown in Table 2, the most frequent scenario (60.4%) combines periods of business cycle expansion and reduction of the velocity of broad money. On the contrary, during recessions (23.5% of the overall sample period), periods of increase (13.3%) and decrease (10.2%) in velocity alternate with a very similar frequency.

Table 1

Average annual growth rates of the velocity of circulation in the four possible scenarios according to Eq. (2). Period: 1919.I -2021.IV.

	Regime of negative velocity growth ($S_t^v = 0$)	Regime of zero or positive velocity growth ($S_t^v = 1$)
Recession (d_recession=1)	-8.6%	-0.2%
Expansion (d_recession=0)	-2.1%	6.3%

Table 2

Percentage of quarters, average duration in quarters, and standard deviation (in parenthesis) of the four possible scenarios of Table 1. Period: 1919.I -2021.IV.

	Regime of negative velocity growth	Regime of positive velocity growth	Overall
Recession	10.2%, 3.5 (2.9)	13.3%, 3.9 (1.0)	23.5%, 5.4 (2.8)
Expansion	60.4%, 11.3 (10.3)	16.0%, 5.1 (4.7)	76.5%, 16.5 (12.6)
Overall	70.6%, 16.2 (15.5)	29.3%, 7.1 (5.6)	

Figure 2 represents the periods which have featured a greater monetary disequilibrium in the US in the last century. These are periods in which either business cycle recessions and a reduction in money velocity or expansions and an increase in money velocity are combined. To determine the realized velocity regime we have used a cut off probability of 0.5. Table 3 shows the dating of periods and their classification according to the four possible scenarios in Table 1. In Table 3 we show in bold the periods of greater monetary disequilibrium observed in Figure 2.

As shown in Table 3, it is clear that since the early 1960s, changes of the regime in money velocity have been less frequent and that the scenarios closer to monetary equilibrium have been dominant. Before 1960, it is worth mentioning two periods of notable monetary disequilibrium - the Great Depression, during which the velocity of money decreased by around 10%, as well as the years during and immediately after the Second World War. These include the expansionary period in the beginning of the war (around 1941-42), the post-war recession of 1945 and the subsequent recovery phase linked to the expansionary effects on the US of the Marshall Plan and the European reconstruction, from 1948 to the beginning of the 1950s.

As observed in Figure 2, the reduction in money velocity during recessive periods is very noticeable, as are the considerable increases in money velocity in subsequent quarters during the beginning of the expansionary phase in the cycle. These strong oscillations along the cycle are clearly seen particularly in the years before 1960. Such sharp fluctuations in the velocity of money after 1960 can only be found during the Global Financial Crisis years (2008-09) and the subsequent recovery period of 2010-11. Note that the sharp contraction in velocity of 2000-01 was not followed by such an abrupt growth in velocity afterwards. Finally, Covid-19 crisis reduced money velocity by more than 20% throughout 2020 (2020.I: -6.9%, 2020.II: -30.2%, 2020.III: -23.6%, 2020.IV: -21.0%, 2021.I: -16.8%), as a result of a surge in the rate of growth of broad money in the US that exceeded 20% per year since the second quarter of 2020. At the same time, nominal GDP fell in the first two quarters of 2020 (actually from March, to be more precise), and remained stagnant for the rest of the year. In 2021 nominal GDP grew at a very high rate (2021.I: 2.6%, 2021.II: 15.5%, 2021.III: 9.3%, 2021.IV: 11.1%) and changes in money velocity started to reverse its negative trend, registering positive rates of growth by the end of 2021.

Figure 2. Periods of greater monetary disequilibrium in the US: recessions and negative velocity growth, and expansions with positive velocity growth.

