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The Recent Rise in US Inflation: Policy Lessons from the Quantity Theory*

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Abstract

We build a scenario for inflation in the United States in the years to come. Following Gao, Kulish, and Nicolini (2021), we use the quantity theory of money as a conceptual framework and confront the theory with evidence from both the United States and other OECD countries. We argue that a) the quantity theory of money works very well in the medium term, which we define to be close to four years; b) deviations from the inflation rate predicted by the quantity theory tend to disappear in the medium term; c) the burst in inflation that started in 2012 in the United States is a deviation from the inflation rate predicted by the quantity theory; and d) if the policy framework does not change, we expect inflation to be back close to its 2% target no later than 2025.

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1 Introduction

A relatively sudden and persistent increase in inflation started by April 2021 in the United States and continued till the third quarter of 2022, with some decline by the last quarter of that year.[1] In certain circles, this event generated fears that an experience similar to the ones in the seventies could happen again.

In the first part of this paper (Section 2), we first review a simple theoretical apparatus known as the quantity theory of money(QTM), which explains the forces behind inflation in the medium term. We purposely leave the definition of "medium term" to be ambiguous at this point. The main objective of Section 2 below is to defend a specific quantitative definition. We then present some evidence that supports the theory. This section heavily borrows from Gao, Kulish, and Nicolini (2021). The main purpose of this discussion is to derive some general principles to be applied in the second part. Specifically, we argue that monetary forces – that is, monetary policy – are the driver of inflation over the medium term, which we argue is somewhere between three and four years. This section corresponds to step a) in the abstract.

In the second part (Section 3), we use this apparatus to assess possible future scenarios for inflation in the United States, which details steps b), c), and d) in the abstract. Specifically, we conclude that as long as the Federal Reserve maintains the Federal Reserve's monetary policy framework, the risk of repeating the events of the seventies is very low. The most likely scenario we foresee is one in which inflation gradually goes down and approaches its target of 2% no latter than 2025. A necessary condition for this scenario to happen is the absence of major shocks like the COVID pandemic in 2020 and 2021 or the Russian invasion of Ukraine in 2022. This conclusion is the result of the general principles mentioned above. The burst in inflation started in 2021, and our analysis implies that there may be limits on what monetary policy can do in the short run. However, over the medium run, which we

[1]Similar experiences were faced by many other countries, but we will focus mostly on the United States in this note.

argue is between three to four years, sound monetary policy can deliver an inflation rate close to the target.

Our main conclusion is derived assuming that monetary authority controls a short-term interest rate, as is the case currently in the United States. In the mainstream New Keynesian models used nowadays for monetary policy analysis, it is assumed that the quantity of money passively adjusts. In this case, monetary aggregates convey no useful information for policy, so there is no reason to monitor them. Under this view, there is no sense in which the current burst in inflation can be associated with monetary policy, and a proper management of policy in the future can deliver price stability in a couple of years.

However, we also consider the case, typically dismissed in monetary policy discussions, in which monetary aggregates may have an impact on inflation above and beyond the effect the short rate has. We mention, very briefly, theoretical frameworks that allow for this possibility and evaluate the recent evidence. Under this scenario, there is a reason to be concerned about the future evolution of inflation: standard monetary aggregates are substantially higher than in the past and above what simple theories would imply, given the current values for the interest rates. Taken at face value, this logic does imply that there may be more inflation coming in the future. However, we do raise concerns about the usefulness of these measures in circumstances in which the short-term interest rate is very close to its zero lower bound, as it was in 2021 in the United States, when inflation started to rise. Some features of the data suggest to us that there are endogenous forces that will substantially reduce the monetary aggregates from the very high values they had by the end of 2022.

So far, our discussion implicitly assumed, as it is customary in the literature, that the monetary authority can unambiguously control intermediate targets as the short term interest rates or monetary aggregates broader than just high powered money. We believe these are the right assumptions for the United States today.

In summary, while we believe that monetary policy in the United States is on the right track to bring inflation close to its target, there is a risk that inflation may take longer to converge to the target if the endogenous forces that should bring monetary aggregates back to the normal levels take longer to act. Closely monitoring monetary aggregates seems to us a useful complement to monetary policy.

The notion that after four years, the economy behaves as if prices are flexible is consistent with both the micro evidence on the frequency of price changes and with the macro evidence of calibrated models. As we show below, this notion is also consistent with past evidence from the Unites States and some other developed countries.

We provide a specific view of what the quantity theory of money represents. We adopt the view proposed in Lucas (1980) and further developed in Gao, Kulish, and Nicolini (2021). This view differs in key dimensions from some of the famous writing of Friedman, examples of which are Friedman (1959) and Friedman (1970). Specifically, Friedman endorsed the view that monetary policy carried on via a control on a short-term nominal interest rate would lead to instability, so he strongly favored a monetary rule aimed at controlling a narrow monetary aggregate. Lucas's definition, which we describe below, does not take a stand on the target of monetary policy, nor on the adopted target in analyzing the data. We discuss this very briefly below and in detail in Gao, Kulish, and Nicolini (2021).

2 Theoretical framework

We follow Lucas (1980) in interpreting the quantity theory of money as being represented by two equations: a demand for real money balances and a Fisher equation. For the demand for real money, we assume the well-known squared root formula popularized by Baumol (1952) and Tobin (1956). How this functional form can be derived in a general equilibrium model and how it relates to other standard empirical specifications is discussed in detail in Benati, Lucas, Nicolini, and Weber (2021).

The first equation involves the relationship between the real money demand and the interest rate:

$$\ln \frac{M_t}{y_t P_t} = \frac{1}{\sqrt{i_t}} \varepsilon_t, \tag{1}$$

where M_t is the nominal quantity of money, y_t is real output, i_t is a short-term nominal interest rate, P_t is a price index, and ε_t is a zero-mean stochastic process.

Taking logs and computing the difference over two consecutive periods, we obtain a relationship between growth rates of the money stock μ_t, the price level π_t, output g_t^y, the interest rate g_t^i and the shock g_t^ε:

$$\mu_t = \pi_t + g_t^y - \frac{1}{2} g_t^i - \frac{1}{2} g_t^\varepsilon. \tag{2}$$

.

We treat the term g_t^ε as an unobservable stationary stochastic variable with mean zero, which should cancel out in relatively long periods. All other variables in the equation are observable.

The Fisher equation can be written in its log-linear version as

$$i_{t+1} = r_{t+1} + E_t \pi_{t+1}, \tag{3}$$

where i_{t+1} is the interest rate on a risk free nominal bond, r_{t+1} is the risk free rate on a real bond, and $E_t \pi_{t+1}$ is the expected inflation rate.

Equation (3) involves an expectation term. But we can write

$$\pi_{t+1} = E_t \pi_{t+1} + \xi_{t+1}^\pi,$$

where ξ_{t+1}^π is a zero mean shocks, independent from any variable in the information set at time t. Thus, for the empirical implementation we use

$$i_{t+1} = \pi_{t+1} + r_{t+1} - \xi^{\pi}_{t+1}, \tag{4}$$

and we treat ξ^{π}_{t+1} as a zero mean unobservable shock, so the sum should cancel out in relatively long periods of time. Both inflation and nominal interest rates are observable. However, real interest rates are not, since inflation-index bonds in the United States were introduced only in the early 2000s. We further discuss this issue below, when we discuss the empirical implementation.

Equations (1) and (3) are equilibrium conditions that hold for a very general class of monetary models, including different frictions that affect the monetary transmission mechanism. They describe the evolution of three key nominal variables – the quantity of money, M_t, the nominal interest rate, i_t, and the price level, P_t – together with the evolution of two real variables: the real interest rate, r_t, and real output, y_t.

In the background, the reader is expected to entertain her preferred model that will complete the equilibrium conditions with equations that describe the evolution of the real variables of the model included in equations (1) and (3), as well as all other real variables that do not appear in equations (1) and (3), like total labor, investment, real wages, and the like.

In order to derive the two main empirical implications of the QTM as defined in Lucas (1980), we must assume that money is neutral. This implies that the real variables in equations (1) and (3) – namely, y_t and r_t – are determined by the other equations of the model and are essentially unaffected by the nominal variables.

Under these conditions, equations (1) and (3) form a system of two equations in three variables, (M_t, i_t, P_t). To close the model, we need to specify a monetary policy rule. This rule could be specified in terms of the sequence of money supplies $\{M_t\}_{t=0}^{\infty}$, and then equations (1) and (3) can be used to solve for $\{P_t, i_t\}_{t=0}^{\infty}$. An alternative would be to define the policy rule in terms of nominal interest rates $\{i_t\}_{t=0}^{\infty}$, so equations (1) and (3) then solve for $\{P_t, M_t\}_{t=0}^{\infty}$.

In either case, the two implications of the QTM are that inflation moves one to one with interest rates and that inflation moves one to one with the growth rate of money relative to output, once the corresponding adjustment is made for changes in nominal interest rates. In this sense, the QTM implies that inflation is controlled by monetary policy, independently of the specific monetary policy instrument.

In models with frictions, like staggered price setting of segmented markets, money is not neutral. Thus, while it is still the case that equations (1) and (3) are equilibrium conditions, the causal effect on impact can be very different. Imagine, for instance, an extreme case in which prices next period are all fixed ex-ante. Then, expected inflation ought to be zero. Imagine also that the monetary policy instrument is the short-term interest rate. Then, equation (3) implies that monetary policy changes have a one-to-one effect on the real interest rate, without affecting inflation expectations on impact.

Most models with frictions used in monetary economics, including the ones with price frictions or segmented markets, do assume that there is monetary neutrality "in the long run." Thus, initially, monetary policy may have real effects, but these dissipate as time goes by.

The remains of this section summarizes the analysis in Gao, Kulish, and Nicolini (2021). Its purpose is to evaluate the ability of equations (1) and (3) to match data, once short-run fluctuations are filtered away. Specifically, we explore how well and, more importantly, at which frequency the implications of equations (1) and (3) with flexible prices are evident in the data.

The largest value added of the analysis is to obtain a quantitative definition of the medium run. We then use that definition to draw inferences regarding the evolution of inflation in the US from 2023 onwards, based on the current framework for policy in the United States. This evaluation of policy is the purpose of Section 3.

We emphasize that by adopting Lucas's view of the QTM, we do *not* mean that monetary policy has been or ought to be carried on by a control of monetary aggregates, although it is consistent with that possibility.

What QTM means in our definition is that inflation is determined by monetary policy over a long enough period of time. This is consistent with the assumption of money neutrality coupled with the assumption that the monetary authority has full control of either the nominal interest rate i_t or the monetary aggregate M_t.

