The U.S. Economy After COVID-19: The Transmission Mechanisms of Monetary Policy *

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Abstract

We explore the lagging effects of some major monetary tightening cycles (MTCs) on macroeconomic activity and inflation. We show that the empirical evidence fits well with a refined variant of the IS-transmission mechanism of monetary policy highlighting the role of the interest rate in the economy. We reexamine the various propagation channels of this mechanism driven by the multiplying effects of investment on output and employment, and the wage and inflation dynamics as portrayed by the volatility of the slope of the Phillips curve, peaking up with positive sign over major MTCs. We then evaluate the timing and intensity of a future recession in the U.S. under various policy scenarios.

Keywords: Monetary Tightening Cycles (MTCs), Systematic Monetary Policy, Transmission Mechanisms, Propagation Channels, Inflation Shocks.

1 Introduction

COVID-19 may be fading away, but it has left profound scars in the world economy. In this healing process, inflation seems a most visible long-term economic concern. After several years of subdued price growth, central banks made bold moves (e.g., *quantitative easing*) and pushed for zero interest rates to favor economic growth. In the meantime, various

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negative shocks—the Russian invasion of Ukraine, supply chain hurdles, and declines in labor participation from COVID-19—have hit world markets and exacerbated the severity and persistence of U.S. inflation at nominal interest rates near the zero lower bound. Energy, commodities, food, housing, and stock values jumped sharply. Besides, inflation is taking a toll on economic uncertainty and income distribution.

It is clear that central banks have a lot of work to do. Now, their main task is to cure inflation without unduly hurting real *GDP* growth. Long-term inflation expectations have remained well anchored [Powell (2023)], but there is no consensus as to the stance of monetary policy and the persistence of inflation. Most diagnostics about the state of the economy and inflation forecasts have been too optimistic [cf., Giles (2023) and *IMF* (2022, Ch. 1)]. Analysts are further coming to terms—repainting a more negative economic outlook. In spite of all these misconceptions, however, the Fed—as well as many other central banks—seems determined to restore its set-in-stone targets and wield its own monetary policy program gradually. Unlike the Fed's and other established organizations' forecasts, our projections below acknowledge that U.S. inflation could be more persistent than in previous monetary tightening cycles (MTCs).

To center the debate, we intend to clarify the transmission mechanisms of monetary policy: the effects of central bank interventions on the various components of *GDP* and inflation. Usually, every research question starts with a set of empirical regularities or stylized facts that one wants to rationalize. Hence, our objective is to pin down some basic facts on the propagation channels of monetary interventions.[1] We focus on some major MTCs in the U.S., and propose a refined variant of the traditional IS-transmission mechanism to account for the lagging effects of monetary policy. We highlight the heterogeneous dynamic response of main macroeconomic aggregates to the interest rate. As argued in Section 2 below, these MTCs are most adequate to shed light on the monetary transmission mechanism. Unlike other central bank interventions, our long MTCs resemble the current economic situation, and would be most suitable to appraise the stance of monetary policy. We reexamine the various propagation channels of the IS-mechanism to trace down the end-impact of changes in the interest rate on real output, employment, wages, and inflation. At the heart of this mechanism, we have the multiplying effects of investment on output and employment, and the wage and inflation dynamics as portrayed by the slope of the Phillips curve. Quantity

[1] These stylized facts (e.g., Tables 4-5 below) should not be confused with structural estimation which must deal with underlying technical issues (e.g., identification, exogeneity, changing government interventions) supported by auxiliary assumptions. Stylized facts should nevertheless be a good starting point for model building.

and price rigidities can generate quite complex, nonlinear lead-lag patterns for the dynamics of employment, wages, and inflation. Then, the slope of the Phillips curve can be rather volatile[2] and may even take on positive values over some alternating phases of a prototypical MTC.

The dynamic effects of monetary policy on the economy have been the *leitmotif* of a large strand of the macroeconomics literature [e.g., Boivin, Kiley and Mishkin (2010) and Ramey (2016)]. The topic, however, is still quite far from settled, which has prompted various authors to pursue different modeling strategies. Thus, understanding the transmission mechanisms of monetary policy is a key step for model building—drawing attention to certain economic assumptions and the relevance of some real and financial frictions. In the absence of a well-established consensus as to the set of basic propagation channels that a good monetary model should be able to reproduce, there is a legitimate controversy as to the significance of major macroeconomic theories for policy analysis [Chari, Kehoe and McGrattan (2009), Cochrane (2022), Lindé, Smets and Wouters (2016), and Rupert and Susteck (2019)]. Essentially, these authors confirm that the most paradigmatic macroeconomic models are not supported on robust microeconomic evidence, and under limited conditions in these models an increase in the interest rate may generate lower output and inflation.

Several macroeconomic models fail to replicate basic aspects of the IS-transmission mechanism of monetary policy. An increase in the interest rate generates a "response chain" of key macroeconomic aggregates lowering output and inflation:

$$i \uparrow \Rightarrow I \downarrow \Rightarrow GDP \downarrow \Rightarrow U \uparrow \Rightarrow \hat{W} \downarrow \Rightarrow \hat{P} \downarrow \Rightarrow M \downarrow .$$

Here, i denotes the interest rate, I denotes investment, GDP denotes real output, U denotes the unemployment rate, $\hat{W}$ denotes average nominal wage growth, $\hat{P}$ denotes inflation, and $\hat{M}$ denotes the accommodating change in a representative monetary aggregate picking up bank credit. Our task would be to reassess the workings of these propagation channels over some selected MTCs. Hence, we intend to quantify the lagging effects of *systematic monetary interventions*. Today's inflation has originated from a rather complex mix of negative supply shocks and positive demand shocks.[3] In the aftermath of COVID-19, these inflation shocks

[2] Blanchard (2016) claims that this high volatility may be due to fluctuations in the natural unemployment rate, or to other misspecifications of the Phillips curve. Nominal wage and price rigidities create an obvious time-varying misspecification problem, which cannot be easily fixed because of the nonlinearities involved in the dynamics of the unemployment rate and real wage growth.

