# US Monetary Policy, 2020-23: Putting the Quantity Theory to the Test

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SOMC | SHADOW OPEN MARKET COMMITTEE

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*Abstract:* Dramatic fluctuations in US money growth since 2020 provide valuable new data with which to test the quantity theory of money. Consistent with the theory, the P-star model – a small-scale econometric model with quantity-theoretic foundations – associates the 2020 surge in money growth with the persistent inflation that has followed. In light of the outright monetary contraction observed since 2022, however, the same model suggests strongly that the Federal Reserve should now pause before implementing further interest rate increases, while past policy actions have their full effect in bringing inflation back down. More generally, with reference to the P-star model and to the quantity theory on which it is based, the Fed can avoid an unwelcome return to the stop-go policy patterns that contributed to macroeconomic volatility and rising inflation throughout the 1970s.

*Keywords:* Divisia Monetary Aggregates, Federal Reserve, P-star Model, Quantity Theory of Money.

*JEL Codes:* E31, E47, E51, E52, E58.

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## Introduction

The quantity theory of money identifies large and persistent movements in money supply growth as the principal driving force behind large and persistent movements in inflation. Milton Friedman's famous dictum that "inflation is always and everywhere a monetary phenomenon" summarizes the quantity theory most succinctly.[1]

In fact, dramatic swings in money growth appear in US data from the past several years. These can be seen in figure 1, which plots the year-over-year growth rates of three measures of the money supply described in more detail below: M2, Divisia M2, and Divisia M4. By all three measures, the US money supply grew at rates exceeding 20 percent throughout 2020 and into 2021.[2] Money growth slowed considerably in 2022, however, and has even turned negative – signaling outright monetary contraction – more recently, partially reversing the previous years' increases.

For economists, these extraordinary movements in the money supply – unprecedented in the post-World War II period – provide valuable information with which to test the quantity theory's key implications. After taking a closer look at the data to place the recent fluctuations in

[1] Milton Friedman. "The Counter-Revolution in Monetary Theory." Occasional Paper No. 33. London: Institute for Economic Affairs, 1970; reprinted in Milton Friedman. *Monetarist Economics*. Oxford: Basil Blackwell, 1991, pp.1-20. The quote is from page 16.

[2] Previous quantity-theoretic analyses of 2020's surge in money growth can be found in John Greenwood and Steve H. Hanke. "On Money Growth and Inflation in Leading Economies, 2021-2022: Relative Prices and the Overall Price Level." *Journal of Applied Corporate Finance* 33 (Fall 2021): 39-51; Peter N. Ireland. "The Recent Surge in Money Growth: What Would Milton Friedman Say?" *Journal of Applied Corporate Finance* 34 (Spring 2022): 65-81; Joshua R. Hendrickson. "Is the Quantity Theory Dead? Lessons from the Pandemic." Special Study. Arlington, VA: George Mason University, Mercatus Center, January 2023; Samuel Reynard. "Central Bank Balance Sheet, Money and Inflation." *Economics Letters* 224 (March 2023): Article 111028; and Michael D. Bordo and John V. Duca. "Money Matters: Broad Divisia Money and the Recovery of Nominal GDP from the Covid-19 Recession." Working Paper 2306. Dallas: Federal Reserve Bank of Dallas, Research Department, May 2023.

money growth in broader historical perspective, this paper uses them to estimate a small-scale econometric model, known as the "P-star model," that links movements in the money stock to subsequent movements in inflation in a manner consistent with the quantity theory.

The P-star model yields, as a useful by-product, a statistical "price gap" measure that summarizes the effects that past rates of money growth have on future inflation. This paper uses that price gap measure to gauge the current stance of US monetary policy, taking into account both 2020's surge in money growth and the monetary contraction that has followed. These estimates show that the Federal Reserve's monetary policy is now consistent with a return to lower, more acceptable, rates of inflation. More generally, the paper argues that with reference to the P-star model and to the quantity theory of money on which it is based, the Federal Reserve can avoid an unwelcome return to the stop-go policy patterns that contributed to macroeconomic volatility and rising inflation throughout the 1970s.

**A Closer Look at the Data**

Historically, the Federal Reserve has provided two measures of the money supply. M1 includes currency and checking account balances. M2 adds savings account balances, including funds held in money market deposit accounts, small certificates of deposit, and retail money market mutual funds. In April 2020, the Fed lifted the last remaining regulatory restrictions that once distinguished checking from savings accounts and redefined the M1 aggregate accordingly.[3] Therefore, M2 now stands as the only historically consistent series on the money supply

[3] See Ireland (2022), p.78, for a more detailed discussion of the gradual changes in regulation that first blurred, then finally removed, the distinction between checking and savings accounts.

provided by the Federal Reserve. This "official" series runs from 1959 through the present; its year-over-year growth rates are shown in the top panel of figure 1.

The M2 monetary aggregate simply adds together the dollar value of funds held in its various component assets, without recognizing that currency and checking account balances are more liquid than certificates of deposits and money market mutual funds shares. In 1970, Milton Friedman and Anna Schwartz envisioned a more sophisticated approach to monetary aggregation:

> In brief, the general approach consists of regarding each asset as a joint product having different degrees of "moneyness," and defining the quantity of money as the weighted sum of the aggregate value of all assets, the weights for individual assets varying from zero to unity with a weight of unity assigned to that asset or assets regarded as having the largest quantity of "moneyness" per dollar or aggregate value.[4]

Ten years later, William Barnett showed how economic aggregation and statistical index number theory could be combined to produce exactly this kind of weighted monetary aggregate. Today, data on Barnett's "Divisia" monetary aggregates running from 1967 through the present are freely available through the Center for Financial Stability's website.[5]

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[4] Milton Friedman and Anna Jacobson Schwartz. *Monetary Statistics of the United States: Estimates, Sources, Methods*. New York: Columbia University Press, 1970. The quote is from page 151.