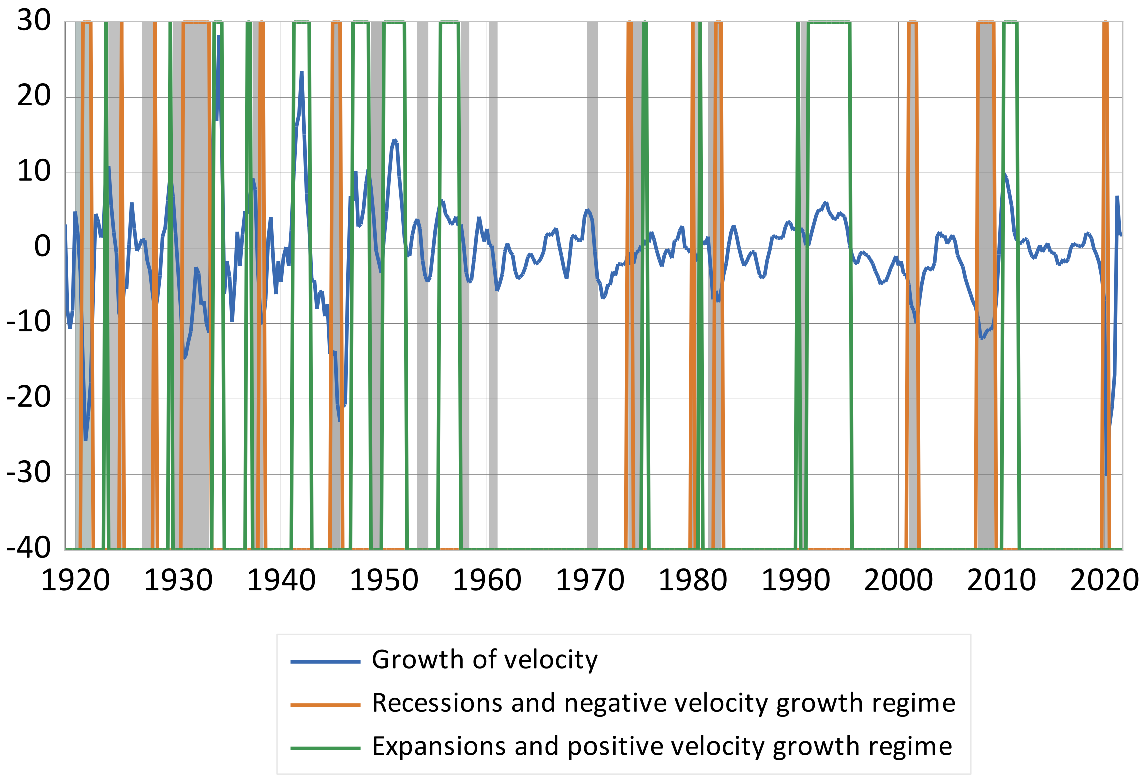


Table 3

Dating of the periods to show the four scenarios of money velocity along the business cycle in the US according to Table 1. In bold, prolonged periods of greater monetary disequilibrium.

Recessive periods according the NBER	#Quarters	Periods of negative velocity growth regime	#Quarters	Periods of null or positive velocity growth regime	#Quarters
1920.I-1921.III	7	1919.I-1919.IV	4	1920.I-1920.III	3
1923.II-1924.III	6	1920.IV-1922.IV	9	1923.I-1924.II	6
1926.III-1927.IV	6	1924.III-1926.II	8	1926.III-1927.III	5
1929.III-1933.I	15	1927.IV-1929.I	6	1929.II-1930.II	5
		1930.III-1933.II	12	**1933.III-1934.II**	4
1937.II-1938.II	5	1934.III-1936.III	9	1936.IV-1937.IV	5
		1938.I-1941.I	13	**1941.II-1942.IV**	7
1945.I-1945.IV	4	1943.I-1946.IV (includes the recessive period: **1945.I-1945.IV**)	16	**1947.I-1952.I** (includes recessive and expansionary periods)	21
1948.IV-1949.IV	5				
1953.II-1954.II	5	1952.II-1953.I	4	1953.II-1954.II	5
1957.III-1958.II	4	1954.III-1955.II	4	**1955.III-1958.II** (includes expansionary periods)	12
1960.II-1961.I	4	1958.III-1960.I	7	1960.II-1961.I	4
1969.IV-1970.IV	5	1961.II-1969.III	34	1969.IV-1970.IV	5
1973.IV-1975.I	6	1971.I-1974.I	13	1974.II-1975.III	6
1980.I-1980.III	3	1975.IV-1980.I	18	1980.II-1980.IV	2
1981.III-1982.IV	6	1981.I-1981.II	2	1981.III-1982.I	3
1990.III-1991.I	3	1982.II-1990.I	32	**1990.II-1995.II** (within an expansionary period)	21
2007.IV-2009.II	7	1995.III-2010.I (includes the recessive period: **2007.IV-2009.II**)	59	**2010.II.2011.III** (within an expansionary period)	6
2020.I-2020.II	2	2011.IV-2021.I (includes the recessive period: **2020.I-2020.II**)	41	2021.II-2021.IV	3