It is important to highlight that equations (1) and (3) are fully consistent with the small-scale three-equation New Keynesian model. The usual assumption in those models is that monetary policy is executed via an interest rate rule. Thus, money endogenously responds to movements in prices, interest rates, and output. This model implies that prices, interest rates, and output cause money.

More importantly, the key assumption in the New Keynesian model is that there are frictions in the setting of prices, so the causal relationship between interest rates – or money growth – and prices is quite different in the short run from that in the model with flexible prices. However, even in that model, the QTM implications hold in the long run.

Our summary of the results in Gao, Kulish, and Nicolini (2021) is based on less restrictive assumptions. We only look at correlations between output-adjusted money growth, nominal interest rates, and inflation, without taking a stand on the direction of causality. And we do so after filtering the data, so we do not need to take a stand on the specific frictions that determine the inflation dynamics in the short run.

Later, in Section 3, our policy analysis of the current situation will loosely refer to models with price frictions, as devices to qualitatively rationalize the recent events.

2.1 Empirical Analysis

In this section, we briefly summarize the discussion in Section 3 of Gao, Kulish, and Nicolini (2021). We focus on the results for the United States and, as a comparison, also for Canada.

The objective is to filter the data and evaluate the two QTM implications. We first briefly discuss the data, then the filter we use, and finally present the results.

We use the short-term interest rate on government debt for i_t, measures of gross domestic product for y_t, and the CPI for P_t. For the monetary aggregate, we use the sum of currency and checkable deposits, or $M1$, for Canada. For the United States, following the analysis of Lucas and Nicolini (2015), we also add the Money Market Demand Accounts (MMDAs), which were introduced in 1984 and served similar purposes as demand deposits.[2] In the Appendix, we explain the data in detail.

As mentioned above, we do not have direct evidence on the behavior of the real interest rate, since index bonds were introduced only in the early 2000s. Thus, in analyzing the evidence for the United States, we treat the variable r_t as unobservable.

Then, as a check, we compare the implied value for r_t from equation (4) with the data starting in the early 2000s, which is when inflation-indexed bonds became traded in the United States.

When considering the Canadian data, we will assume, as Gao, Kulish, and Nicolini (2021) do, that because of capital market integration between the United States and Canada, the real interest rate ought to be similar in the two countries. So we can use the United States data plus equation (4) to compute a real rate for Canada.[3] Then, in evaluating the illustration 1 (equation (3)) for Canada, we treat the real interest rate also as observable and use the one estimated for the US.

Owing to frictions in the functioning of markets that create non-neutrality effects, the key to unraveling the empirical power of our model is to separate the data between short-lived movements and the more long-lived ones. The specific way this is done determines a particular definition of "long run," which we use for policy analysis in Section 3. We discuss the filter next.

[2]As argued in Lucas and Nicolini (2015), the regulatory change that introduced the Money Market Demand Accounts explains the apparent instability of money demand in the United States. As shown by Benati et al. (2021), this apparent instability of money demand is specific to the United States.

[3]See Gao, Kulish, and Nicolini (2021) for further details.

2.1.1 The filter

We use the Hodrick-Prescott (HP) filter to decompose the data.[4] One advantage of that filter is that the decomposition made between cycle (or high frequency) and trend (the low frequency) is controlled by a single parameter, typically called λ.

We want to calibrate the value for λ using data other than inflation, which is the variable that our theory wants to explain. Thus, we follow Gao, Kulish, and Nicolini (2021) and use the monetary policy experience with the short-term interest rate in the US for the last 60 years. Specifically, they propose choosing the lowest value for λ that removes the tightening cycles from the federal funds rate. By "tightening cycle", we mean the periods in recent US monetary history of increases in the federal funds target rate, presumably done to affect the cyclical behavior of the US economy.

In Figure 1(a), we plot the value for the short-term nominal interest rate. In Figure 1(b), we decompose the interest rate into a low- and a high-frequency component with $\lambda = 100$. As becomes clear from the picture, the low frequency obtained using the parameter equal to 100 does remove all the tightening cycles.

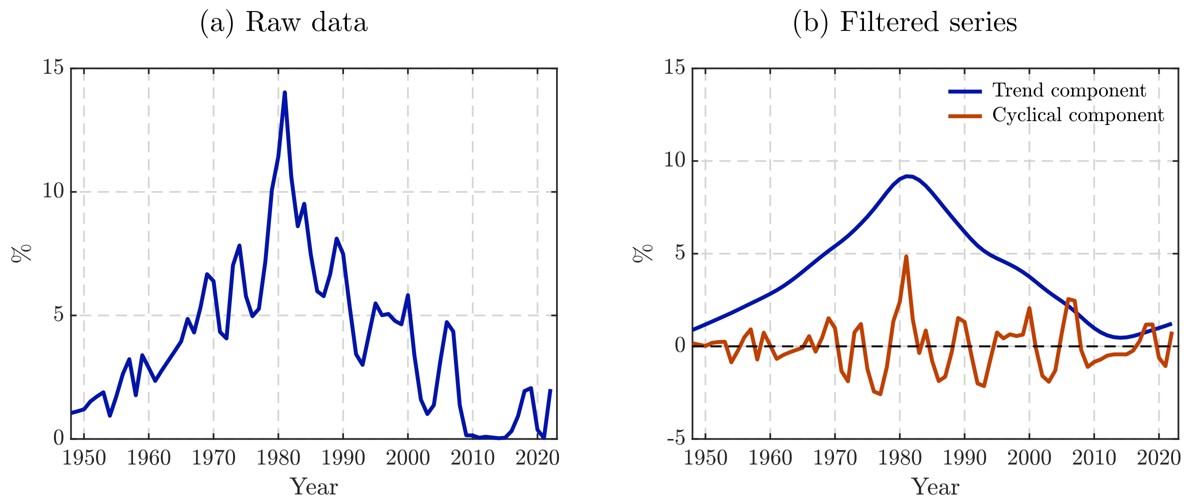

Figure 1: US nominal interest rates

In Figure 1(b), the tightening cycles correspond to the portions of the curve above the

[4] Results are very similar with other filters. See Gao, Kulish, and Nicolini (2021).

horizontal axis, while the easing cycles correspond to the periods when the curve is below it. The average cycle is 3.5 years, with a maximum of 6 for the tightening cycle that starts in 1994 and ends in 2000. The shortest is the easing cycle that lasted two years at the end of the '60s.

Our preferred interpretation of the filter we use, then, is that we leave out of the data all fluctuations around our trend that last around four years on average, which amounts to the average duration of the monetary policy tightening cycles in the United States.

2.1.2 Results

Figure 2 depicts the two illustrations for the United States. In Figure 2(a), illustration 1 shows the low-frequency component of inflation, together with the low frequency component of the theoretical value for inflation according to equation (2) . To compute the theoretical value, we first filter the growth rates of money, output and the nominal interest rate, and use those values in the equation. The two series move together to a large extent. The most noticeable failure in the theory happens precisely in the early 80s. These are the years in which new regulations were introduced that changed the way agents made transactions, as we mentioned above. Specifically, as discussed in detail in Lucas and Nicolini (2015) in those years two new accounts were created, the NOW accounts and the MMDAs. Those accounts were very similar to demand deposits, but they could pay interest. These changes led to a large substitution away from the traditional demand deposits and into the two new accounts. The NOW accounts were included in the definition of M1, but the MMDAs were not. After less than a year of being introduced, the MMDAs amounted to around 10% of GDP.

Once the regulatory changes are taken into account in the theory, the MMDAs should be included in the definition of M1, as argued in Lucas and Nicolini (2015). Once this is done, a stable real money demand function arises in the data. But, in line with the theory, the regulatory change may affect both the level of the real money demand and the slope.

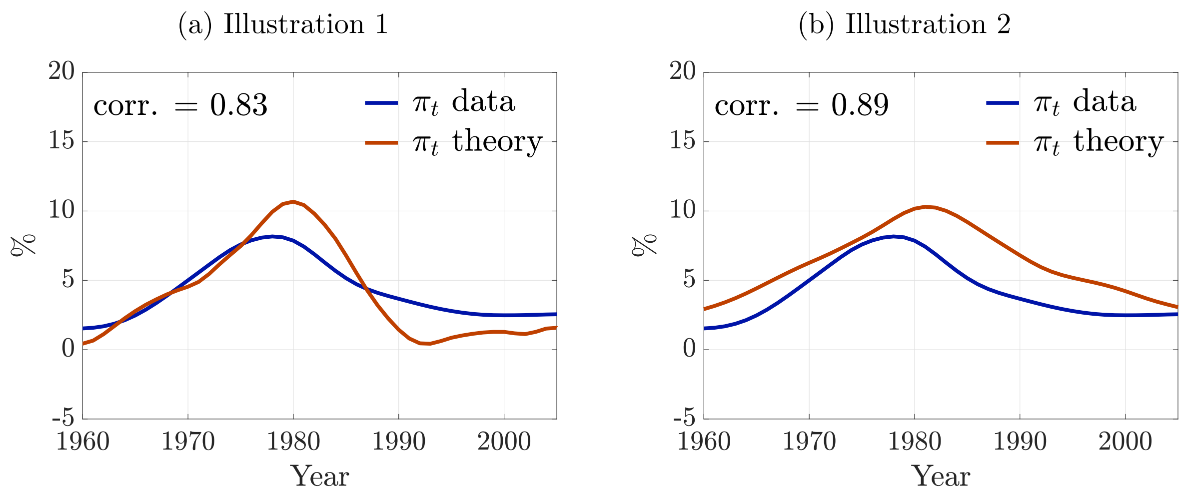

Figure 2: Two illustrations for the US, HP filtered

As we are using a single curve defined in (2) to fit the entire period, these changes are not included in our simple theory.[5]

Figure 2(b) depicts illustration 2, which shows the low frequency component of inflation, together with the low-frequency component of the theoretical value for inflation according to equation (4) . To compute the theoretical value, we filter the nominal interest rate in the data and treat the real interest rate as unobservable. The correlation coefficient is reported in the figure.

The two series move together to a large extent. But it is clear from the figure that the theoretical value overestimates the inflation rate for most of the period, until sometime in the early 2000s, when the gap becomes essentially zero. This pattern is consistent with a positive real interest rate for most of the period, but one that decreases from the '80s onwards and becomes negative after the financial crisis that broke in 2008. This is indeed what many estimates suggest the real interest rate did (see, for example, Bauer and Rudebusch (2020)). It is also consistent with the behavior of the return on Treasury Inflation-Protected Securities (TIPS), as Figure 3 shows. The TIPS are available only at long-term maturity, so in plotting Figure 3, we use the five year bond. We adjusted

[5]It is possible to use the model to estimate the magnitudes of the changes in the level and the slope. We are currently working on that project; see Gao and Nicolini (2023).

that rate for a 0.5% average term premium. This term premium between a five year inflation-adjusted bond and a three month one is obtained by interpolating an estimated linear term structure of interest rates, using the last 10 years of data on interest rates on existing TIPS maturities.