[5] For the original derivation of formulas defining the Divisia monetary aggregates, see William A. Barnett. "Economic Monetary Aggregates: An Application of Index Number and Aggregation Theory." *Journal of Econometrics* 14 (September 1980): 11-48. For a broader discussion of the Divisia monetary aggregates and their usefulness, see William A. Barnett. *Getting it Wrong: How Faulty Monetary Statistics Undermine the Fed, the Financial System, and the Economy*. Cambridge: MIT Press, 2012. For details on the construction of the series made available through the Center for Financial Stability, see William A. Barnett, Jia Liu, Ryan S. Mattson, and Jeff van den Noort. "The New CFS Divisia Monetary Aggregates: Design, Construction, and Data Sources." *Open Economies Review* 24 (February 2013): 101-124.

Divisia M2 includes the same component assets – currency, checking, and savings account – as the Fed's official M2 aggregate, but re-weights each component according to what Friedman and Schwartz called their degree of "moneyness," measured using the spread between the interest rate on a "benchmark" asset that provides no special liquidity services and the lower interest rate offered on each of the monetary assets. The top two panels of figure 1 show that M2 and Divisia M2 usually move together, but with some notable exceptions. Most significantly, the disinflationary policies pursued by the Federal Reserve under Chair Paul Volcker in the early 1980s show up much more clearly in the Divisia M2 series than in the Federal Reserve's official statistics.[6]

More recently, Don Chew has argued that

> the disintermediation of banks and rise of "shadow banking" have undermined any stability in the money multiplier or velocity of money – and thus any predictability with which increases in M0 [the monetary base, consisting of currency and bank reserves] make their way from banks into the broader economy.[7]

Chew's critique points to the need for even broader measures of money, which account the wider range of safe and highly liquid assets issued by non-bank institutions. In fact, Barnett and his associates at the Center for Financial Stability provide such a measure in the form of Divisia M4,

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[6] Barnett (2012) pp.107-111 discusses the contradictory signals sent by "simple sum" versus Divisia monetary aggregates during and immediately after the Volcker disinflation. Other studies show that, throughout the postwar period, Divisia monetary aggregates display stronger statistical links to inflation and the business cycle. See, for example, Michael T. Belongia, "Measurement Matters: Results from Monetary Economics Reexamined." *Journal of Political Economy* 104 (October 1996): 1065-1083; Joshua R. Hendrickson. "Redundancy or Mismeasurement? A Reappraisal of Money." *Macroeconomic Dynamics* 18 (October 2014): 1437-1465; and Michael T. Belongia and Peter N. Ireland. "Money and Output: Friedman and Schwartz Revisited." *Journal of Money, Credit, and Banking* 48 (September 2016): 1223-1266.

[7] Don Chew. "A Message from the Editor." *Journal of Applied Corporate Finance* 33 (Fall 2021): 2-3. The quote is from p.3.

which includes funds held in all of the assets from M2, plus institutional money market funds, large negotiable certificates of deposit, overnight and term repurchase agreements, commercial paper, and even US Treasury bills, all weighted according to their degree of moneyness using interest rate spreads.

The third panel of figure 1 shows that Divisia M4 also behaves similarly to M2 and Divisia M2, but again with some notable exceptions. Only Divisia M4 captures, for example, the extreme tightness of monetary and financial conditions during the financial crisis of 2008, which of course was centered in the shadow banking system.[8]

Yet all three measures of money growth pictured in figure 1 show the same behavior over the past several years. Money growth surged in 2020, exceeding by far even the rates experienced during the high inflation years of the 1970s. Thus, the quantity theory provides an easy explanation of why the US inflation rate remains elevated, despite the gradual easing of supply disruptions following the 2020 economic shut-downs. In retrospect, the Fed clearly provided too much monetary stimulus during 2020 and 2021.[9]

More recently, however, money growth has not only fallen substantially, but actually turned negative. This type of outright monetary contraction has rarely been seen before. Over the postwar period covered by the data in the graphs, the Volcker disinflation of the 1980s and

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[8] Thus, several studies point to the usefulness of Divisia M4 in explaining movements in output and inflation, particularly over samples that include the financial crisis of 2008 and its aftermath. See Cosmas Dery and Apostolos Serletis. "Interest Rates, Money, and Economic Activity." *Macroeconomic Dynamics* 25 (October 2012): 1842-1891; John W. Keating, Logan J. Kelly, A. Lee Smith, and Victor J. Valcarcel. "A Model of Monetary Policy Shocks for Financial Crises and Normal Conditions." *Journal of Money, Credit, and Banking* 51 (February 2019): 227-259; and Patrick J. Horan. "Divisia Money, Output, and Prices: 1967-2022." Manuscript. Fairfax, VA: George Mason University, Department of Economics, May 2023.

[9] Again, see Greenwood and Hanke (2021), Ireland (2022), Hendrickson (2023), Reynard (2023), and Bordo and Duca (2023) for quantity-theoretic analyses of the 2020 surge in money growth.

the financial crisis of 2008 are the only previous episodes where one of the measures of money growth dropped well into negative territory. Today, for the first time, all three measures of the money supply are contracting.