[3] As negative aggregate supply shocks, we consider inflation in commodities (including energy and food), low *TFP* growth, and the contraction in the labor force participation. As positive aggregate demand shocks, we consider the rise in housing rentals and values, and expansionary monetary and fiscal policies.

may attenuate the operation of the propagation channels of the IS-transmission mechanism upon cumulative increases in the interest rate, and so inflation could become more persistent. We break down consumption C into consumer durables C_{dur}, consumer nondurables C_{ndur}, and services C_{srv}. Changes in i will translate into end-effects in GDP and $\hat{P}$ representing feasible policy tradeoffs. The fall in GDP could actually be dampened by countercyclical fiscal policy and the induced effects of international trade. From the IS-transmission mechanism we should then expect $\hat{P}$ to have a smaller response than GDP upon a cumulative interest rate change: the demands for C_{ndur} and C_{srv} are inelastic with respect to the interest rate but make up for the bulk of the inflation basket. Nonetheless, we vindicate a second channel for reducing inflation: lower growth in the nominal wage W will be translated into lower growth in the price level P. A declining real wage from higher unemployment will pave the way for the reduction in inflation.

We then present some ballpark figures to evaluate the extent of the current MTC and the state of the economy, which appears to go more in the direction of a *hard landing* in order to bring down inflation to desired targets. Under our baseline calibration of the IS-transmission mechanism the Fed should hike the Federal Funds Rate (FFR) to 700 basis points to meet the pre-specified two-percent inflation mark, but we posit that 550 basis points for the FFR is possibly a red line not to be surpassed. Both are conservative estimates inferred from previous data under the assumptions of low financial risk and moderate inflation persistence. Although some inflation shocks may attenuate the contractionary effects of monetary policy [e.g., Waller (2022)], greater inflation persistence does not generally preclude the risk of a financial crisis originating from a downfall in investment. Therefore, the main current policy issue is rather to determine an *upper limit* for the cumulative FFR increase compatible with acceptable losses in investment, output, and employment.[4]

We organize the discussion around a basic small-scale, short-run model of aggregate supply and demand. We focus on some episodes of prolonged, systematic increases in the FFR in which the Fed attempts to cool off economic activity to combat inflation. These "predetermined" policy shifts should be less contaminated by changes in expectations of the private sector and further government responses to the evolution of the economy.[5] As illustrated in

[4]Based on our selected MTCs excluding the Great Recession of 2007-2009, at the end of the Online Appendix we present the expected dynamic response of output, employment, and inflation for an FFR hike of 550 basis points. PCE-core inflation should be below 3 percent by 2025-Q4, and below 2 percent by 2026-Q3. The peak of the unemployment rate should be reached in 2025-Q1 at over 6 percent. The output contraction will occur earlier. We project negative GDP growth rates in 2023-Q4 and 2024-Q1, and an overall loss of over 3.8 percentage points between 2023-Q1 and 2024-Q4 as a cumulative deviation from trend. Of course, a financial crisis would substantially darken this outlook.

[5]More precisely, we start with the presumption that the lagging effects of monetary policy could be

the Online Appendix, the estimated response to the *FFR* of macroeconomic activity and inflation measures over these selected MTCs is about three times greater than over an extended period encompassing the MTCs. Further, the much higher degrees of statistical significance and explanatory power attest for the monetary nature of these MTCs.

The literature [cf., Ramey (2016) and Romer and Romer (2023)] has further dived into deep, technical identification issues to determine the economic response to *monetary shocks,* but does not specifically get into isolating and testing the monetary transmission mechanism to configure propagation channels of monetary policy. We take a step further and go into great detail to study leading and lagging economic aggregates of output upon cumulative changes in the interest rate. We then rearrange the empirical evidence within the lenses of the aforementioned IS-transmission mechanism of monetary policy, and gauge the impact of *FFR* hikes on the various *GDP* components and inflation.

We rely on U.S. data, and hence some of these patterns may not fully extend to most other countries in which exchange rate and credit channels, labor markets, and further economic policy considerations are not on par with the U.S. economy. The U.S. dollar operates as the international reserve currency. Both the U.S. dollar and the public debt have proved to be very resilient—enjoying top credit ratings. The U.S. Fed has a dual mandate, which has been reflected in a disposition for more active policies towards stabilization of the economy as compared to many other central banks in advanced economies. While some inflation sources are external to the economy, the Fed must have a well-defined policy plan; i.e., a time-table to reduce inflation. Economic activity does not respond immediately to monetary policy. Lagging effects preclude a fine-tuning of the economy and may result in suboptimal interventions of the form: *too little too late* or *too much too late.* The transmission mechanisms of monetary policy should guide central bank strategies.

In Section 2 we lay out our framework of analysis. We focus on four salient periods of systematic interest rate hikes, and take a close look at the effects of monetary policy on economic activity and inflation. Section 3 is the heart of the paper. Based on the empirical evidence from these MTCs, we study the IS-transmission mechanism of U.S. monetary policy and discuss implications for economic modeling. In Section 4 we evaluate current sources of inflation persistence. We frame this discussion within a *conventional model of inflation.* In Section 5 we debate about the future state of the economy and advance some prescriptions

confounded by changes in expectations of economic agents and government responses to contemporaneous economic conditions. Therefore, in these protracted episodes in which the Fed is persistently exerting pressure on inflation there could be a stronger impact of interest rate hikes on economic activity and inflation. For further discussion, see Section 2.3 below.

for monetary policy. We conclude in Section 6 with a summary of our main findings. The Online Appendix goes over various quantitative exercises about the timing and magnitude of the response of our economic aggregates upon changes in monetary policy. Several claims made in the paper are based on this econometric work.