4. Inflation, money growth and monetary disequilibrium in the US (1948-2022)

In this section we will test the relationship between money growth and consumer price inflation[5] by estimating a model that explicitly considers the effects of a monetary disequilibrium scenario, as signalled by the growth of the velocity of money, $\Delta \log(v_t)$. This model allows us to study the influence of monetary growth on inflation in a non-linear way, by identifying sub-periods in the sample where, while maintaining the said relationship, the elasticity parameters have increased their value significantly. For its part, growth in the velocity of money captures imbalances between the supply and demand for broad money that eventually end up being transferred to the prices of consumer goods. With this model we will be able to assess whether the Quantity Equation can be used as a framework to anticipate changes in inflation. In particular, we will test whether periods of high monetary growth lead to higher inflation once changes in money velocity have returned to its average (long term) value.

The general specification of the model is as follows:

$$\Delta \log(P_t) = \left(\alpha_0 + \beta_0(L)\Delta \log(M_t)\right)(1 - S_t^{\pi}) + \left(\alpha_1 + \beta_1(L)\Delta \log(M_t)\right) S_t^{\pi} + \gamma(L)\Delta \log(v_{t-1}) + a_t^{\pi} \quad (3)$$

where the annual rate of inflation, $\Delta \log(P_t)$, depends on broad money growth according to a regime switching model where two inflationary regimes have been identified. These are firstly, an ordinary elasticity regime when the state variable $S_t^{\pi} = 0$, and secondly a high elasticity regime when $S_t^{\pi} = 1$. The subscripts 0 and 1 in the parameters $\alpha_{S_t^{\pi}}$ and in the polynomials in the lag operator, $\beta_{S_t^{\pi}}(L) = \beta_{0,S_t^{\pi}} + \beta_{1,S_t^{\pi}} L + \beta_{2,S_t^{\pi}} L^2 + \ldots$, refer to the value they take in each of the two regimes, $S_t^{\pi} = \{0,1\}$. The polynomial in the lag operator, $\gamma(L) = \gamma_0 + \gamma_1 L + \gamma_2 L^2 + \ldots$, shows the impact on inflation of lagged monetary imbalances, measured by $\Delta \log(v_{t-1})$, and thus the impact of being under a monetary disequilibrium scenario. The parameters in $\gamma(L)$ do not depend on the inflationary regime, S_t^{π}. Table 4

[5] Consumer Price Index for All Urban Consumers: All Items in U.S. City Average, seasonally adjusted (https://fred.stlouisfed.org).

shows the results of the estimate of five alternative models. All of them identify the said elasticity regimes with a significant difference in the parameters $\alpha_{S_t^\pi}$ and β_{j,S_t^π}. We have checked that monetary imbalances, according to the value of $\Delta\log(v_{t-1})$, affect inflation without significant differences between both regimes. Actually, as shown in a Wald test, the hypothesis of equality between regimes of the parameters in $\gamma(L)$ is not rejected. The estimated transition probabilities, p_{00}^π and p_{11}^π, show the higher persistence of the ordinary elasticity regime.

We have estimated five alternative models (see Table 4 below) to assess the time lag with which changes in the annual growth of money are translated into inflation. These models capture the impact of monetary growth on inflation under different time lags: model 1 considers the impact within the same quarter, models 2 and 3 the impact after one quarter and models 4 and 5 with a two quarters delay. The estimated information criteria (which we seek to minimize) inform the degree of fit of each model, penalizing the mere addition of lags in the growth rate of money that are not really informative. So, taking into account the significance of the parameters and the calculated information criteria in Table 4, we choose Model (4) as our reference model for all subsequent analysis.