From a quantity theoretic perspective, the most recent monetary contraction indicates quite clearly that Federal Reserve policy actions – to raise the federal funds rate target from a range near zero at the start of 2022 to its present level in excess of 5 percent and to wind down and then reverse its previous large-scale asset purchases known popularly as "quantitative easing" or "QE" – are working as intended to remove excess monetary stimulus. But is the dramatic swing in money growth from positive to negative enough to bring inflation back down to lower, more acceptable levels?

As a first step in answering this question, figure 2 presents the monetary data in a different way, expressing each measure of the money supply as a percentage deviation from a constant growth path. In each case, the constant rate of money growth along the reference path equals the average growth rate in the series over the twenty-year period beginning in 2000 and ending in 2019: 6.1 percent annually for M2, 6.0 percent for Divisia M2, and 4.5 percent for Divisia M4. Again, the message sent by the three measures of money is the same: the money stock peaks close to 20 percent above its trend in 2021, before falling back to a level about 10 percent above trend in the first quarter of 2023.

This second set of graphs confirms that the effects of the recent monetary tightening have been significant, reversing approximately half of the bulge in the money stock that appeared in 2020 and 2021. But again: what do these changes imply for inflation? In answering this question, two complicating factors appear.

First, presumably, Federal Reserve officials seek only to bring inflation – that is, the rate of change in the aggregate price level – back down to their two-percent long-run target. Regarding the price level itself, they will likely let "bygones be bygones." This consideration implies that the money supply series shown in figure 2 don't have to fall all the way back to trend to achieve the Fed's goals. Money growth only needs to decline as needed to slow down the rate of inflation.

Second, the equation of exchange

$$M_t V_t = P_t Y_t \tag{1}$$

clarifies that even with real GDP $Y_t$ held constant, changes in the money supply $M_t$ will translate into proportional changes in the aggregate price level $P_t$ only if the velocity of money $V_t$ remains stable. Figure 3 plots the velocities of the three monetary aggregates, revealing that to the contrary, each has fluctuated considerably over the past several years.[10] In particular, by all measures, velocity declined in 2020 and 2021, partially offsetting the effects of rapid money growth in raising inflation. Then, during 2022 and 2023, velocity rebounded, partially offsetting the effects of slower money growth in lowering inflation.

Thus, accurately gauging the effects that swings in money growth have had and will have on inflation requires a statistical model that accounts, at once, for three sets of factors. First, the model should account for the fact that the recent monetary contraction has occurred, not in

[10] In comparing the numbers across the three panels of figure 3, it is important to note that M2 as the simple sum of funds held in its various component assets is measured in units of dollars. Divisia M2 and Divisia M4, by contrast, are index numbers normalized to equal 100 in the base year of 1967. Thus, unlike the level of M2 velocity, which can be interpreted as ratio of the current dollar value of GDP to the current dollar value of the money supply, the levels of Divisia M2 and Divisia M4 have no special meaning. Instead, the *changes* in Divisia M2 and Divisia M4 velocities may be compared directly to the changes in M2 velocity: all three measure the growth of nominal GDP relative to the growth of the nominal money supply.

relative isolation as it did during the severe deflationary episodes of the early 1980s and 2008, but instead in a way that partially – but only partially – reverses the even bigger increase in the money supply that occurred previously, in 2020 and 2021. That is, the model should use information in the *level* on the money stock to measure the cumulative effect of all past changes in the growth rate of money.

Second, the model should recognize that, by contrast, the Federal Reserve's concerns are with inflation – that is, the *growth rate* of prices – instead of the price level itself. The Fed's goal, in other words, is to bring the rate of inflation back down, not to force prices to return to the much lower trendline they were following before 2020. Third, the model must account for the shifts in velocity that would otherwise weaken the links between money growth and inflation.

The "P-star" model described next has all three of these features. It is, therefore, ideally-suited for using the recent data to test the quantity theory's implications and to assess whether, at present, monetary policy remains too accommodative or appears broadly consistent with the Fed's goal of bringing inflation back down.

**Testing the Quantity Theory**

The P-star model was developed by researchers at the Federal Reserve in the late 1980s, at the request of then-Chair Alan Greenspan. An article presenting and testing the model was published by Jeffrey Hallman, Richard Porter, and David Small in the September 1991 issue of the *American Economic Review*, the flagship journal of the American Economic Association and one of the "top five" scholarly journals in economics.[11] These facts are not just trivia. They

[11] Jeffrey J. Hallman, Richard D. Porter, and David H. Small. "Is the Price Level Tied to the M2 Monetary Aggregate in the Long Run?" *American Economic Review* 81 (September 1991): 841-858. The P-star model's quantity-theoretic foundations are analyzed in more detail by Thomas

serve as reminders that quantity-theoretic models of monetary policy were once of practical interest to top policymakers and their advisors at the Fed and to academic economists as well. Perhaps they should remain so, today.

The P-star model uses the equation of exchange shown above as (1) to identify the long-run aggregate price level – the $P_t^*$ that gives the model its name – that is implied by the current level of the money supply $M_t$ once velocity and real GDP return to their own long-run equilibrium levels $V_t^*$ and $Y_t^*$. To do this, the model rewrites (1) as

$$P_t^* = \frac{M_t V_t^*}{Y_t^*}. \tag{2}$$

The model thereby recognizes that monetary policy actions that change the money supply affect the aggregate price level, but only with a lag. During the adjustment period between the initial change in money and the eventual change in the price level, an increase in the money supply must work to decrease velocity (that is, to increase the public's holdings of money relative to income), to increase real GDP (reflecting a Phillips curve through which expansionary monetary policy increases output in the short run), or some combination of these two.