2 Propagation Channels of U.S. Monetary Policy

We begin with a reduced-form model of real aggregate supply and demand [cf., Friedman (1970)]. The equilibrium condition determines both the general level of economic activity and employment. To this simple framework we add a twist to *the missing equation* (in Friedman's terminology) regarding the evolution of nominal wage growth and inflation. We then want to inquire into the timing and magnitude of the response of economic aggregates over these prolonged MTCs. We shall be concerned with the following basic issues. Upon a prolonged, systematic increase in the interest rate: (i) What are the major quantitative changes in the expenditure items to account for the contraction in output and employment? (ii) How does the contraction in output and employment translate into declines in nominal wage growth and inflation? And (iii) how are nominal wage growth and inflation linked along the equilibrium adjustment process?

2.1 The Framework of Analysis

The Aggregate Supply and Demand. From the supply side, assume that real *GDP* or *current* aggregate output, Y, can be represented by a production function $F(A, K, hL)$, where A is total factor productivity, K is physical capital, and hL is hours worked or employment. We can think of h as the employment fraction of the active population, L. Thus,

$$Y = F(A, K, hL).$$

In the following discussion, A, K and L are predetermined variables. Regarding the expenditure side, we may suppose that consumption, C, investment, I, and net exports, NX, are functions of output, Y, the interest rate, i, and some policy variables, Σ. Government expenditure, G, is exogenously given. We break down C into consumption of nondurables, services, and durables:

$$Y = C_{ndur}(Y, i, \Sigma) + C_{srv}(Y, i, \Sigma) + C_{dur}(Y, i, \Sigma) + I(Y, i, \Sigma) + G + NX(Y, i, \Sigma).$$

Besides G and the interest rate, i, we can think of related policy variables, Σ, that determine the demand for the domestic and foreign sectors. Hence, Σ may include monetary aggregates,

M, and fiscal variables such as taxes and public budget deficits. Changes in these policy variables may be thought as unexpected policy shocks or innovations, but for the most part we want to interpret these changes as desired policy actions or systematic, unconditional moves towards the accomplishment of certain targets.

For fixed (G, i, Σ), our above two equations determine aggregate output, Y, and the fraction h of the employed population, or hours worked, hL. Under the IS-transmission mechanism there could be an asymmetric response of output and inflation to a systematic interest rate hike: consumer durables C_{dur} and investment I would be main drivers of output but consumer nondurables and services, C_{ndur} and C_{srv}, make up for the bulk of the inflation basket. Hence, besides the fall in aggregate demand we want to understand the behavior of wages toward the reduction in inflation.

Nominal Wage Growth and Inflation. We postulate that the economic system initially clears through quantities—followed by wages and prices. As discussed in Friedman (1970), this quantity-price response would be *Keynesian* rather than *Marshallian.*[6]

Let us assume the following standard adjustment law for the nominal wage, W, in which we take into account productivity gains:

$$\hat{W} = h(U) + \hat{P}^e + \hat{A},$$

where $\hat{P}^e$ denotes expected inflation and $\hat{A}$ denotes *TFP* growth. We shall identify $\hat{P}^e$ with current and future realized inflation. Then, this latter equation basically reduces to the textbook *Phillips curve* over unemployment U and productivity-adjusted real wage growth; e.g., Blanchard and Katz (1999), Galí (2011), Hazell *et al.* (2022), and Stock and Watson (2019). Moreover, Blanchflower, Bryson and Spurling (2022) claim that there is no significant relation between the unemployment rate and wage growth; i.e., the mean value of the correlation between these two variables is close to zero, and this correlation turns out to be highly volatile. We depart from this literature in that we are interested in the behavior of nominal wage growth over these prolonged large changes in output along with pronounced lagging responses in employment, wages, and inflation. The slope of the Phillips curve peaks at these MTCs—sometimes with the wrong sign.

[6] Rather than a *lagging nominal adjustment process* over a competitive setting, most macro models are founded on *forward-looking pricing mechanisms.* For instance, in a Rotemberg-type model a firm can always reset its price after bearing a quadratic adjustment cost and in a Calvo-type model a firm may reset its price with a certain probability at each period independently of the last adjustment. These price setting rules require monopoly power projecting *future* market conditions. Price stickiness comes from adjustment costs in a Rotemberg-type model, and from restricted agent participation in a Calvo-type model; e.g., see Rupert and Susteck (2018).

We shall also present some empirical evidence shedding light on the following parity between future inflation and nominal wage growth adjusted for gains in productivity:

$$\hat{P}' = \hat{W} - \hat{A},$$

where $\hat{P}'$ may refer to future inflation; say, inflation within the next one to three quarters. For the U.S. economy, this equality holds quite well over long-term averages. Large deviations from this parity may stem from short-term volatility of the asynchronous behavior of wages and inflation to a systematic increase in the interest rate. Energy prices and varying price-cost markups could be other sources of volatility. Accordingly, we may think of price growth as core inflation, while simply assuming competitive price formation. Thus, varying price-cost markups may be linked to lagging effects of nominal wage and price rigidities rather than changing monopoly power.