Figure 3 shows the fit of the model ($R^2 = 0.70$) and the filtered probabilities of the regime of higher elasticity, $S_t^\pi = 1$, with respect to monetary growth. Using a cut off probability of 0.5, the ordinary elasticity regime, $S_t^\pi = 0$, occurs in 84% of the sample. This regime has a substantially longer predicted duration of 35 quarters compared to 9 for the alternative regime. The average inflation rates of each one of the two regimes have been around 2.6% and 6.1% for $S_t^\pi = \{0,1\}$, respectively. The parameters $\alpha_{S_t^\pi}$ have been significantly higher under $S_t^\pi = 1$, for which a direct relationship between higher elasticity of money growth and higher inflation rate could be affirmed. In Model (4), although the elasticity with respect to $\Delta\log(M_{t-1})$ is practically the same in both regimes (around 0.4), this is not the case with respect to $\Delta\log(M_{t-2})$ where it is not significant under $S_t^\pi = 0$, but it definitely is under $S_t^\pi = 1$. For fluctuations with a period greater than one year, the annual rate considered in money and inflation data in our regression selects a variable medium-term range of between 5.3 quarters and 4 years.[6] Consequently, the relationship between inflation and monetary growth in Model (4) is pronounced in both the medium and long term components of both series. Throughout this range of variation, the effect of monetary growth on inflation occurs with a lag of two quarters.

Of interest is the value of the long-term elasticity of monetary growth, $\beta_{S_t^\pi}(1)$, which, for Model (4), has been $\beta_0(1) = 0.56$ in the regime of ordinary elasticity, and $\beta_1(1) = 0.90$ in the high elasticity regime. These values do not differ excessively from those obtained in the other estimated models in Table 4. The periods of time featuring high elasticity, $S_t^\pi = 1$, whose probabilities are drawn in grey in Figure 3, are the following: 1948.I-1948.IV, 1958.II-1958.IV, 1970.I-1971.I, 1974.I- 1975.IV, 1979.II-1981.IV, 1990.III-1994.II, and 2010.I-2012.I. From 1970 onward, these periods roughly coincide with those of the regime of zero or positive velocity growth estimated in the preceding section (see Table 3). Consequently, greater growth in the velocity of circulation and indeed a greater deviation from its mean (i. e. greater monetary imbalances) has been associated with a more powerful transmission of money growth on to inflation. Finally, as shown in Figure 3, it should be noted that the accuracy of the model since 2020 is particularly high, although the probability of being in the regime of highest elasticity continues to be zero. The model also explains the lack of inflation during the period of the Global Financial Crisis (under a negative velocity regime), as well as the recovery of inflation in 2012-14.