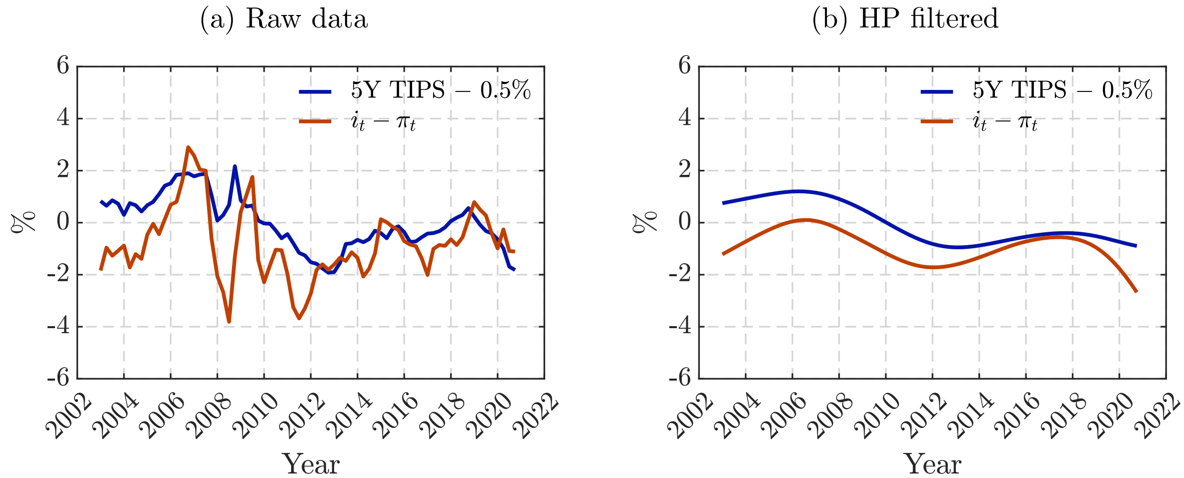

Figure 3: Co-movements with TIPS
Notes: Data is quarterly, filtered with smoothing parameter $\lambda = 1600$.

For completeness, we also report the results using Canadian data. Two reasons motivate this decision. First, under the assumption that capital markets are reasonably integrated between the two countries, real interest rates would tend to be the same. Thus, we can *assume* that the Fisher equation (4) holds in the United States, use the equation to estimate a real interest rate, and treat that estimate as the real interest rate in Canada. Thus, if indeed there was a downward trend in the real interest rate in the United States and Canada, as many studies show, this would not bias our illustration 2 for the case of Canada. The second reason is that Canada did not go through a regulatory change in the early '80s, so we do not have a theoretical reason to expect any differential behavior in deposits during that period. Figure 4 is similar to Figure 2, but uses Canadian data. As expected, neither of the two issues discussed in the case of the United States appear in this case.

A visual inspection of the filtered data in Figures 2 and 4 supports the first bullet of the abstract; that is, that the QTM works very well in the medium term, which we define

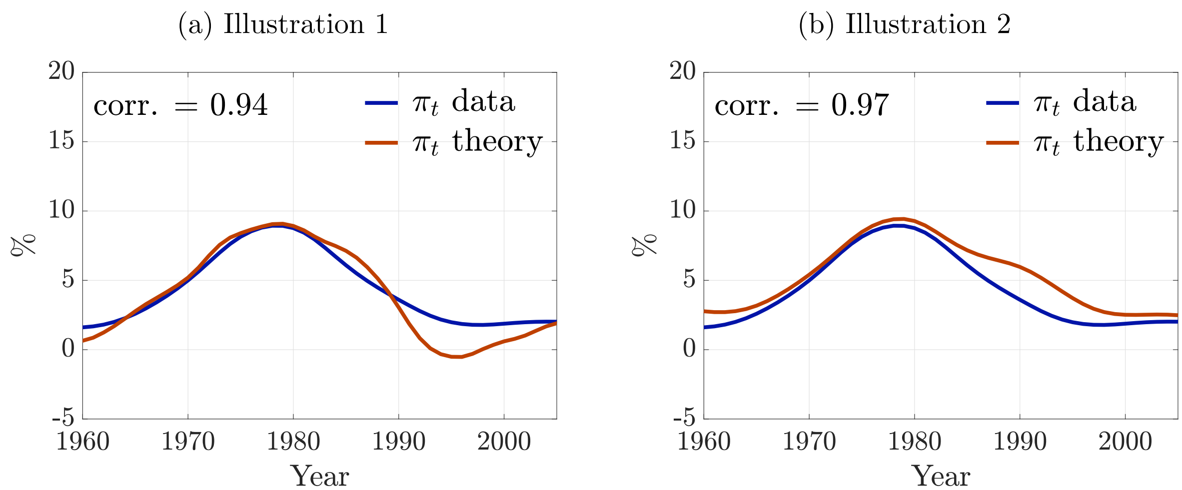

Figure 4: Two illustrations for Canada, HP filtered

to be close to four years. It is also consistent with Lucas's comment in his 1980 paper:

"The two quantity-theoretic propositions ... possess a combination of theoretical coherence and empirical verification shared by no other propositions in monetary economics."

2.1.3 The case of the zero bound

A caveat is in order regarding illustration 1. As documented in Benati and Nicolini (2021) and in Gao, Kulish, and Nicolini (2021), identifying the behavior of (1) at very low values for the interest rate is very difficult in practice. This is so for both theoretical and empirical reasons.

From the theory side, the derivation of equation (2) typically implies assuming that money is return dominated by bonds. But the equation may hold as an inequality only if the nominal interest rate in bonds is close to zero. Small details of the environment can change substantially the implications of the theory.

From the empirical side, it has been only very recently that short-term nominal rates have been close to zero, so it proved difficult to bring data to discipline the lack of precision of our theories. But we now have recent experiences with low interest rates. The most prominent case is Japan, which kept its policy rate essentially at zero for the last 25 years.

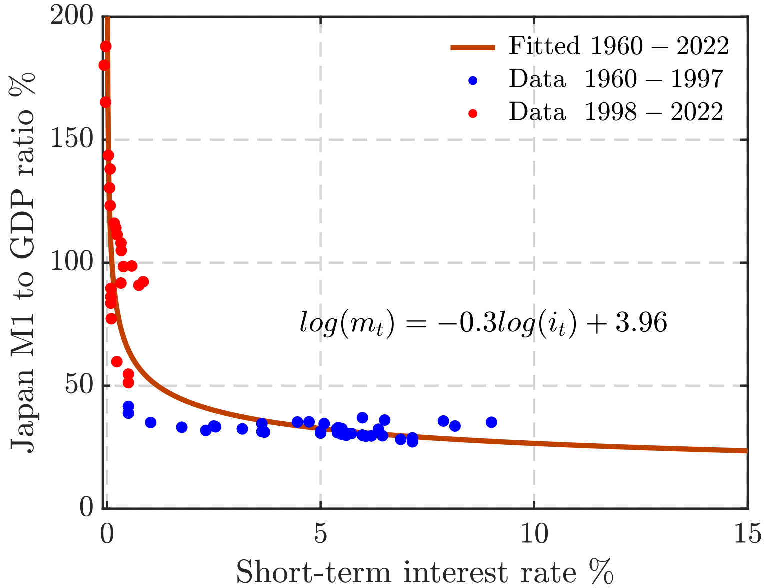

Figure 5: Real money demand for Japan

Notes: The fitted line is estimated using yearly observations with positive interest rates between 1960 and 2022.

The evidence in Japan is consistent with the model's lack of precision. In Figure 5, we plot the ratio of money to output against a short-term interest rate from 1960 to 2022. In addition to the data, we also plot a constant interest rate elasticity real money demand function similar to (1), but one whose interest rate elasticity is chosen to fit the data, rather than imposing a 0.5 value, as implied by the Baumol-Tobin specification.

The figure makes clear that once the interest rate became lower than 1%, the value for real money demand oscillated between 40% and 200% of output.

One could interpret this fact as a situation in which short-term bonds or higher order deposits have no clear advantage to cash or zero interest bearing checking accounts, which are the components of M1. Thus, all those assets are perfect substitutes, and the portfolio composition is indeterminate.

A similar pattern emerges when considering the case of the United States post-2008, when the Federal Reserve lowered the interest rates to almost zero. It was only in 2016 that rates started increasing. They did so until 2018 and then went back toward zero in March 2020. Rates remained at zero until April 2022, when the steepest tightening in decades started. Figure 6 shows the data in three different patterns.

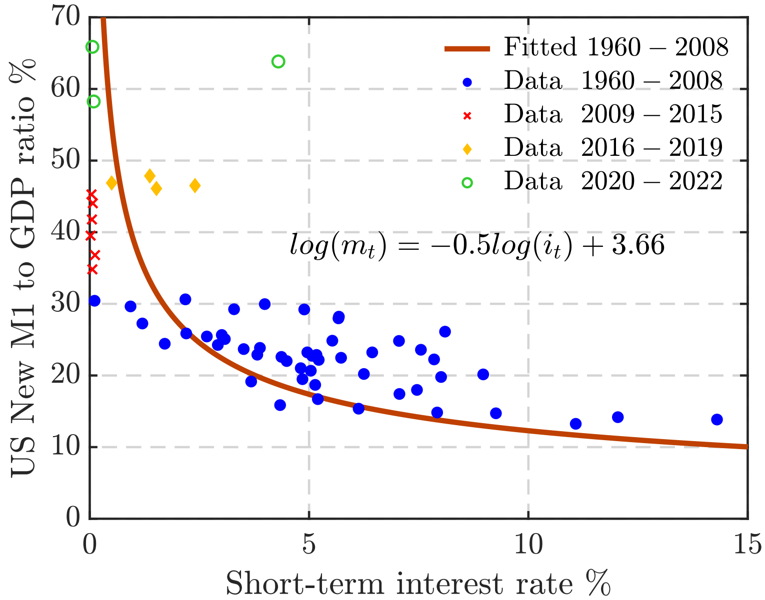

Figure 6: Real money demand for the US, annually

Notes: The fitted line is estimated using yearly data between 1960 and 2008 by imposing a money demand elasticity of 0.5.