2.2 The Evolution of Real and Monetary Aggregates, and the Federal Funds Rate (FFR)

(*i*) *Consumption of Nondurables and Services:* $C_{ndur} + C_{srv}$. Figure 1a depicts the evolution of $(C_{ndur} + C_{srv})/Y$ and the *FFR*. Observe that this consumption ratio has been quite flat for a few decades: $C_{ndur} + C_{srv}$ moves evenly with Y but peaks slightly in the shaded areas—time periods of *NBER*-dated U.S. economic recessions. Therefore, $(C_{ndur} + C_{srv})/Y$ is quite insensitive to changes in the *FFR*. In spite of the stability of this ratio, there have been secular shifts within C_{ndur} and C_{srv}. Over time, C_{ndur}/Y has trended downwards, and C_{srv}/Y has trended upwards. Also, with COVID-19, C_{srv}/Y went down roughly from 0.46 to 0.44, which was compensated by a similar and corresponding upward move in C_{ndur}/Y. In conclusion, $(C_{ndur} + C_{srv})/Y$ just hovers around 0.60. HANK models focus on the variation in consumption from liquidity-constrained consumers [e.g., Kaplan, Moll and Violante (2018)], while consumer durables and investment would be the main drivers of output in the IS-transmission mechanism upon the cumulative increase in the *FFR*.

(*ii*) *Consumption of Durables and Investment:* $C_{dur} + I$. Figure 1b depicts the evolution of $(C_{dur} + I)/Y$ and the *FFR*. As in the business cycle literature [e.g., Lucas (1977)], we group together C_{dur} and I. From this literature it is known that this investment measure is about three times more volatile than output. Besides the *FFR*, several other sources such as technological innovations may account for the volatility of investment. Fluctuations of the ratio $(C_{dur}+I)/Y$ accord with the traditional investment channel—playing second fiddle in most monetary models—where $C_{dur} + I$ is a leading indicator of Y. Therefore, it becomes key to pin down the sensitivity of the ratio $(C_{dur} + I)/Y$ to changes in the *FFR*. This ratio hovers around 0.26, but can go up till 0.30, and in the Great Recession of 2007-2009 came down to 0.20.

(*iii*) *Government Expenditure and Net Exports:* G and *NX*. The ratio G/Y usually peaks in the *NBER*-dated recessions. As discussed below, while investment is initially a leading indicator of output, in the recovery phase investment may even lag output. Hence, there could be some role for fiscal policy to boost output growth at the end of the propagation effects of systematic increases in the *FFR* [Cochrane (1994), and Romer and Romer (1994)]. Moreover, $Y - C - I - G$, which amounts to net exports, *NX*, is generally countercyclical. The open-economy framework may dampen the multiplier effects of $C_{dur} + I$ on economic activity upon changes in the *FFR*.

(*iv*) *Output, Employment, and Wages.* For output, we apply a band-pass filter[7] isolating frequencies of this variable between 6 and 32 quarters [Christiano and Fitzgerald (2003)]. In a severe recession from peak to trough our measure of output could go from 3 to -4. This move would represent an output contraction of 7 percentage points as a cumulative deviation from its exponential trend.[8] As discussed below, even under our filtered measure of output, changes in the unemployment rate tend to be smaller than those of the output contraction, and changes in nominal wage growth tend to be slightly above those of the unemployment rate. The weaker response of employment to the contraction in real output is accommodated through a decline in *TFP*. Real wage growth will be adjusted for productivity gains. Generally speaking, this measure of the real wage slightly lags unemployment, and unemployment lags output. In these severe recessions the drop in our productivity-adjusted measure of the real wage growth could be of the order of 7 percentage points.

(*v*) *Output, Inflation, and Bank Credit.* Inflation lags output in major recessions pointing at nominal rigidities. While the *FFR* is a primary policy variable and could lead output growth, bank credit may accommodate to changes in the interest rate, the available amount of bank reserves, and economic activity. Indeed, the short-term evidence does

[7]For comparison, we shall later report some results using the Hodrick-Prescott (*HP*) filter. Filtered components of *GDP* and productivity measures are computed by applying the filter to the linearly detrended natural log of each variable and multiplying by 100. Hence filtered values for these variables should be interpreted as percentage deviations from their deterministic exponential trends.

[8] Note that the average annual growth rate of *GDP* is roughly given by $g_{GDP} \approx (1/n)\Delta BP(GDP) + g_T$ where g_T is the annual trend growth rate of the order of 3 percent, $\Delta BP(GDP)$ is the change in our filtered measure of *GDP*, and n denotes the length of the annual adjustment period.

not support strong links between money, real activity, and inflation [Lucas (1977)]. Therefore, broad monetary aggregates like *M2* and *M3* may not be good predictors of output growth [cf., Bernanke and Blinder (1992) and Ramey (2016)]. Obviously, monetary aggregates can also operate as policy targets (i.e., helicopter drops, stimulus checks) anticipating moves in the *FFR*.

2.3 MTCs in the U.S.

While the aforementioned empirical evidence is quite suggestive about the effects of the *FFR* on output and inflation, several other explanatory factors may be reshaping these trends. Indeed, it seems quite challenging to disentangle the lagging effects of monetary policy on economic activity over unrestricted data sets; see footnote 5. Our purpose now is to explore the various propagation channels of monetary policy for some salient U.S. MTCs triggered by acute runs on inflation. We shall be mostly concerned with the timing and magnitude of the response of our macroeconomic variables to the cumulative interest rate hike.