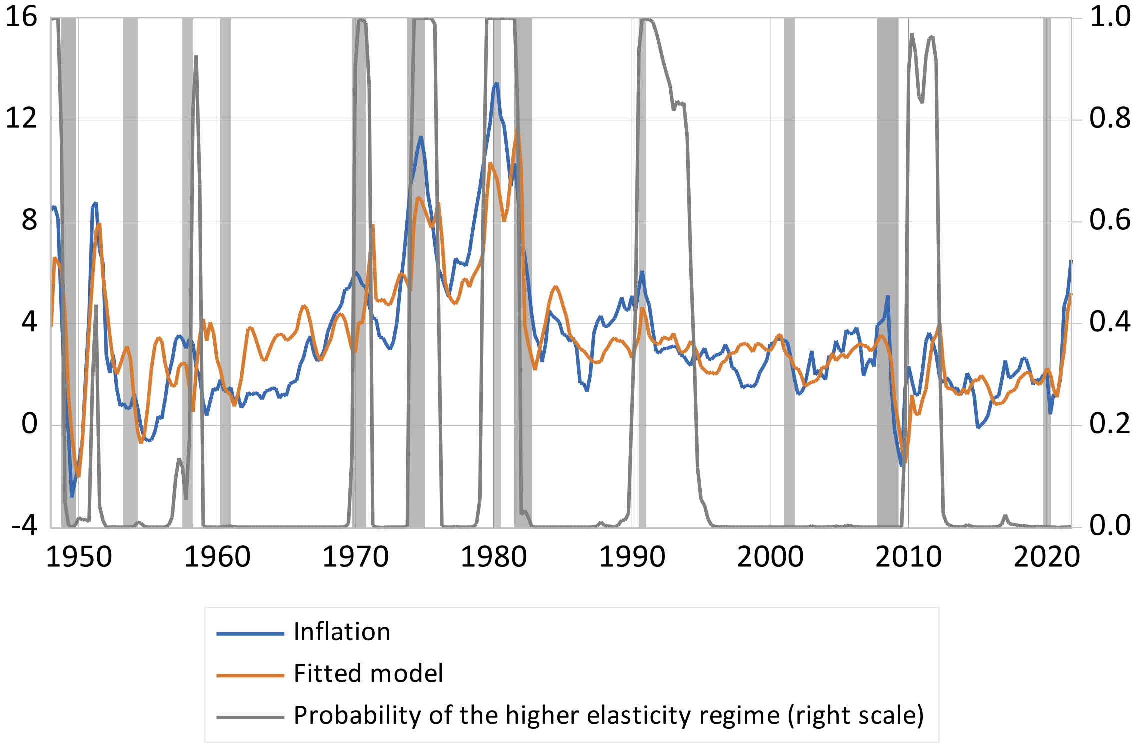
[6] We refer to the spectral gain of the filter $1 - L^4$, which is applied when calculating the annual rate of a time series. The spectral gain measures the increase in amplitude of any specific frequency component of a time series. For the filter $1 - L^4$, the spectral gain in the frequency domain is $2(1 - \cos 4\omega)$ with ω a frequency component. This filter eliminates the trend and seasonal variation components, letting the remaining components pass. Within them, above the year, the fluctuations with a period between 5.3 quarters and 16 quarters have a greater weight (i. e. a normalized gain greater than 0.5).

Table 4

Estimate of alternative models of Eq. (3) (in parenthesis: standard errors). Significance levels: 10% (*), 5% (**), 1% (***). Period: 1948.I-2021.IV.

Model #	(1)	(2)	(3)	(4)	(5)
α_0	0.2804 (0.2911)	-0.5543* (0.3323)	-0.5770* (0.3199)	-0.8523*** (0.3264)	-0.8458*** (0.3197)
$\beta_{0,0}$ (lag=0)	0.3788*** (0.0437)	-0.0316 (0.0719)	-	-	-0.0228 (0.0719)
$\beta_{1,0}$ (lag=1)	-	0.5526*** (0.0826)	0.5250*** (0.0459)	0.4408*** (0.1055)	0.4578*** (0.1408)
$\beta_{2,0}$ (lag=2)	-	-	-	0.1203 (0.0998)	0.1213 (0.1050)
α_1	3.8440*** (0.5288)	1.8820*** (0.4286)	1.8486*** (0.4154)	1.3838*** (0.3786)	1.2728*** (0.3756)
$\beta_{0,1}$ (lag=0)	0.5833*** (0.0631)	-0.1534 (0.1614)	-	-	0.2160 (0.1999)
$\beta_{1,1}$ (lag=1)	-	1.0044*** (0.1716)	0.8607*** (0.0707)	0.4255*** (0.1579)	0.0674 (0.3512)
$\beta_{2,1}$ (lag=2)	-	-	-	0.4777*** (0.1569)	0.6313*** (0.2028)
γ_0	0.2725*** (0.0427)	0.2754*** (0.0411)	0.2839*** (0.0404)	0.2407*** (0.0540)	0.2357*** (0.0566)
γ_1	0.0292 (0.0381)	0.1108*** (0.0364)	0.1010*** (0.0341)	0.1604*** (0.0478)	0.1589*** (0.0491)
p_{00}^{π}	0.9725*** (0.0109)	0.9740*** (0.0109)	0.9742*** (0.0107)	0.9714*** (0.0115)	0.9705*** (0.0118)
p_{11}^{π}	0.8569*** (0.0557)	0.8848*** (0.0484)	0.8862*** (0.0477)	0.8891*** (0.0440)	0.8902*** (0.0432)
Akaike info. criterion	3.8474	3.7325	3.7245	3.7079	3.7136
Schwarz criterion	3.9596	3.8697	3.8364	3.8447	3.8757
Hannan-Quinn criterion	3.8923	3.7874	3.7693	3.7627	3.7785