The P-star model does not require velocity to be constant, but it does assume that over time, velocity will return to some long-run equilibrium level $V_t^*$ that can be estimated with available data. Likewise, the P-star model allows changes in monetary policy to have effects on output and employment in the short run as well as on prices in the long run. However, it also assumes that over time, output will return to some long-run equilibrium or "natural" rate $Y_t^*$ that can also be estimated with available data.

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M. Humphrey. "Precursors of the P-star Model." Federal Reserve of Richmond *Economic Review* 75 (July/August 1989): 3-9.

Hallman, Porter, and Small took M2 as their measure of money and, observing that between 1955 and 1988, M2 velocity fluctuated in a relatively narrow range around its average value of 1.65, simply took $V_t^* = 1.65$ to be a constant. This modelling choice, though quite convenient, proved unfortunate when, as shown in the top panel of figure 3, M2 velocity moved unexpectedly higher throughout the 1990s. Then, starting in 2000, M2 velocity reversed course and followed a downward trend. These movements in M2 velocity threw the original P-star model's predictions off track almost immediately after the publication of the Hallman-Porter-Small article![12]

My own research with Michael Belongia recognizes, however, that the absence of any trend before 1990 is a special feature possessed by M2 velocity alone.[13] The Divisia aggregates, by contrast, generally have velocities that trend upwards in data before 2000 and downward thereafter. In our research, therefore, we looked for alternative estimates that allow for time-variation in $V_t^*$. We find, in particular, that a one-sided version of the Hodrick-Prescott filter – essentially, by taking a moving weighted average of current and past values of velocity – provides estimates of $V_t^*$ that greatly improve the P-star model's predictive performance.[14]

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[12] For a discussion of this breakdown, see Athanasios Orphanides and Richard D. Porter. "P* Revisited: Money-Based Inflation Forecasts with a Changing Equilibrium Velocity." *Journal of Economics and Business* 52 (January-April 2000): 87-100.

[13] See Michael T. Belongia and Peter N. Ireland. "A 'Working' Solution to the Question of Nominal GDP Targeting." *Macroeconomic Dynamics* 19 (April 2015): 508-534; and Michael T. Belongia, and Peter N. Ireland. "Circumventing the Zero Lower Bound with Monetary Policy Rules Based on Money." *Journal of Macroeconomics* 54 (December 2017): 42-58.

[14] For the original derivation of the Hodrick-Prescott filter, which decomposes macroeconomic time series into trend and cyclical components, see Robert J. Hodrick and Edward C. Prescott. "Postwar U.S. Business Cycles: An Empirical Investigation." *Journal of Money, Credit, and Banking* 29 (February 1997): 1-16. The one-sided variant, which uses current and past data alone to estimate these two components, is described by James H. Stock and Mark W. Watson. "Forecasting Inflation." *Journal of Monetary Economics* 44 (October 1999): 293-335. Ireland

Importantly, the "one-sided" nature of this filter means that only current and past – but not future – observations of velocity are used to estimate $V_t^*$. This allows the model to be used for forecasting and policy evaluation in real time.

The red lines in each panel of figure 3 superimpose these estimates of $V_t^*$ on the plots of the velocities themselves. While deviations of velocity from its estimated long-run value occur throughout the sample, these deviations tend to be small and short-lived. Likewise, estimates of the natural rate of output $Y_t^*$ produced with the one-sided Hodrick-Prescott filter yield a series for the output gap, defined as the percentage-point difference between real GDP $Y_t$ and the natural rate $Y_t^*$, that as shown in figure 4 tracks historical business cycles quite well and can also be computed in real time.

Hallman, Porter, and Small test the quantity-theoretic implication of the P-star model by regressing the quarterly changes in the inflation rate, $\Delta\pi_t$, on a constant, four of its own lags, and the lagged value of the "price gap," defined as the percentage-point difference between the value of $P_t^*$ implied by (2) and the aggregate price level $P_t$. Specifically, their econometric model is

$$\Delta\pi_t = \alpha_0 + \alpha_1\Delta\pi_{t-1} + \alpha_2\Delta\pi_{t-2} + \alpha_3\Delta\pi_{t-3} + \alpha_4\Delta\pi_{t-4} + \beta(p_{t-1}^* - p_{t-1}) + \varepsilon_t, \qquad (3)$$

where the difference between $p_t^* = 100\ln(P_t^*)$ and $p_t = 100\ln\,(P_t)$ measures the price gap, $\pi_t = 4(p_t - p_{t-1})$ measures the annualized rate of inflation, $\Delta\pi_t = \pi_t - \pi_{t-1}$ is the change in inflation, and $\varepsilon_t$ is a regression error that, as usual, is assumed to be normally distributed with zero mean and constant variance and uncorrelated with the regressors as well as its own lagged values.

(2022) and Reynard (2023) also show how quantity-theoretic links between money and prices appear much stronger once slow-moving trends in velocity are accounted for.

The quantity theory implies that the least squares estimate of the slope coefficient $\beta$ in (3) should be positive. When $P_t^*$ is above $P_t$, inflation must accelerate as the effects of past monetary expansion work to increase prices and thereby close the price gap. And when $P_t^*$ is below $P_t$, inflation must decelerate as the effects of past monetary tightening work to decrease prices and close the price gap. As promised, therefore, the model uses information in the current level of the money supply to forecast future changes in inflation, while at the same time accounting for the gradual adjustment of velocity and real GDP back to their long-run equilibrium levels.