The blue dots correspond to the values from 1960 until 2008. The red crosses correspond to the years 2009 till 2019, while the green circles correspond to the years 2020 and 2021. As the picture make clear, the values of real money demand for the years 2009 till 2014 are very different from the values in 2020 and 2021, in spite the fact that the nominal interest rate was essentially the same. We will come back to the difficulty of identifying the behavior of real money demand when rates are very low when we discuss current events at the end of Section 3. For more details on this issue, the reader is directed to discussions in Benati and Nicolini (2021) and Gao, Kulish, and Nicolini (2021).

3 Policy analysis: The recent inflation surge

We start this discussion by quantifying a measure of our ignorance. In Figure 7(a), we separately plot the medium-run (low-frequency) and the short-run (high-frequency) components of inflation for the United States from the end of World War II until 2019. In what follows, we focus our discussion on the short-run component of inflation. This is the component that our theory is unable to explain, which we encompass in the stochastic terms ε_t and ξ_t^{π}.

(a) Cyclical component

(b) Postive cycles

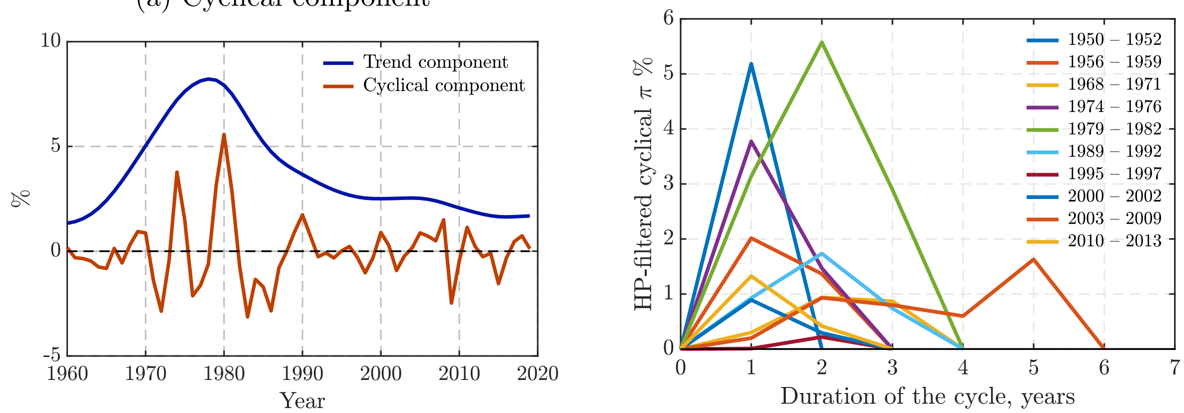

Figure 7: Cyclical component of US inflation 1948–2019
Notes: Data is yearly, filtered with smoothing parameter $\lambda = 100$.

As the figure makes clear, there are substantial – albeit temporary – deviations of inflation around its monetary policy determined trend. There are a plethora of shocks that can generate the behavior of the cyclical component observed in Figure 7(a). It is tempting to relate the spike right after WWII to the lifting of price controls that were prevalent until 1945, the spike in the early 50s to the supply chain shortages during the Korean War, and the spikes in the 70s to the oil price shocks.

What we want to emphasize is that while some of the spikes are sizable, they are short-lived. In fact, none of them lasts more than four years, as Figure 7(b) shows, with the only exception being the six year period between 2003 and 2009. This period was characterized by the rally in asset prices and in primary commodity prices. The difference between inflation and its trend was very small and, in most years, below 1%. In Figure 8, we present similar figures for Canada, and the message is essentially the same.

We mostly abstract from discussing the specific reasons why inflation can have large and temporary spikes. However, we now briefly discuss a specific view of what drove inflation

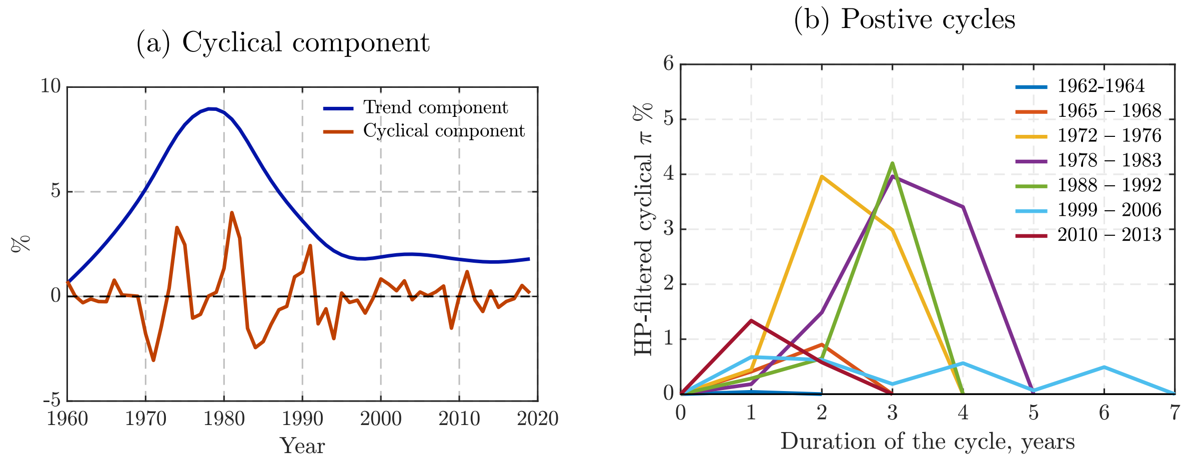

Figure 8: Cyclical component of Canada inflation 1960–2019
Notes: Data is yearly, filtered with smoothing parameter $\lambda = 100$.

up in the United States from April 2021 onwards. The purpose of this discussion is to argue that the magnitude of the COVID shock was to some extent comparable to the ones mentioned above.

Figure 9 updates a figure discussed in a very interesting paper by Martin (2022) and presents the evolution of the three main components of personal consumption expenditure in the United States in 2012 dollars. What we observe is an immediate drop in all consumption categories following the lockdowns due to COVID in 2020. But, more importantly, as the immediate effects of the pandemic start to fade away and overall consumption recovers, we see that goods consumption (both durable and non-durable) goes above its pre-COVID trend, whereas service consumption remains substantially below pre-COVID trend.

This massive reallocation shock to spending has its counterpart in the evolution of prices. Figure 10 also updates a figure discussed in Martin (2022) and shows the evolution of the price indexes of each of the three components of spending described in Figure 9. As Figure 10 makes evident, the low inflation experienced by the United States in the years before COVID was a combination of a relatively higher inflation in services, essentially zero inflation in non-durable goods, and some deflation in durable goods. Then, on impact, the COVID crisis implies a drop in the three price indices, consistent with the deflation observed in the second quarter of 2020. But once the initial shock recedes and the reallocation shocks becomes evident, the trend in both durable and non-durable goods reverts. At the same time, the trend in the price level of services resumes.

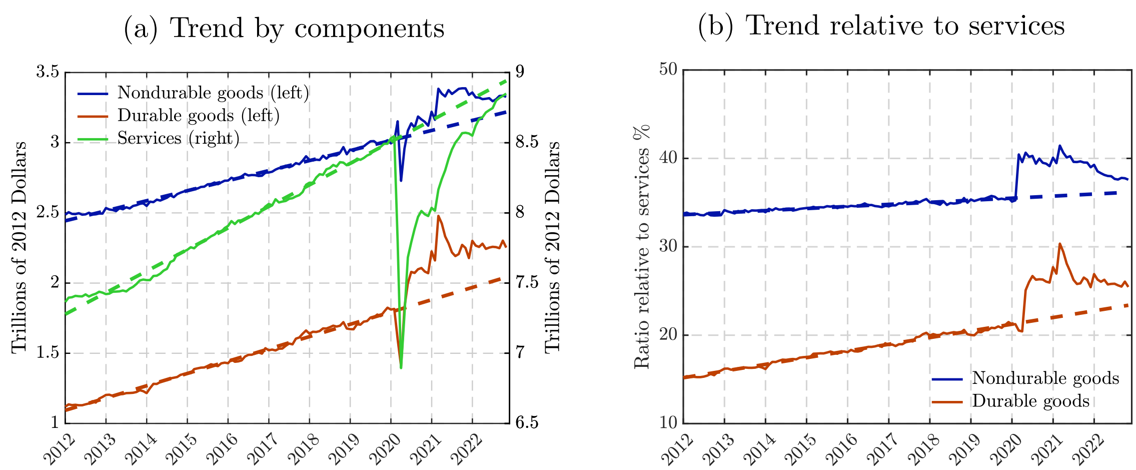

Figure 9: Real PCE by major components

Notes: Solid lines are raw monthly data. Dashed lines are interpolated values using linear trends between 2012 and 2019.

This narrative is consistent with the very interesting analysis of supply chain disruptions in Alessandria, Khan, Khederlarian, Mix, and Ruhl (2023a). It shows that supply chain disruptions, measured as average delivery days, are clearly and positively associated with inflation, not only during the recent COVID crisis but also during the Korean War and the oil shock spikes depicted in Figure 7(a).

Thus, in a purely accounting sense, the recent rise in inflation is fully explained by the differential behavior of the prices of goods. This differential behavior is fully consistent with the reallocation shock: the relative price of goods must rise, especially in the short run, when installed capacity is hard to change. This relative price story is of course not enough to explain why inflation went up: the same relative prices could be obtained by a lower increase in prices in both goods and services so as to maintain inflation at the 2% target or, for that matter, any other average inflation rate. This is where short-run price stickiness plays a role: to the extent that prices of services exhibit some downward stickiness, the

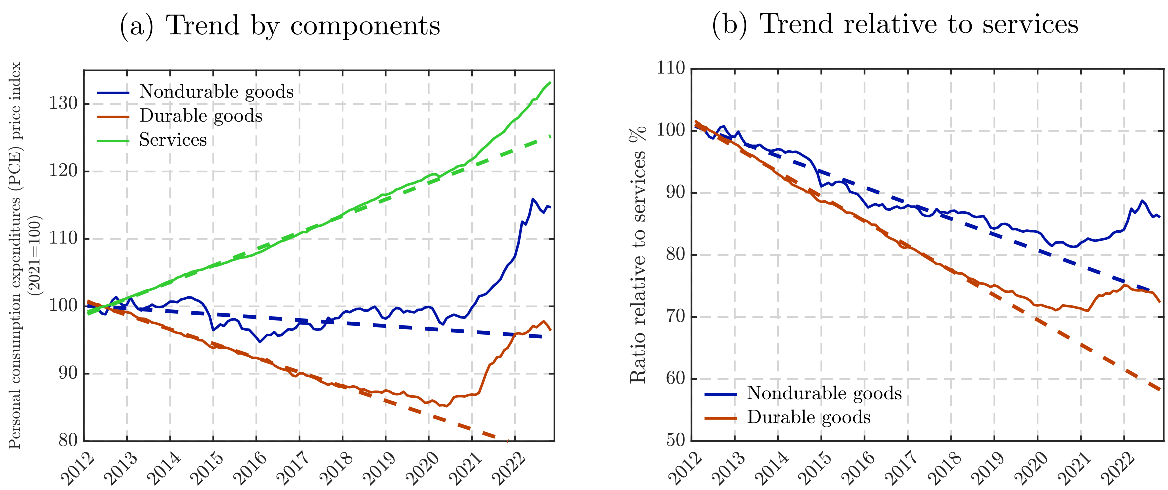

Figure 10: PCE price index by major components

Notes: Solid lines are raw monthly data. Dashed lines are interpolated values using linear trends between 2012 and 2019.