Figure 3. Annual rate of inflation, fitting of Model (4) and filtered probabilities of the high elasticity regime of money growth for the US. Period 1948.I-2021.IV.



5. Summary and conclusions: changes in broad money as a policy indicator?

In this paper, using data for the US, we have shown that changes in both money velocity and in the amount of money (broadly-defined) matter when trying to explain the levels of consumer price inflation over the medium to the long term. We have done so firstly by identifying periods of monetary disequilibrium, where sharp changes in the velocity of money from its mean break up the relation bewteen changes in the amount of money and in inflation. However, once changes in money velocity revert to its long term trend, monetary equilibrum is restored and inflation reflects earlier changes in the amount of money. The degree to which changes in the amount of money will be transmitted into consumer inflation, and thus the elasticity of inflation to changes in the amount of money, will largely depend on the behaviour of the velocity of money. When it grows significantly so will the degree of transmission of monetary changes into inflation. In conclusion, our model demonstrates a delayed and a medium to long term relationship between changes in the amount of money and inflation.

Using a sample of the last 70 years of data from the US, we have found that a period of sustained monetary growth over the medium to the long term will be followed by a similar period of sustained inflation, albeit with a two quarter delay. Critically, in our analysis we have used a broad definition of money in the US (M3), one that includes cash in circulation plus the majority of bank deposits in the economy.

In line with the results found in the post-pandemic literature on this topic (see Borio et al. 2023, Greenwood and Hanke, 2022, Hanke and Cheng, 2022, Congdon 2022, and Reynard, 2023), our article suggests that central bank policies and their inflation record would benefit from incorporating broad monetary aggregates in assessing inflation over the medium to the long term, given the delayed relation identified between these variables in our model. Our results also suggest that we focus our attention not only on the effects of changes in broad money as the literature quoted above does, but also on (1) changes in money velocity along the cycle, and (2) the implications of the stability of changes in money velocity over the medium and long term. This stability property of changes in money velocity is what allows us to identify situations of monetary equilibrium and disequilibria as temporary phenomena, and thus to anticipate corresponding changes in inflation over time. Therefore, our results recommend the use of both variables (i.e. changes in broad money and changes in money velocity) to improve the analysis and forecast of inflation when applied to the medium to the long term.

References

Anderson, R. G., Bordo, M., Duca, J. V., 2017. Money and Velocity during Financial Crises: From the Great Depression to the Great Recession. Journal of Economic Dynamics and Control 81 (C), 32-49.

Benati, L., 2009. Long run evidence of money growth and inflation. Working Paper series, No. 1027. European Central Bank.

Benati, L., Lucas, R., Nicolini, J.P, Weber, W., 2019. International Evidence on Long-Run Money Demand. Staff report 587. Federal Reserve Bank of Minneapolis.

Benati, L., 2020. Money velocity and the natural rate of interest. Journal of Monetary Economics, 116 , 117-134.

Borio, C., Hofmann, B. and Zakrajšek, E., 2023: Does money growth help explain the recent inflation surge? BIS bulletin 67. January 2023. Accessed online.

Castañeda, J. and Congdon, T. (2020): Inflation, the next threat? Covid Briefing Paper 7. June. Institute of Economic Affairs

Clarida, R., 2020. U.S. Economic Outlook and Monetary Policy. Speech at the New York Association for Business Economics. New York (via webcast). May 21st 2020.

Congdon, T., 2021: Can monetary policy run out of ammunition? The role of the money-equities-interaction channel in monetary policy. In Economic Affairs. Vol. 41, 1. February. 21-37.