Table 1 reports estimates from the P-star regression (3), obtained both from the full samples of data – beginning in 1959:1 for M2 and 1967:1 for Divisia M2 and Divisia M4 and, in all cases, running through 2023:1 – and for the subsample starting in 1990:1, just as the original P-star model of Hallman, Porter, and Small began to break down. The estimates of the key parameter $\beta$ are always positive and highly statistically significant. Across all six cases combining the three measures of money and two sample periods, these estimates range from 0.10 to 0.16 – strikingly similar to the value of 0.148 obtained by Hallman, Porter, and Small with data on M2 from 1955:1 through 1998:4.[15] These estimates imply that a one-percentage-point price gap is associated, one quarter ahead, with a rise in inflation between 0.10 and 0.16 percentage points. Most importantly, the estimates point to the continued usefulness of the quantity theory of money – and the P-star model in particular – for predicting the effects that monetary policy will have on inflation.

[15] See Hallman, Porter, and Small (1991), p.847.

**Implications for Monetary Policy**

As a useful by-product, the P-star model yields real-time estimates of the price gap, plotted for all three measures of money in figure 5. These graphs confirm that monetary policy was extraordinarily accommodative during 2020 and 2021: the large and positive price gaps during those years imply that monetary policy was putting strong upward pressure on the inflation rate. By the same price-gap measures, however, monetary policy is more restrictive today that it has ever been over the postwar period, including the Volcker disinflation of the early 1980s and the financial crisis of 2008.

These most recent price-gap readings are reassuring, in that they confirm that the series of aggressive interest rate increases implemented by the Federal Reserve since early 2022 are working, as intended, to bring inflation back down to target. But they also send a strong note of caution. The Fed should now wait, as those past policy actions to have their full effects on inflation, before raising rates any further.

Figure 5 also reveals these recent price-gap swings, from large and positive to large and negative, appear like exaggerated versions of the cyclical movements that occurred throughout the 1970s. This resemblance raises a broader concern: do the recent patterns in money growth signal an unwelcome return of the "stop-go" patterns of alternating monetary ease and tightness that, according to Robert Hetzel, fueled both macroeconomic volatility and rising inflation during the 1970s?[16] Back then, as in 2021, the Fed held interest rates too low for too long during the "go" phase as the economy emerged from recession. In response to the sharp rise in inflation

[16] See Chapter 18, "Stop-Go and the Collapse of a Stable Nominal Anchor," in Robert L. Hetzel. *The Federal Reserve: A New History*. Chicago: University of Chicago Press, 2022.

that inevitably followed, the Fed would raise interest rates too far and too fast during the "stop" phase, pushing the economy back into recession.

The quantity theory of money, embodied in the P-star model, emphasizes the importance of maintaining more stable money growth and recognizes that monetary policy's effects on inflation appear only with a substantial lag. These quantity-theoretic principles should guide the Fed, as it brings inflation back down today and seeks to re-establish an environment of price stability in the future.

**Appendix: Data Sources**

Quarterly data on M2, nominal GDP, real GDP, and the GDP deflator, 1959:1 through 2023:1, are taken from the Federal Reserve Bank of St. Louis' Fred database (https://fred.stlouisfed.org). Data on Divisia M2 and M4, 1967:1 through 2023:1, are quarterly averages of monthly series from the Center for Financial Stability (https://centerforfinancialstability.org/amfm_data.php).

**Table 1. Estimated P-star Forecasting Equations for Changes in Inflation using Money**

Dependent variable: Change in inflation $\Delta\pi_t$.

Independent variables: Constant, four quarterly lags of changes in inflation, lagged price gap $p^*_{t-1} - p_{t-1}$ based on the indicated measure of money.

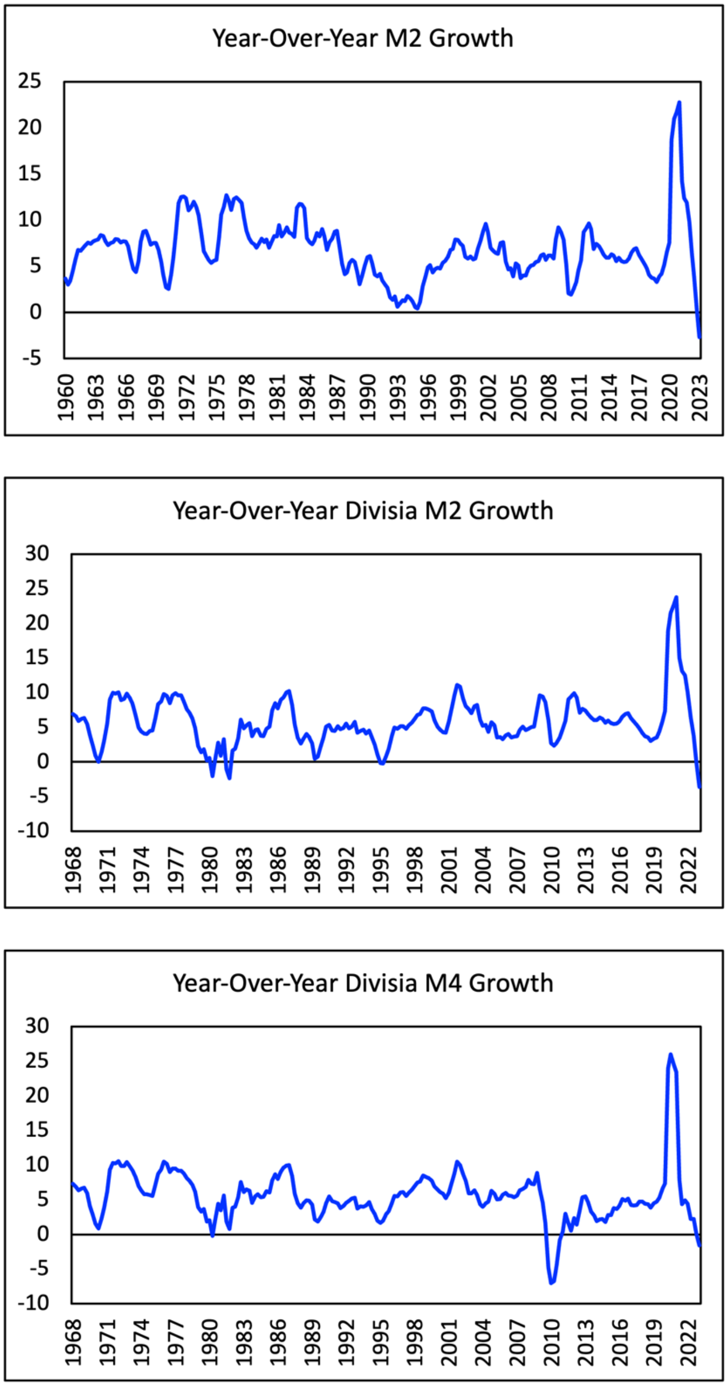
Full Sample: 1959:1 – 2023:1 (M2) or 1967:1 – 2023:1 (Divisia M2 and M4)