only way relative prices can converge to their new equilibrium value is through a higher average increase of prices.[6]

If we take this story as a good approximation of current events, then it is natural to expect a deceleration of inflation, since as the figures show, the reallocation shock started to subside by the first quarter of 2022. Figure 9 shows that for both categories of goods, total spending is converging back to pre-COVID levels, relative to services. As the reallocation shock has been ebbing for several quarters now, relative prices are also reverting back to its previous trend. This deflationary force in both goods categories should remain a force towards a convergence of inflation to its target, as long as the policy framework does not change and no other major shocks hit the economy. This is consistent with the evidence in Alessandria, Khan, Khederlarian, Mix, and Ruhl (2023b): average delivery days peaked by mid-2022, then started to go down, roughly at the same time that inflation did so.

This narrative, which emphasizes the interaction between a massive reallocation shock and price rigidities, has implications for the ability of monetary policy to fight inflation in the short run. The reason is that monetary policy, at least according to the lessons of

[6]Notice that this logic is based on asymmetric restrictions on price setting, as for instance in Schmitt-Grohé and Uribe (2016).

mainstream models, operates through its effect on aggregate demand. Thus, it is not clear that aggregate demand manipulation is a good remedy to deal with a reallocation shock. See, for instance, the analysis in Guerrieri, Lorenzoni, Straub, and Werning (2022).

Will this short-run deviation be longer that the ones in the past? We do not know; we are not aware of reallocation shocks of this magnitude in recent history. However, major shocks like the 1974 oil price increase did not last that long - inflation itself did last way too long, but what explains most of the permanent rise in inflation in the '70s is the permanent shift in the medium term stance of policy, as documented in Figure 7(a). In addition, the shock started to reverse by the beginning of 2022 (Figure 9(b)), and the reversal started to affect the relative prices by mid-2022 (Figure 10(b)), roughly at the same time that inflation rates started to go down.

In an accounting sense, for the low and stable inflation rate that prevailed in the United States from 2012 till 2019 to return, non-durable goods prices must return to a zero trend behavior, and durable consumption goods prices return to the 1,5% deflation experienced during the pre-COVID period. The reversal of the reallocation shock depicted Figure 9 and Figure 10 suggests an optimistic stance is reasonable.

One could clearly argue against price-level trends turning back to what they were before the COVID shocks, an assumption implicitly adopted in the previous paragraph. These trends respond to different productivity growth rates across sectors, which may be permanently different from now onwards. But, as argued in Section 2, over a four year period, monetary policy can control inflation. Thus, whatever the new trends in relative prices that prevail in the post-COVID period, our evidence suggests that by 2025, the current monetary policy framework ought to bring inflation close to its target.

In the remainder of this section, we discuss the role of policy by taking a stand on which is the intermediate instrument of monetary policy. We start by considering the short-term nominal interest rate as the policy target, which is the most common assumption in the literature. We then go on and consider the possible effect of monetary aggregates on inflation. In either case, we ignore possible difficulties the monetary authority may have in controlling those intermediate targets. For example, in setting the short-term interest rate, we rule out possible runs against the policy of the type considered in Bassetto and Phelan (2015). In discussing monetary aggregates, our first exploration abstract from the role of banks in the money creation process. But in the final discussion, the interaction between banks and depositors will play an important role.

3.1 When the short-term rate is the policy instrument

In this section, we assume that monetary policy is done by controlling an interest rate, which, in the case of the United States is the federal funds rate (FFR). Can monetary policy be blamed for the inflation burst from the perspective of the quantity theory?

The answer is clearly negative. Figure 11 makes this point clear by plotting the evolution of inflation and the FFR since 2000. It shows that inflation started to grow when the interest rate was almost zero and kept on rising well above the level of the FFR. There is therefore no indication of inflation responding to a perceived increase in the medium-term component of the the short-term interest rate, as the theory discussed in Section 2 would require. On the contrary, the behavior of inflation resembles the spikes depicted in the high frequency components of Figure 7(a).

As additional evidence, Figure 11 also shows the interest rate on five- and ten-year government bonds for the last ten years. Long-term rates show no expectations by the market of short-term interest rates increasing persistently as they did in the late '70s.[7] It is worth pointing out that long-term rates were very sluggish in the late '60s and early '70s, in the sense that they did not anticipate the posterior rise in short rates and inflation. And long rates exhibited a similar behavior, but in the other direction, in the early '80s. Thus, this evidence ought to be interpreted with care.

The substantial rise in interest rates observed in 2022 is explained by Federal Reserve's

[7] The notion that permanent and temporary changes in interest rates have very different effects on inflation has been developed in detail in a recent paper by Uribe (2022).

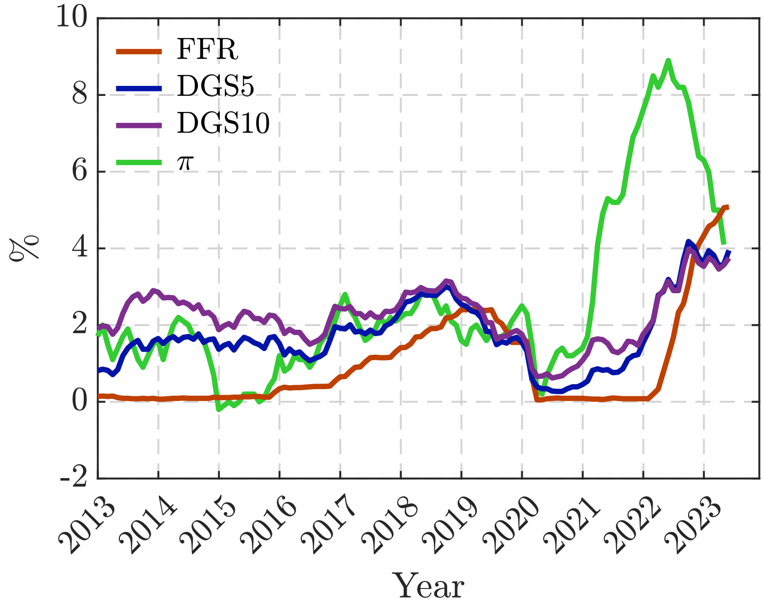

Figure 11: Inflation and fed funds rates in the US since 2013
Notes: DGS5 and DGS10 refer to market yield on U.S. treasury securities at 5-year and 10-year constant maturity, respectively.

attempt to reduce inflation, following the New Keynesian theory of short-term fluctuations. According to this theory, the short-run effect on inflation of a temporary increase in the interest rate is negative.[8] This is the right policy action if one wants an immediate effect on inflation, given the theory of the transmission mechanism of monetary policy embedded in the New Keynesian model. It is in the context of this theory of short-run fluctuations that the Federal Reserve has been criticized for delaying the response for too long after inflation started to climb, as we discuss below.

In the medium run, which we take it to be around four years, for inflation to go back to its target, the interest rate should converge to the perceived equilibrium value for the real rates, that can be estimated from the return of TIPS plus the value of the 2% target. Thus, if the current value of the real rate, around 1.5%, were to stay at that value for the next few years, a medium-run target for the nominal interest rates is 3.5%. This number is roughly in line with the value of the long rates in the last couple of quarters, as shown in

[8]Note that the sign is the opposite of the one in our theory for the medium run, in which inflation goes up one to one with the interest rate. Uribe (2022) masterfully integrates these seemingly contradictory views.

Figure 11.

Figure 11 also shows that while the rise in interest rates lagged the rise in inflation, it has been catching up in the last quarters. This is consistent with our discussion so far, focusing on the notion that the interaction of real shocks with price rigidities generates only short-lived departures of inflation from the target implied by policy. And it is also consistent with the fact that inflation rates have been going down in the last two quarters. If one is willing to adopt the the usual New Keynesian assumptions in the short run, this increase in the FFR ought to ameliorate the burst in inflation.

As noted above, the Federal Reserve has been heavily criticized for not reacting quickly enough. For instance, the cover of the April 2022 edition of the Economist read, "The Fed that Failed: How inflation humbled America's central bank." A full assessment of the best response to the COVID shock requires estimating a specific model and performing counterfactuals, which are well beyond the scope of this paper. But it is conceivable that the reallocation shock implied an abnormally low value for ξ^{π}_{t+1} – albeit a temporary one – on which monetary policy had little room to act, precisely because policy acts on aggregate spending, and by 2021, the economy was facing a reallocation shock.

And it is also conceivable that even if monetary policy could have partially avoided the burst in inflation, the distortions created by the price frictions would have implied a large efficiency cost of doing so.

As it turns out, there are other episodes in history in which the inflation rate spiked up and overshot the nominal interest rate. In our interpretation of the events, as we describe them below, the shocks that hit the United States or the other countries that we consider were different in nature from the recent COVID reallocation shock. However, as we argue now in each case, the evolution over time of the gap between inflation and the interest rate exhibited common patterns that are, coincidentally, consistent with our four-year definition of the medium run implied by the behavior of the short-term nominal interest rate.

Our theory, together with the evidence provided, implies that by controlling medium-term interest rates (or average growth of monetary aggregates) the central bank controls medium-term inflation. But this logic does not apply on a quarter-to-quarter or even a year-to-year basis. We interpret those short-run events as prices responding to real shocks interacting with frictions that are beyond the control of monetary policy, which are captured in our theory by non-zero values for the shocks ε_t and ξ_t^π. Imagine, for instance, an increase in consumption taxes. This directly affects the measure of the price level, in a way that does depend on the existing frictions and is unrelated to monetary policy.[9]

In order to shed light on current events, we review previous situations in which there was a sudden burst of inflation overshooting the nominal interest rate. We do so for past episodes in the United States and for several other examples in other developed economies.