De Grauwe, P., Polan, M., 2005. Is Inflation Always and Everywhere a Monetary Phenomenon?. Scandinavian Journal of Economics, 107 (2), 239-259.

De Santis, R., 2012. Quantity theory is alive. The role of international portfolio shifts. Working Paper series, 1435. European Central Bank.

Dery, C., Serletis, A., 2023. Macroeconomic Fluctuations in the United States: The Role of Monetary and Fiscal Policy Shocks. *Open Economies Review*. February.

European Central Bank (2022): 'Overview of monetary policy strategy'. European Central Bank, 2022. Available online: https://www.ecb.europa.eu/home/search/review/html/ecb.strategyreview_monpol_strategy_overview.en.html

Federal Reserve Board of Governors, 2020. 2020 Statement on Longer-Run Goals and Monetary Policy Strategy. Press release. August 27th 2020.

Friedman, M., 1956. Studies in the Quantity Theory of Money. University of Chicago Press. Chicago.

Gao, H., Kulish, M., Nicolini, J. P., 2020. Two illustrations of the quantity theory of money reloaded. Working Paper 774. Federal Reserve Bank of Minneapolis.

Greenwood, J. and Hanke, S., 2022: On monetary growth and inflation in leading economies, 2021–22: Relative prices and the overall price level. In Economic Affairs. July. Vol. 42, 2. Pp. 288-306.

Haas, J., Neely, C., Emmons, W., 2020. Responses of International Central Banks to the Covid-19 Crisis. Federal Reserve Bank of St. Louis Working Paper, No. XXX, October.

Hall, S., Swamy, P., Tavlas, G., 2012. Milton Friedman, the demand for money and the ECB monetary policy strategy. Federal Reserve Bank of St. Louis Review. May-June, 153-185.

Hamilton, J. D., 1989. A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle. Econometrica, 57 (2), 357-384.

Greenwood, J. and Hanke, H. 2022. On monetary growth and inflation in leading economies, 2021-22: Relative prices and the overall price level'. In Economic Affairs, vol. 42(2), 288-306, June.

Hanke, S., Ma, Z. and Cheng, R. (2022). On the Quantity Theory of Money: some monetary facts. Studies in Applied Economics, Num. 224, December. Johns Hopkins Institute for Applied Economics, Global Health, and the Study of Business Enterprise.

Kim, C. J., Nelson, C. R., 1999. State-Space Models with Regime Switching. Cambridge: The MIT Press.

King, M., 2021. Monetary Policy in a World of Radical Uncertainty. IIMR Public Lecture, November 2021. Accessed online.

Lucas, R., Nicolini J. P., 2015. On the Stability of Money Demand. Federal Reserve Bank of Minneapolis. Working Paper 718. Federal Reserve Bank of Minneapolis.

Lucas, R., 1980. Two Illustrations of the Quantity Theory of Money. American Economic Review, 70 (5), 1005-14.

Lucas, R., 1996. Nobel Lecture: Monetary Neutrality. Journal of Political Economy, 104 (4), 661-82.

Milas, C., 2009. Does high M4 money growth trigger large increases in UK inflation? Evidence from a regime-switching model. Oxford Economic Papers, 6 (1), p. 168–182.

Nelson, E., 2008. Why money growth determines inflation in the long run: answering the Woodford critique. Working Paper 13. Federal Reserve Bank of St. Louis.

Papadia, F., Cadamuro, L., 2021. Does money growth tell us anything about inflation?. Working Paper 11. Bruegel.

Powell, J., 2021a. Semi-annual Monetary Policy Report to US Congress. February 23rd.

Powell, J., 2021b. House Financial Services Committee. December 1st.

Teles, P., Uhlig, H., 2013. Is quantity theory still alive?. Working Paper 1605. European Central Bank.

Reynard, S. (2023): Central bank balance sheet, money and inflation. In Economic Letters, Vol. 224. March. Accessed online.

Schnabel, I., 2020. The ECB's monetary policy during the coronavirus crisis – necessary, suitable and proportionate. Berlin Economic Roundtable. 2nd July 2020. See https://www.ecb.europa.eu/press/key/date/2020/html/ecb.sp200702_1~977101f696.en.pdf