| | M2 | | | Divisia M2 | | | Divisia M4 | | |
|---|---|---|---|---|---|---|---|---|---|
| | estimate | *t* stat | *p* value | estimate | *t* stat | *p* value | estimate | *t* stat | *p* value |
| constant | 0.01 | 0.10 | 0.92 | –0.02 | –0.21 | 0.83 | –0.02 | –0.23 | 0.82 |
| $\Delta\pi_{t-1}$ | –0.35 | –5.76 | 0.00 | –0.36 | –5.51 | 0.00 | –0.35 | –5.29 | 0.00 |
| $\Delta\pi_{t-2}$ | –0.17 | –2.55 | 0.01 | –0.16 | –2.29 | 0.02 | –0.14 | –2.02 | 0.04 |
| $\Delta\pi_{t-3}$ | 0.00 | 0.05 | 0.96 | 0.00 | 0.01 | 0.99 | 0.02 | 0.24 | 0.81 |
| $\Delta\pi_{t-4}$ | 0.12 | 1.90 | 0.06 | 0.12 | 1.82 | 0.07 | 0.14 | 1.98 | 0.05 |
| $p^*_{t-1} - p_{t-1}$ | 0.12 | 4.31 | 0.00 | 0.10 | 4.22 | 0.00 | 0.10 | 3.99 | 0.00 |

Recent Sample: 1990:1 – 2023:1

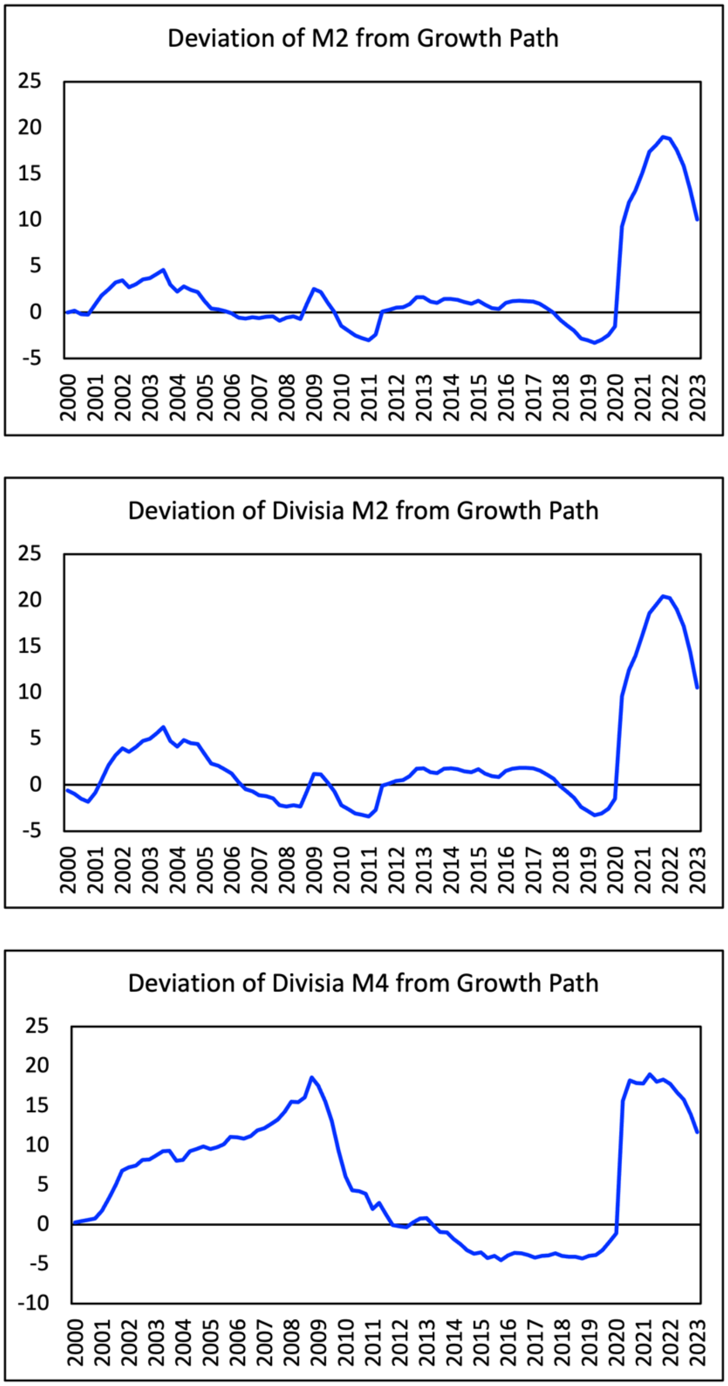
| | M2 | | | Divisia M2 | | | Divisia M4 | | |
|---|---|---|---|---|---|---|---|---|---|
| | estimate | *t* stat | *p* value | estimate | *t* stat | *p* value | estimate | *t* stat | *p* value |
| constant | –0.05 | –0.59 | 0.56 | –0.03 | –0.36 | 0.72 | –0.02 | –0.24 | 0.81 |
| $\Delta\pi_{t-1}$ | –0.47 | –5.52 | 0.00 | –0.48 | –5.68 | 0.00 | –0.42 | –4.91 | 0.00 |
| $\Delta\pi_{t-2}$ | –0.23 | –2.46 | 0.02 | –0.24 | –2.63 | 0.01 | –0.16 | –1.76 | 0.08 |
| $\Delta\pi_{t-3}$ | –0.07 | –0.66 | 0.51 | –0.08 | –0.82 | 0.41 | –0.01 | –0.12 | 0.91 |
| $\Delta\pi_{t-4}$ | –0.04 | –0.47 | 0.64 | –0.05 | –0.56 | 0.58 | –0.01 | –0.10 | 0.92 |
| $p^*_{t-1} - p_{t-1}$ | 0.16 | 4.84 | 0.00 | 0.16 | 5.05 | 0.00 | 0.11 | 4.00 | 0.00 |