The idea of replicating a *monetary shock*—a carefully setup and controlled *economic experiment*—has been present at least since the *Monetary History* of Friedman and Schwartz (1963). Macroeconomic theorists have been elaborating on the *crucial experiment;* e.g., see Christiano, Eichenbaum and Evans (2005), Gertler and Karadi (2015), and Romer and Romer (1989). Nonetheless, most attempts at *identifying* a monetary shock—loosely defined in various ways—obviate that both the government and private sector are forward looking.[9] Given the technical complexity involved in sorting out this give-and-take among economic sectors, our main purpose is to quantify the effects on economic activity and inflation of systematic interest rate hikes; that is, certain time periods in which the Fed is *persistently* fighting inflation. As the Fed credibly focuses on a long-term objective, their actions may have stronger impact on the economy. Hence, these selected episodes are most adequate to shed light on the monetary transmission mechanism. While an MTC could even be thought as an *exogenous policy change* for monitoring economic activity to reduce inflation, we are hesitant to take a stand on this exogeneity assumption, which may again obviate that economic agents could factor in the actions and reactions of all other agents.

Rather, we want to explore the lagging effects of *systematic monetary policy* through these

[9]Stubbornly and authoritatively, the Fed may sometimes defeat reality, but the private sector may foresee an ensuing MTC. Private agents may presume that the Fed will come to terms and correct their wrong perceptions and diagnostics about the economic situation. Besides, among the many policy tools, the Fed may want to coordinate agents' expectations through forward guidance—raising further issues of time-inconsistency—or by not revealing actual policy plans.

MTCs. Table 1 refers to the following four MTCs after the U.S. postwar period: 1967-Q3–1969-Q3, 1972-Q1–1974-Q3, 1977-Q1–1981-Q2, 2004-Q2–2006-Q3. In all these cycles, the cumulative increase in the *FFR* is over 400 basis points—spanning over two years. Such systematic increases in the interest rate are possibly the most prominent—in the various dimensions studied below—to evaluate the effects of current Fed's interventions under present economic conditions. They all ended up in sizable drops in output levels and inflation. Bernanke and Blinder (1992) and Romer and Romer (1989) identify the first three MTCs as deliberate Fed's attempts to slow down the pace of economic activity—lowering inflation. We are just adding the MTC that ended in the Great Recession of 2007-2009, which offers a rather different perspective of the effects of monetary policy under more adverse financial conditions. We have discarded some notable recessions in the interwar period since quarterly data from the national accounts are available since 1947. Besides, structural changes in the implementation of monetary policy make these earlier tightening cycles hard to compare. Financial panics and banking crises surrounded some well-known crashing times of negative output growth.

Blinder (2022) and some other literature [e.g., see Perez and Santos (2022) for a brief overview] contend that the Great Recession of 2007-2009 was not primarily caused by the associated MTC. To get a deeper understanding of these major recessions, in the next section we intend to shed light on the propagation channels characterizing the IS-transmission mechanism of monetary policy.

In Table 1, we report changes in filtered measures of output and its various components, employment and nominal wages, measures of *PCE*- and *CPI*-inflation, and monetary aggregates. Below each economic indicator the table lists the corresponding time interval in which this variable was continuously decreasing or increasing as the case may be. By including the time period in which a given aggregate was falling or rising (say from peak to trough, or vice versa), we can dig into leading and lagging indicators of output, as well as the magnitude of the impact of the cumulative increase in the *FFR*. Table 2 goes into changes in the various components of output demand and measures of risk. Real variables are the first to respond to these systematic *FFR* increases. We can now summarize the timing and magnitude of these changes over our selected MTCs:

(*i*) *Magnitude of the Changes in Output, Employment, and Inflation.* Over these four episodes, the average cumulative increase of the *FFR* is 775 basis points. The average cumulative drop in our filtered measure of output is about 5.66 percentage points, while the average cumulative increase in the unemployment rate is 4.30 percentage points.

The average cumulative drop in our two measures of core inflation is 4.55 percentage points, while the average cumulative drop in nominal wage growth is 5.30 percentage points.

(*ii*) *Leading and Lagging Indicators of Output: Real Variables. TFP, Consumer Durables and Investment Lead Output. Unemployment Typically Lags Output.* Note that *TFP* is the first economic aggregate to decline, and the first one to recover. This points to readjustments of labor and capital utilization in the production sector for initial changes in output. Then, consumer durables drops a few quarters before output; investment drops just before output; and unemployment typically lags the output contraction. Government expenditure goes up upon the output contraction—avoiding a bigger decline in economic activity. In the recovery phase, investment and employment move more slowly than durable goods and output, which accords with the behavior of *TFP* and may suggest the existence of adjustment costs and search frictions in the allocation of the production factors.

(*iii*) *Lagging Indicators of Output: Price Variables. Nominal Wage Growth and Inflation Lag Output, while Inflation Lags Nominal Wage Growth.* These lagging indicators point at price and wage stickiness: the market clearing mechanism is initially projected on the quantity space. Inflation lags output for approximately four or five quarters, and nominal wage growth for about two or three quarters. Bank credit may accommodate to the propagation effects of monetary policy and lags output. *M2* follows more closely the monetary tightening cycle because of direct Fed's interventions.

Certainly, leading and lagging indicators vary in both timing and the relative magnitude of the change across these severe recessions. In all four episodes, it takes at least *five quarters* from the start of the MTC till the start of the contraction in our measure of output. Likewise, it takes at least *five quarters* from the start of the contraction of our measure of output till the end of such output contraction. Moreover, it takes at least *nine quarters* from the start of the MTC till the start of the reduction in *CPI*-core inflation.

Bernanke and Blinder (1992), Romer and Romer (1989), and the related literature [e.g., Ramey (2016)] run a battery of econometric tests to substantiate the real economic effects of monetary policy. These papers consider the index of total industrial production (*IP*) and the unemployment rate. The *IP* obviously accounts for a rather small employment fraction, and does not conform to the variation in *GDP*. In the Great Recession of 2007-2009, the *IP* fell about 17 percent, while our filtered *GDP* measure fell about 4.70 percentage points.[10] This is actually short of our purposes. We are trying to identify the transmission mechanisms of monetary policy for the U.S. economy and quantify the various propagation channels. We then assess the timing and magnitude of the response of the various *GDP* components and inflation to changes in the *FFR*. In the next section we pursue a systematic account of the empirical evidence within the framework of the IS-transmission mechanism of monetary policy.