3.1.1 The historical evidence: the United States

Figure 12 depicts the behavior of yearly inflation and the FFR at monthly frequency since 1940. There are several instances in the last decades in which inflation increased abruptly and overshot the nominal interest rate, as documented in Figure 13. The first case coincides with the start of WWII. There is a second case right after the end of WWII, which we identify with the lifting of price controls that prevailed during the war. A third burst occurs in 1950, coinciding with the Korean war. A fourth burst takes place around the time of the end of the Bretton Woods period and the first oil shock at the end of 1973.

There is another episode of inflation being above the interest rate right after the 2008 financial crisis, which lasted several years. However, we believe that event to be of a very different nature, since there was no burst in inflation. Rather it was the policy rate that undershot inflation during a period of negative real rates, as evidenced by the return on TIPs. The fifth event is the one that started in 2021 and that motivates this paper.

For ease of exposition, we plot in Figure 13 the difference between inflation and the

[9] Incidentally, a substantial literature developed to study precisely how taxes and monetary policy can impact the price level in similar ways. See for instance Adão, Correia, and Teles (2009), Correia et al. (2013) and Farhi, Gopinath, and Itskhoki (2014).

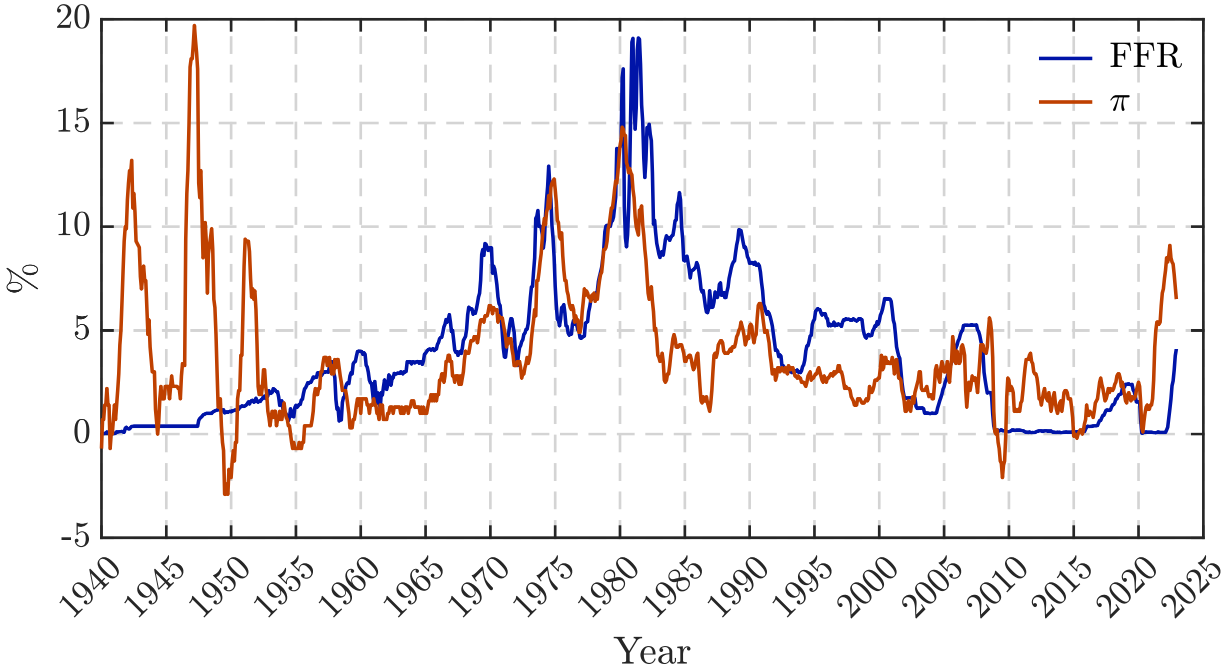

Figure 12: Annualized monthly inflation and interest rates in the US

nominal rate, setting to zero in each episode, the first month in which inflation was above the interest rate. As the figure shows, in all previous cases the overshooting lasted about four years or less.

The current episode appears as no outlier. It is true that a fraction of the gap was closed by the Fed's steep tightening during 2022. But that was also the case in some - but not all - of the other events. More importantly, a fraction of the gap was also closed by a reduction in inflation that became evident by the last quarter of 2022.

The figure shows that inflation did converge in all cases to the interest rate in a period that was no longer than four years. This four-year period is perfectly consistent with our definition of the medium run discussed in Figure 1 and used in Section 2 of this paper.

What Figure 13 hides, by construction, is the value at which both the inflation rate and the interest rate converged. But that is exactly what we wanted to analyze by focusing on the short run in this section! The value at which inflation converges after those four years, ought to depend, according to the analysis of the previous section, on the medium-term behavior of the interest rate.

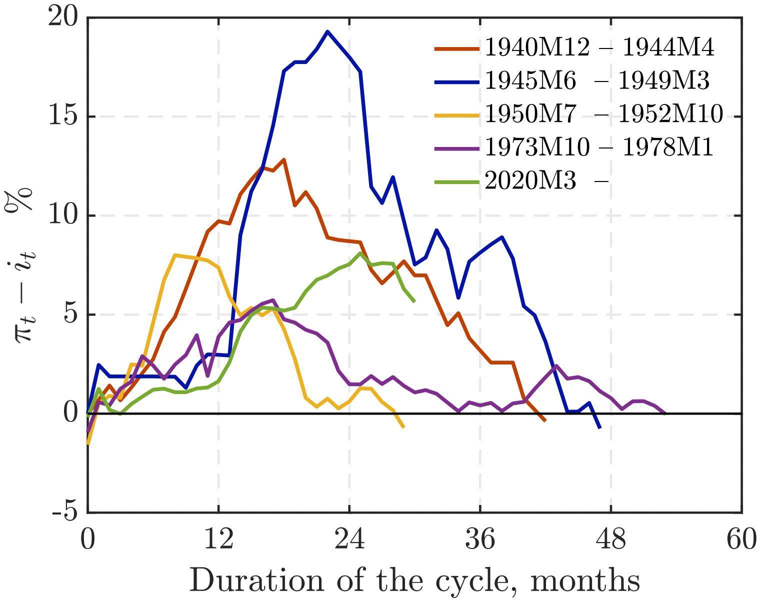

Figure 13: $\pi_t - i_t$ in selected episodes for the US

3.1.2 The historical evidence: Other developed countries and the oil shocks

Figure 14 is similar to Figure 13, but it shows quarterly data – rather than monthly – for other developed countries following the oil shock of late 1973.

A similar pattern emerges. While for most countries, inflation does overshoot the level of the short-term interest rate, the gap is essentially eliminated by 1978, four years after the shocks.

The evidence discussed in this section supports the last three bullets from our abstract: deviations from the inflation rate predicted by QTM tend to disappear in the medium term; the burst in USA inflation that started in 2012 is a deviation from the inflation rate predicted by the quantity theory; and if policy doesn't change, the prediction of the quantity theory is inflation close to the 2% target by 2025.

3.2 When the monetary aggregate is the policy instrument

The conceptual framework discussed in Section 2 implies that in the medium run, when the equilibrium behaves as if there were no restrictions, there is only one policy instrument.

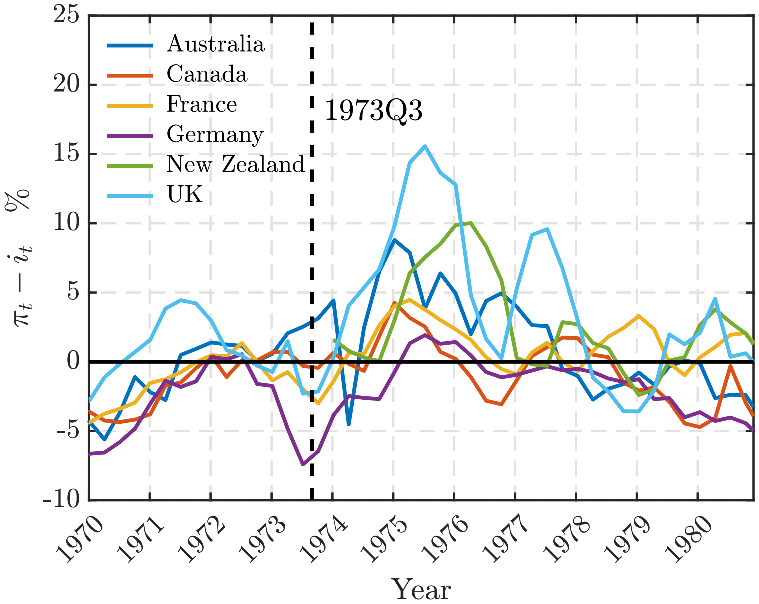

Figure 14: $\pi_t - i_t$ in the 70's for selected OECD countries

The empirical evidence provided is consistent with this view. Thus, if, as we assume in the previous section, the control of interest rates pins down the inflation rate, then the quantity of money passively responds to inflation, as implied by equation (1).

The same conceptual framework, on the other hand, is silent with respect to the potential independent roles that monetary aggregates and the short-term rate may have on the economy in the short run – that is, less than four years. Thus, one may argue, there is value in evaluating a specific event like the recent rise in inflation to look for risks that monetary aggregates may represent.

It is important to highlight that this is not the view of the mainstream modern New Keynesian models. In those models, monetary aggregates are a sideshow also in the short run, so no policy relevant information can be obtained by looking at monetary aggregates. If the reader is willing to adopt only this New Keynesian view, then the rest of this paper will be of no use for her. This is a real warning, since we have frequently found a reluctance to engage in a discussion that includes looking at the evolution of monetary aggregates.

In this section, we relax that view for three reasons. First, as we argue below, one of the policy responses to the COVID shock resembles, among other things, the closest thing to the "helicopter drop" experiment that Friedman popularized in his analysis of monetary policy decades ago. Second, the behavior of the ratio of monetary aggregates to real output - real money demand - does exhibit what can be called quite unusual features relative to past experiences, as we discussed in Figure 6. Finally, there are theoretical models that explore frictions that are not mainstream, like market segmentation, in which it is possible that in the short run, increases in the stock of money may have a short-run impact on inflation, above and beyond the effect of the policy rate.[10]

The analysis that follows will not be directed by any of those models. Rather, we just discuss the recent behavior of the monetary aggregates and evaluate the possibility that their rapid increase could be associated with the rise in inflation. These models are note quite ready for quantitative policy analysis, so we do not follow them closely. However, we believe that when making policy analysis in the short run, we need to consider all possibilities. That is what we do next.