**Figure 1. Money Growth Rates**



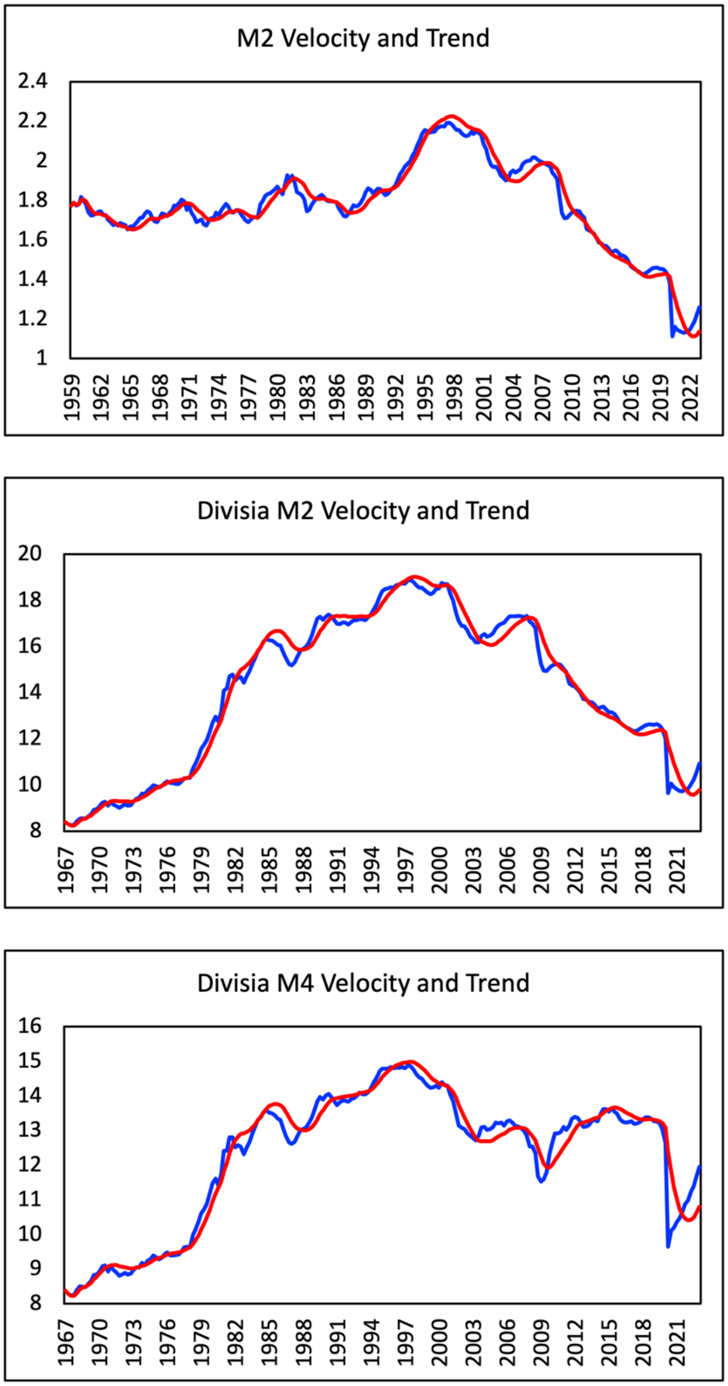

*Note:* Each panel shows the year-over-year percentage growth rate of the indicated monetary aggregate.