From Table 2 we can observe a greater response of fiscal policy over time, a greater role of international trade possibly because of the emergence of globalization, and a more fragile or impacted financial system possibly because of greater leverage and financial sophistication, while the Fed has also been increasingly more active in the provision of credit and liquidity to the economy; e.g., quantitative easing. Table 2 also reports various financial indicators and measures of risk. As our measure of the credit spread (*CS*), we use the Moody's seasoned *Baa* corporate Bond yield relative to yield on ten-year treasury constant maturity. The *CS* increased 145 basis points in the monetary tightening cycle between 1967-Q3 and 1969-Q3, and monotonically this increment went to 397 basis points for the Great Recession of 2007-2009.

3 The IS-Transmission Mechanism of Monetary Policy

We now go over propagation channels of the IS-transmission mechanism of monetary policy to evaluate quantitative changes in *GDP* and inflation. These computations illustrate the orders of magnitude of the response of different variables to systematic changes in the *FFR*. Certainly, the *FFR* is a benchmark rate affecting a variety of interest rates. Besides interest rate changes, the increase in financial risk and uncertainty—interacting with real and financial frictions—may amplify the effects of *FFR* changes on investment and bank credit.

3.1 Response of Economic Aggregates

(i) *Elasticities of Investment Over Cumulative Increases in the FFR*. In Table 2 we report percentage changes in filtered consumer durables, residential and nonresidential fixed investment, and total investment upon cumulative increases in the *FFR*. From Table 2, the average *FFR* semi-elasticity of C_{dur} is 2.23. This semi-elasticity is estimated

[10]The *IP* is conveniently available on monthly data since 1919. The *IP* has been overshadowed by the service sector in the U.S. economy. Using quarterly data since 1947, our filtered measures of *IP* and real *GDP* exhibit a correlation of 0.9, but *the volatility of IP is twice the volatility of real GDP*. Hence, estimates based on the *IP* magnify the real effects of monetary policy.

as the average over our MTCs of the change in filtered C_{dur} over the change in the *FFR*. In contrast, the average *FFR* semi-elasticity of $C_{ndur} + C_{srv}$ is 0.35. All in all, in spite of a much smaller output share, C_{dur} has a similar contribution to the variation in expenditure[11] than $C_{ndur} + C_{srv}$.

From Table 2, the average *FFR* semi-elasticity of residential fixed investment, I_{res}, is 4.36, and the average *FFR* semi-elasticity of nonresidential fixed investment, I_{nres}, is 2.60. Residential fixed investment substantially affects employment [e.g., Boldrin *et al.* (2020)]. Equipment goods are also quite sensitive to the interest rate while structures display smaller fluctuations. Again, in spite of the unequal output shares, I and C have similar contributions to the output variation.

(ii) Accounting for the Contraction in Output. In Table 1, we report three measures of output contraction: real *GDP* growth, *DGDP*, real *GDP* under a standard version of the *HP*-filter, *HP(GDP)*, and real *GDP* under the band-pass filter isolating frequencies for this variable between 6 and 32 quarters, *BP(GDP)*. The variation in *HP(GDP)* is greater than the variation in *BP(GDP)*. Over these MTCs, the average drop in *BP(GDP)* is 5.66 percent, the average drop in *HP(GDP)* is 6.50 percent, while the average drop in *DGDP* is 1.92 percent.

The average *FFR* semi-elasticity of *BP(GDP)* is 0.80. The contributions of C and I to the fall in aggregate expenditure are often dampened by fiscal policy and international trade, which have been increasingly gaining importance in these MTCs (see Table 2), resulting in smaller variations in output to those cumulative *FFR* hikes.

(iii) Accounting for the Loss in Employment: Okun's Law. The fall in production would be accommodated by a drop in employment. Initial job losses should be attributed to the fall in investment predicated by the IS-transmission mechanism; e.g., a decline in housing investment. Additionally, the fall in output demand over the MTC generates a further loss in employment through *Okun's Law*: the output contraction is accommodated by both a fall in *TFP* and a reduction in employment. Moreover, *TFP* leads output, whereas employment lags output. The increase in the unemployment rate is expected to be smaller than the percentage output contraction. While in the above four severe recessions the average contraction in our filtered measure of output, *BP(GDP)*, was 5.66 percentage points, the average cumulative increase in the unem-

[11] For a different sample period, Bernanke and Gertler (1995) get a similar contribution for C_{dur} and $C_{ndur} + C_{srv}$ to the variation in output demand.

ployment rate was 4.30 percentage points. In the Great Recession of 2007-2009 the greater increase of the unemployment rate has been associated with the implosion of residential investment.

(iv) *Accounting for the Reduction in Nominal Wage Growth and Inflation: The Phillips Curve.* To evaluate nominal wage and price rigidities, let us consider a stripped-down, linear version of the Phillips curve discussed above:

$$\hat{W} = \hat{A} + b \cdot (U - NU) + \hat{P}^e,$$

where b is the slope coefficient (expected to be negative), and NU is the natural unemployment rate which can vary with time. Let us identify $\hat{P}^e$ with future inflation. In the Online Appendix we estimate coefficient b over various specifications for future inflation, the nominal wage, and TFP. As it would be clear from the analysis below, myopic price expectations may bias coefficient b; such a bias can be positive or negative depending upon the various phases considered below.