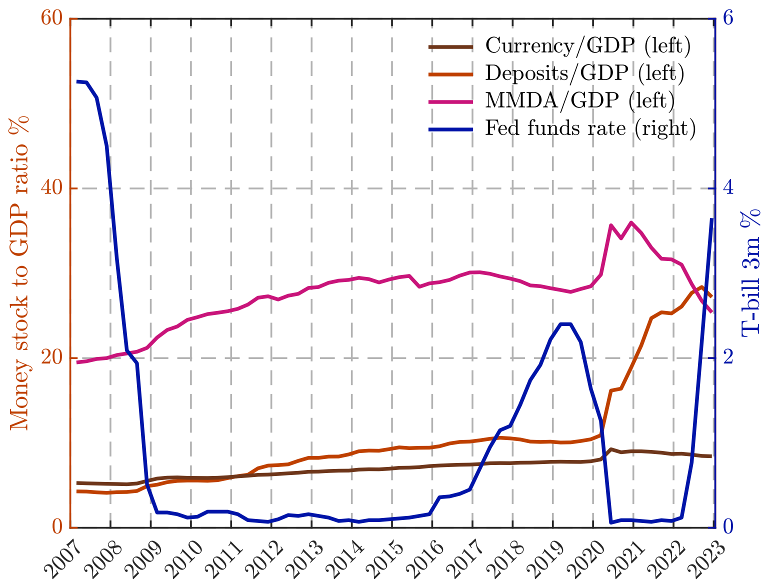

Figure 15: Components of M1 in the US

In Figure 15, we depict the evolution of each of the three components of the monetary aggregate for the United States (cash, demand deposits and MMDA) since 2007, together

[10]See for instance, Alvarez, Atkeson, and Edmond (2009), Alvarez and Lippi (2014), and Piazzesi, Rogers, and Schneider (2022).

with the short-term nominal interest rate. Each component is plotted as a fraction of total output. We can observe the large drop in interest rates that followed the financial crisis of 2008 and then the gradual increase over time of the three components of money. This sluggish response of each of the components is a common feature of real money demand. It can also be observed in Figure 6 as the vertical sequence of dots when the nominal interest rate is almost zero, indicated with red crosses.

Then, when the tightening cycle of 2016 begins, the three components start going down as a fraction of output - although the effect on cash is barely noticeable. This corresponds to the orange diamonds in the diagonal moving south-east in Figure 6.

When the interest rate suddenly goes back to zero because of the COVID crisis, the three components start going up substantially, qualitatively in line with the theory. But on impact, there is a clear heterogeneity not present before: while cash and MMDAs go up between 10% and 20%, checking accounts tripled. What explains this abrupt heterogeneity is the transfers made to households and firms as part of the policy reaction to the COVID crisis.

The increase in the monetary aggregates, particularly in the early quarters of the crisis, followed very closely the excess transfers made by the federal government. In Figure 16(a), we show the extraordinary transfers made by the federal government and the extraordinary increase in NewM1 above trend. In both cases, the units correspond to percentage points of total output (about 21 trillion by the last quarter of 2019).

In order to compute the extraordinary transfers, we compute a linear trend from 2013Q1 to 2019Q4. We extrapolate the trend until 2022, and we compute the extraordinary transfers as the difference between the observed transfers and the trend. The solid blue line in Figure 16(a) shows the ratio of government transfers to GDP in the raw data, and the dashed blue is the imputed trend. We proceed in a similar fashion in computing the extraordinary increase in NewM1 and depict its raw data and trend in Figure 16(a) as the solid and the dashed red lines.

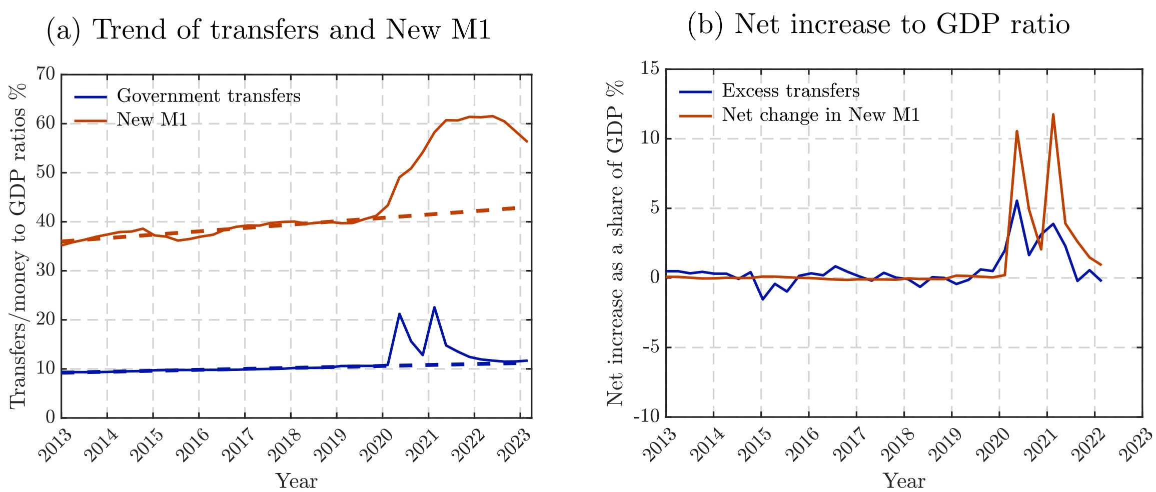

Figure 16: Government transfers and money stock in the US
Notes: Data is quarterly. In Panel (a), solid lines are raw data, and dashed lines are interpolated using linear trends between 2012 and 2019.

Figure 16(b) makes clear that initially, the transfers were saved as almost one-to-one increases in the monetary aggregate. In this way, the COVID policies resemble a "helicopter drop" of a sizable magnitude.[11]

This helicopter drop was made at a time in which the policy rate is zero. As time goes by, the new transfers were accumulated into the monetary aggregate, but in smaller proportions. Overall, in the first six quarters following the COVID shock, transfers were close to 30% of output, and a little more than half of that was accumulated into our measure of money by the first quarter of 2022, when the Federal Reserve started hiking rates.

Given the temporary nature of these transfers, a substantial fraction of them were saved by households. The natural question is why agents left their new savings in demand deposits, which do not pay interest. The answer is that the interest rate on higher order financial assets – like time deposit, that are not part of NewM1 – was essentially zero, like the policy rate. Thus, while a fraction – unknown to us – of those deposits were not

[11]Notice that this was not a direct intervention of the Federal Reserve. The transfers were made by the Treasury. However, this is a subtle difference, since the Treasury issued bonds to finance these transfers and the Federal Reserve bought those bonds.

transactional assets, households had no incentive to reallocate their portfolio towards less liquid assets.

What is striking is the heterogeneous response of the three assets. After 2020 both currency and the MMDAs start going down. The fall accelerates as the tightening cycle starts in 2022, while no such adjustment is observed in demand deposits. This extremely large increase in savings remained in the original asset in which the transfers were made: demand deposits.

This massive increase in the availability of means of transactions is consistent with increases in the price level. However, two caveats, which are related to some extent, must be mentioned. First, as discussed above, there is evidence that the relationship between money to output measures and the short-term interest rate, which is quite visible in the data when nominal interest rates are positive, becomes blurred when the interest rate is close to zero.[12] Second, and more importantly, the distinction between transactional assets, like cash and demand deposits, and less liquid assets that pay higher interest rates also becomes blurred when interest rates become near zero. The reason is that the incentives to transfer the extra 20% of output from a zero interest bearing asset, like demand deposits, to government bonds or savings accounts essentially vanished during 2021 and most of 2022.

The attentive reader probably noticed that our second caveat is an attempt to explain the empirical evidence provided in the first. As it turns out, this is an implication of models that go beyond a single aggregate and try to explain each particular assets, like the one in Freeman and Kydland (2000), which is based on earlier work by Prescott (1987).[13]

But the major paradox remains: why have households not moved their demand deposits into higher return assets much faster? We do not have an answer to that question, but we would like to note that this is not just households. During the recent Silicon Valley Bank crisis, we learned that technically sophisticated firms had demand deposits of hundreds of

[12]See Benati et al. (2021) and Benati and Nicolini (2021) for a detailed discussion.
[13]Lucas and Nicolini (2015) extend the model to include three assets.

millions of dollars that were making zero return.

In conclusion, on a first pass, one cannot reject the hypothesis that the large increase in transactional assets could explain the rise in inflation observed between the second quarter of 2021 and the last quarter of 2022. However, a puzzle remains: if this were the reason, why was inflation so much lower than the increase in transactional assets? We believe that really disentangling the role of monetary aggregates in explaining the burst in inflation will prove really hard. But a more important question is, What role can the excess of money over output play today in the evolution of future inflation?

The honest answer is that we do not know. Given the discussion above, our best guess is that the excess of money – demand deposits, really – over output today reflects the fact that households maintained their savings in their demand deposits, since, given the very low return on less liquid assets, they had little incentive to switch. As the interest rate rises, as it has been doing for over a year now, we expect to see a substantial flow out of demand deposits and into interest bearing assets that are not in our definition of money. As Figure 16(a) shows, this process already started in the second half of 2022.

To put it differently, the data suggest to us that this abnormal stock of demand deposits is the unique combination of a "helicopter drop" into checking accounts and a negligible interest rate differential between higher order assets and demand deposits. Under our interpretation, we should observe a very large transfer of resources from demand deposits to higher order assets in the quarters to come. Quantitatively, this transfer should be more than 20% of output, since the interest rate will be higher than in 2010-2020. But the lack of comparable previous experiences casts a shadow of doubt on the four bullets of our abstract.

4 Conclusion

In this paper, we reviewed the inflation experience of the United States following the COVID-19 shock. The conceptual framework adopted is the quantity theory of money, as defined in Lucas (1980).

Drawing heavily on the evidence provided in Gao, Kulish, and Nicolini (2021), we argue that the empirical implications of the quantity theory of money hold in the data once fluctuations that last less than four years are removed. This implies that, for instance, by controlling the short-term nominal interest rate, monetary policy can control inflation over a four year horizon. At this horizon, changes in the nominal interest rate translate one to one into changes in the inflation rate.

We argue this to be the case, independently of how real and nominal shocks affect the economy in the short run. We provide several examples from the history of the United States of shocks of different nature, in which this four year pattern appears consistent with the data. We also provide examples from the history of other countries in which this is also the case.

We then briefly review the recent policy experience with the short-term interest rate and with monetary aggregates. We conclude that the behavior of the short-term interest rate so far is fully consistent with inflation turning back close to its 2% target about four years after inflation started to increase in the spring of 2021. Thus, we expect this to happen no later than mid-2025. This scenario obviously requires that only the usual business cycle shocks hit the economy.