**Figure 2. Deviations of Money from Growth Paths**



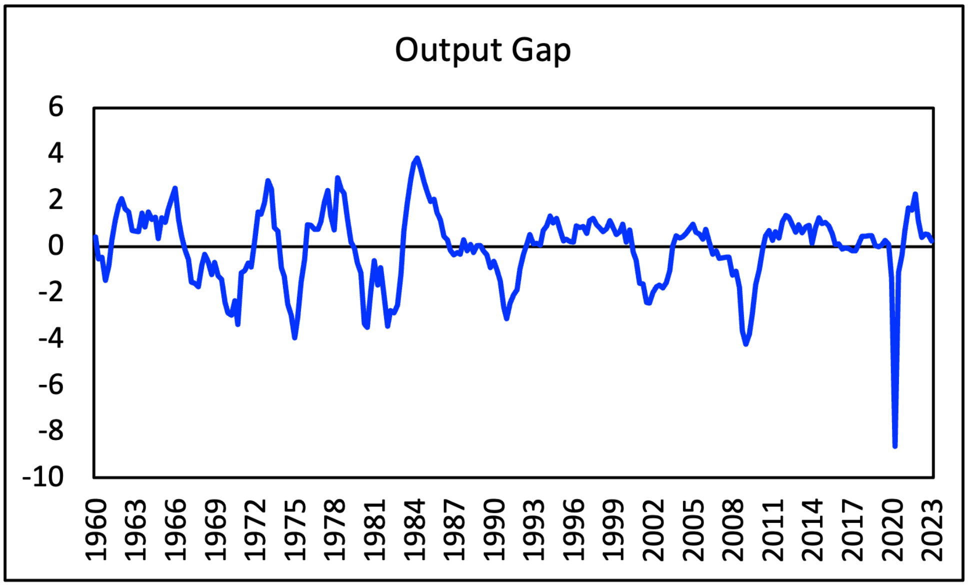

*Note:* Each panel shows the percentage-point deviation of the indicated monetary aggregate from a constant growth path: 6.1 percent annually for M2, 6.0 percent annually for Divisia M2, and 4.5 percent annually for Divisia M4.

**Figure 3. Monetary Velocity and Trends**



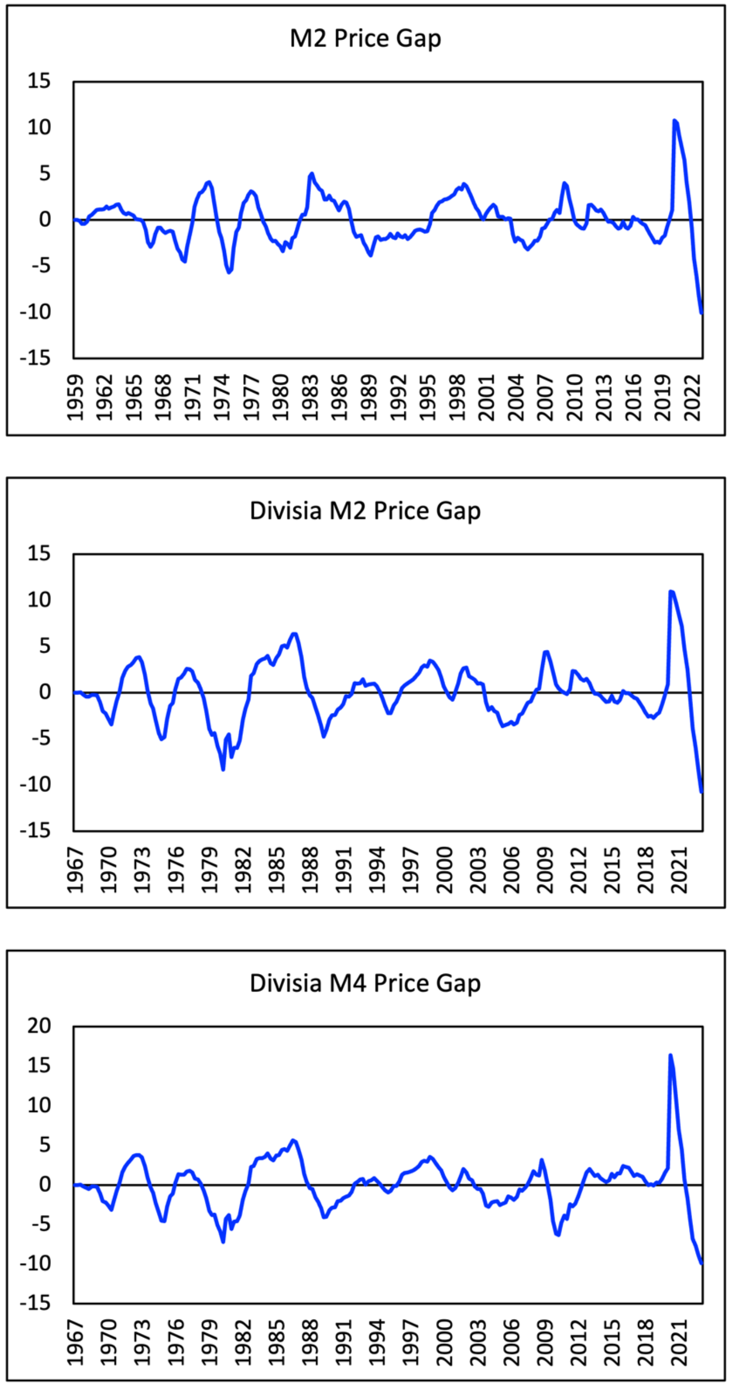

*Note:* Each panel shows the velocity (blue line) of the indicated monetary aggregate, calculated by dividing nominal GDP by the monetary aggregate, together with a shifting long-run trend (red line), computed using the one-sided Hodrick-Prescott filter.

**Figure 4. Output Gap**




*Note:* The output gap is calculated as the percentage-point difference between the level of real GDP and the natural rate of output computed using the one-sided Hodrick-Prescott filter.

**Figure 5. P-star Price Gaps**




*Note:* Each panel shows the P-star price gap computed using the indicated monetary aggregate. Positive values indicate periods when monetary policy puts upward pressure on inflation; negative values indicate periods when monetary policy puts downward pressure on inflation.