Before getting into the computation of the b-coefficient, Figure 3 plots deviations of inflation from nominal wage growth adjusted from productivity gains:

$$\hat{P}' - \hat{W} + \hat{A},$$

where $\hat{P}'$ denotes inflation in the following quarter. As displayed in the figure, the sample mean of $\hat{P}' - \hat{W} + \hat{A}$ is equal to zero, and so this conjectured parity between inflation and productivity-adjusted nominal wage growth holds over long-time averages. Note that if $\hat{P}' - \hat{W} + \hat{A} > 0$, then our productivity-adjusted measure of the real wage is decreasing, and if $\hat{P}' - \hat{W} + \hat{A} < 0$, then it is increasing. Therefore, $\hat{P}' - \hat{W} + \hat{A} > 0$ is observed with a certain lag at all peaks of the unemployment rate, and $\hat{P}' - \hat{W} + \hat{A} < 0$ is observed with a certain lag at all lows of the unemployment rate. Accordingly, in a prototypical MTC we can identify the following three phases:

(a) Phase I: $\hat{P}' - \hat{W} + \hat{A} > 0$. As we can see from Figure 2, inflation may rise quickly at the beginning of an MTC [e.g., see Banerji (2005)]. This inflation rise could be unexpected, and erodes the real wage.

(b) Phase II: $\hat{P}' - \hat{W} + \hat{A} < 0$. A low unemployment rate may push up the real wage. Since employment usually lags output and wages and prices lag unemployment, increases in the real wage may happen at the beginning of an economic recession.

(c) Phase III: $\hat{P}' - \hat{W} + \hat{A} > 0$. As the unemployment rate goes up, nominal wage growth is expected to go down at a faster pace than inflation. In fact, the drop in the real wage may be necessary to bring down inflation.

Therefore, an MTC may be triggered by unexpected inflation; moreover, real wage growth adjusted for productivity mimics the evolution of the unemployment rate—albeit in a sluggish way. In an MTC, unemployment would go down, and then up. As illustrated in Figure 3, Phases I-III purport these associated ups and downs for $\hat{P}' - \hat{W} + \hat{A}$ over our MTCs—as well as in the economic recessions of 1990 and 2001. Further, note from this figure that $\hat{P}' - \hat{W} + \hat{A}$ becomes positive for long time periods in the 1990s and 2010s: the unemployment rate was coming down but it took quite a bit of time for $\hat{P}' - \hat{W} + \hat{A}$ to respond and become negative. These fluctuations in $\hat{P}' - \hat{W} + \hat{A}$, however, are evened out for filtered data. Indeed, there are no apparent changes in Figure 3 over time in the lagging behavior and "flattening" of these fluctuations in filtered data for $\hat{P}' - \hat{W} + \hat{A}$ when compared to the unemployment rate.

As a metric for comparing these observed changes in $\hat{P}' - \hat{W} + \hat{A}$, we can now look at the slope of the Phillips curve, which should reflect the magnitude and asynchronous dynamic behavior of changes in employment, wages, and prices. Using quarterly data, Figure 4 depicts the b-coefficient—as well as a filtered measure of b—at each point in time. First of all, this coefficient hovers around the mean value, $\overline{b} = -0.49$, with a standard deviation $\sigma = 2.00$. Indeed, b is quite volatile, since $\hat{P} - \hat{W} + \hat{A}$ lags changes in $U - NU$. Second, this high volatility is non-linear; that is, it cannot be easily fixed by lagging $\hat{P} - \hat{W} + \hat{A}$; see the Online Appendix. The lead-lag patterns for the unemployment rate, nominal wage growth, and inflation can even cause the b-coefficient to be *positive*. More specifically, b is positive in the above Phase I when the unemployment rate is decreasing, and in the above Phase II when the unemployment rate is increasing. Therefore, the b-coefficient could be positive at the start of a monetary tightening cycle in which inflation may rise faster than nominal wage growth but the unemployment rate is still declining, and at early stages of an economic recession in which the real wage is rising but the unemployment rate is already increasing. And third, while the mean sample value of b is about -0.49, the main peaks for b happened in the monetary tightening cycles, 1972-Q1–1974-Q3, 1977-Q1–1981-Q2 and 2004-Q2–2007-Q2. Outside these monetary tightening cycles, for filtered data the b-coefficient just wanders around its mean value.

To conclude, the b-coefficient is the slope of the Phillips curve and is meant to indicate a policy tradeoff between changes in our measure of the real wage and the unemployment gap. Because of the asynchronous dynamic behavior of final good prices and nominal wages to changes in output and the unemployment rate, the b-coefficient can be highly volatile and may take on positive values. Consequently, the slope of the Phillips curve may give us a distorted idea of the available policy tradeoffs between wage growth and unemployment. Broadly speaking, we have not observed dynamic structural changes over the last few decades in the b-coefficient as well as in the lagging behavior and fluctuations in filtered $\hat{P}' - \hat{W} + \hat{A}$. Some puzzling fluctuations in both $\hat{P}' - \hat{W} + \hat{A}$ and the b-coefficient tend to vanish for filtered data.

Under the IS-transmission mechanism of monetary policy an increase in the *FFR* will eventually generate a contraction in output and a later reduction in inflation. There is then an important role for countercyclical monetary policy. Inflation lags output, and hence monetary policy can be time-inconsistent. The *FFR* semi-elasticity of real *GDP* is usually less than 1. The reduction in inflation seems to operate through the labor market channel and occurs after a drop in nominal wage growth. The percentage contraction in output is typically greater than the increase in the unemployment rate (Okun's Law), while the increase in the unemployment rate is of the same order of magnitude as the reduction in both nominal wage growth and inflation. Therefore, the percentage output contraction is expected to be greater than the reduction in inflation. For our estimates of the propagation channels of the IS-transmission mechanism, a one-percent contraction in output will translate into an associated later reduction in the rate of *CPI*-core (*CPI-C*) inflation of 0.92 percentage points, and in the rate of *PCE*-core (*PCE-C*) inflation of 0.65 percentage points. These estimated values differ from the literature [e.g., see Hazell *et al.* (2022) for an overview of recent results] because we focused on these salient MTCs, while taking into account the inflation lag.