When looking at monetary aggregates, we show them to be substantially above the levels that should be normal given the current interest rates. However, we argue that this is consistent with a liquidity trap scenario, in which interest rates were at zero. Looking at the composition of money holdings across assets, we observe that only one of the components – demand deposits – became abnormally high by mid-2023, after the short-term rate has increased substantially. We suspect that this abnormal behavior is likely the lagged effect of agents not yet having fully adjusted their portfolios. We expect to see these portfolio adjustments intensify in the next quarters, as interest rates remain high.

We draw two policy implications from our analysis. The first relates to a recent debate regarding the short-run behavior of inflation. To the extent that the observed reduction in inflation slows down and a tighter policy is perceived as necessary by the Federal Reserve, opting for increasing the rate for a short period over keeping it high for longer periods appears as a better option.

Announcing a longer period of high rates may be signaling a more permanent change in rates, which, according to our analysis, can have a positive impact on inflation. On the other hand, a temporary increase in rates that will return to lower levels as inflation recedes is clearly perceived as temporary and ought not to carry a positive load on medium-term inflation. This debate between "higher rates" or "keep it high for longer" has been present in the press in the past months.

The second implication relates to the medium-run policy framework. Our discussion indicates that under severe real shocks, like the one experienced in 2020 (or in 1950, 1973,...), it proves really difficult - if not impossible - for standard monetary policy to control inflation in the short run. A natural monetary policy framework that takes this into account would define a target not as a number but as an interval – say, between 1% and 3%. And it would also specify that it aims at achieving that target over some period of time – say, three or four years.

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Online Appendix for

The Recent Rise in US Inflation: Policy Lessons from the Quantity Theory

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A Data

A.1 The United States

The series of nominal GDP, the three-month Treasury bill rate, currency in circulation, and "standard" M1 are collected from FRED.[14] Currency and the three-month T-bill rate are used as the measures of cash and the interest rate associated with it.

NewM1 The construction of NewM1 follows Lucas and Nicolini (2015):

$$\text{NewM1} = \text{M1} + \text{MMDAs}.$$

The Money Market Demand Accounts (MMDAs) series are constructed by aggregating term RCON6810 under Schedule RC-E from individual banks' call reports. The original data are publicly available at the Central Data Repository Public Data Distribution website of Federal Financial Institutions Examination Council.[15]

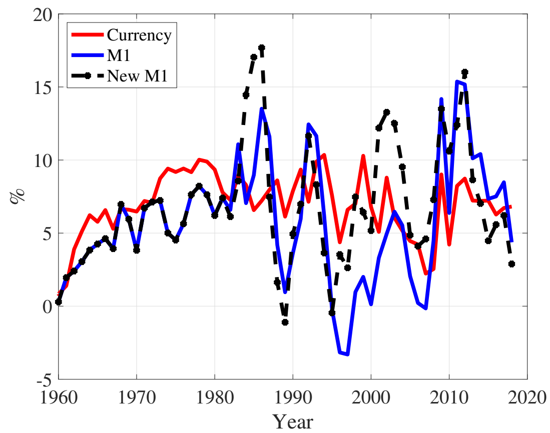
The MMDAs series have been issued since 1982Q3, but the data are available only after 1984Q2. We apply a linear interpolation of money growth rates for the periods in between. Figure A1 depicts the money growth rates of cash, the "standard" M1, and the New M1 series since 1960.

Imputed interest rate We impute the interest rate associated with the New M1 by subtracting the fraction of interest paid by deposits and by MMDAs from the three-month T-bill rate; that is,

$$\tilde{r} = r^{3\text{m}} - s_d i^d - s_a i^a,$$

[14] FRED: https://fred.stlouisfed.org/.
[15] FFIEC: https://cdr.ffiec.gov/public/.

(a) Raw data



(b) Filtered, $\lambda = 100$

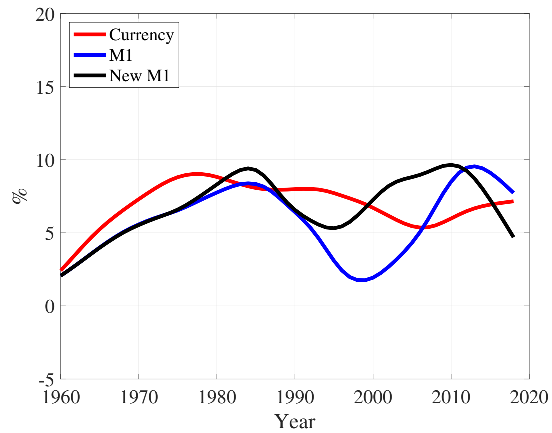


Figure A1: Money growth in the United States

where s_d and s_a are the ratio of deposits to NewM1 and the ratio of MMDAs to NewM1, and i^{3m},i^d, and i^a are the interest rates on three-month T-bills, deposits, and MMDAs, respectively.

Real interest rates The real interest rate is constructed by subtracting the three-month T-bill rate by inflation. In view of the lack of real interest rates for other countries, we use the real rates of the United States as the proxy of real rates in other countries for the quantitative illustration of Fisher equation. Figure A2(a) plots the constructed raw series of US real interest rates since 1960 and the HP-filtered series using smoothing parameter 100. Figure A2(b) compares the imputed real interest rates with interest rates on Treasury Inflation-Indexed Securities (TIPS) at five- and ten-year maturities. As can be seen from Figure A2(b), the difference between our imputed real interest rates and interest rates on long-term TIPS is very stable over time.

A.2 Other OECD countries

In addition to the US, we also use data for a broader set of OECD countries — namely, Australia, Canada, France, Germany, Japan, New Zealand, and the UK. We collect data for prices, money stock M1, GDP, and interest rates for each country. In view of the lack of real GDP, we collect data of nominal GDP in local currency and impute real GDP with prices. The main source for nominal interest rates and M1 is the OECD data website, and the main source for nominal GDP is the International Financial Statistics (IFS) of the International Monetary Fund (IMF).[16] We collect data starting from 1960 for all countries

[16] OECD data: https://data.oecd.org/; IFS data: https://data.imf.org/.

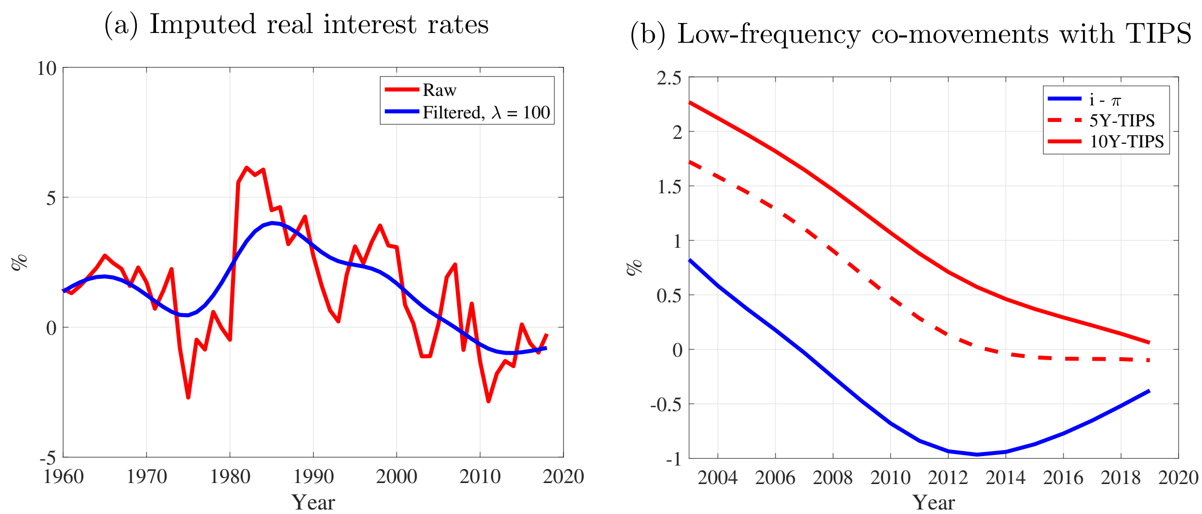


Figure A2: Imputation of US real interest rates

as long as there is availability. For countries with missing values up till 1960, we splice the series from the OECD and the IFS with data constructed in Benati et al. (2021).[17] Money data for countries in the eurozone are available only up till 1998. The following list details regarding the construction of the dataset.

Australia Interest rates in 1960–1967 and M1 in 1960 are spliced with Benati et al. (2021).

Canada Nominal GDP in 1960 is spliced using Benati et al. (2021). Between 1982 and 2005, M1 in the OECD dataset has faster growth at the beginning and lower growth in later years than the M1 data in Benati et al. (2021), which results in a similar cumulative growth across these two sources.

Germany The IFS provides nominal GDP only after 1992. For consistency, we use Benati et al. (2021) for nominal GDP in all periods.

Japan Interest rates before 2003 are spliced using Benati et al. (2021).

New Zealand Interest rates before 1974, nominal GDP before 1970, and M1 before 1978 are spliced using Benati et al. (2021).

[17] See Benati et al. (2019) for more details about the original data sources.

The UK We use all variables for all years from Benati et al. (2021).

Table A1 provides the summary statistics of mean and standard deviation of inflation π, nominal interest rate i, money growth μ, and real GDP growth g by country.

Table A1: Mean and standard deviation of main variables

Country	Periods	π	i	μ	g
USA - Currency	1960–2005	4.26	6.16	7.25	2.94
		(2.91)	(3.13)	(2.34)	(2.43)
USA - Standard M1	1960–2005	4.26	6.16	5.14	2.94
		(2.91)	(3.13)	(3.71)	(2.43)
USA - New M1 - Interp1	1960–2005	4.26	4.97	7.32	2.94
		(2.91)	(2.57)	(6.16)	(2.43)
USA - New M1 - Interp2	1960–2005	4.26	4.97	6.50	2.94
		(2.91)	(2.57)	(4.11)	(2.43)
Australia	1960–2005	5.48	8.28	9.01	3.73
		(4.03)	(4.06)	(6.21)	(2.74)
Canada	1960–2005	4.36	7.18	8.06	3.70
		(3.18)	(3.50)	(4.58)	(2.95)
Germany	1961–2005	3.00	5.61	8.18	3.16
		(1.80)	(2.53)	(3.51)	(2.95)
Japan	1960–2005	3.85	4.22	11.36	4.51
		(4.37)	(2.60)	(7.07)	(4.94)
New Zealand	1960–2005	6.56	9.65	8.82	2.88
		(5.38)	(4.50)	(7.62)	(2.35)
The UK	1960–2005	6.38	8.35	9.72	2.75
		(5.44)	(3.57)	(6.13)	(2.04)