3.2 The Great Recession of 2007-2009

Was the Great Recession of 2007-2009 caused be the MTC taking place in 2004-Q2–2006-Q3? We want to approach this question within the framework of the IS-transmission mechanism of monetary policy.[12] Unlike many accounts of the Great Recession, we should point out

[12]For instance, Blinder (2022, p. 117) argues: *I am dubious in the extreme. First, notice the long time lag. The Fed's tightening cycle began in June 2004 and ended in June 2006. The first negative quarter of real GDP growth was not until 2008:I, and the really severe declines did not occur until 2008:IV (-8.5 percent) and 2009:I (-4.6 percent) ⋯ So to my mind, the deep recession of 2007-2009 was sui generis. It was surely "hard," but it was not a "landing" from an episode of tight money. I can even imagine that the U.S. economy might have experienced a soft landing had the financial system not imploded.*

that we use filtered data, which in this case should be helpful to discard some high-frequency fluctuations of the bubble economy from boom to bust.

The cumulative increase in the *FFR* was 424 basis points but our filtered measure of the real output contraction was 4.69 percent. This relatively high output response occurred in spite of very expansionary fiscal measures and positive effects of international trade; see Table 2. The reduction in annual *CPI-C* inflation was about 2.17 percent.

Inflation Shocks. The MTC between 2004-Q2 and 2006-Q3—extending into the financial crisis—was prompted by soaring energy inflation and one of the biggest housing bubbles. (Between January 2000 and January 2006, the S&P/Case-Shiller U.S. National Home Price Index went from 100 to 184.6 while associated rental values remained nevertheless unaffected.) Market sentiment and wealth effects surrounding the housing bubble may have slowed down the response of consumption and output to the cumulative *FFR* increase; see the Online Appendix. Between January 2002 and June 2008 there was a sevenfold increase in the spot price of crude oil, and then sharply went down to one-third of the peak value in December 2008. Inflation was highly monitored by the Fed, and did not really rise at the beginning of the MTC. Hence, the drop in core inflation was quite small.

The Contribution of Investment and Consumption to the Output Variation. $(I + C_{dur})/Y$ peaked at 0.29 in 2005 and then dropped to 0.20 in 2009. Hence, there was a rather large decline in $(I + C_{dur})/Y$ surrounded by the financial crisis. Residential fixed investment was quite high peaking at about 6.7 percent of *GDP*, and equipment investment was also very high peaking at over 6.25 percent of *GDP*. For filtered data, we obtain that the *FFR* semi-elasticity of residential fixed investment was quite comparable to all our other MTCs. However, the *FFR* semi-elasticities of C_{dur} and $C_{ndur}+C_{serv}$ were 1.5 times the corresponding averages in the previous MTCs. The drop in I for the given cumulative increase in the *FFR* was about twice as much as what one would have predicted from other tightening cycles. While *TFP* and the unemployment rate responded fairly rapidly, private investment and consumption did respond with an extra lag of about 6 quarters to the cumulative interest rate increase; see the Online Appendix.

Okun's Law. From Table 2, government expenditure and international trade delayed the output contraction. The increment in the unemployment rate was 5.50 percentage points, about 80 percent higher than what it would be predicted by Okun's Law as documented in previous economic recessions. This employment loss does not seem fully explained by the direct loss of jobs in the construction sector. Boldrin *et al.* (2020) claim nevertheless that the construction sector was strongly interconnected with various other economic sectors.

The economy lost 8.6 million jobs, and the construction industry lost 2.3 million jobs. The unemployment rate went up very steeply to about 10.05 percent.

The Phillips Curve. The increase in the unemployment rate of 5.50 percentage points translated into a drop in nominal wage growth of about 5.41 percentage points. (The drop in our productivity-adjusted measure of real wage growth was 7.44 percent; see Table 1.) Since inflation was closely monitored by the Fed, there was not a pronounced inflation jump at the beginning of the MTC. Hence, the slope of the Phillips curve only peaked up (with positive sign) at advanced stages of the recession. That is, Phase II above was clearly well defined but Phase I went unnoticed; see Figure 4. Fluctuations in the filtered b-coefficient are quite similar to those of other MTCs; i.e., there is no evidence of the "flattening" of the Phillips curve in the unemployment-wage space.

Inflation. Because of the downward rigidity of nominal prices for low inflation rates, one may argue that inflation had a relatively standard response to the *FFR* increase. The reduction in inflation was not commensurate with the drop in nominal wage growth. Roughly, *CPI-C* inflation went down from 2.8 percent to less than 0.63 percent.

In short, the contraction in real output may have been triggered by the bursting of the housing bubble, the monetary tightening cycle, and the financial crisis. The direct effect of the bursting of the housing bubble washed out in our filtered data: the *FFR* semi-elasticity of our filtered measure of housing investment was in line with the other economic recessions considered. Market sentiment and wealth appreciation surrounding the housing bubble, however, may have delayed the effects of monetary policy on consumption and investment and may have ignited the financial crisis. *TFP* and the unemployment rate responded fairly quickly to the interest rate increase. The falls in real investment and consumption were over fifty percent higher than what one would have predicted from the given cumulative increase in the *FFR*. Hence, the financial meltdown appears to have contributed to a larger drop in $I+C_{dur}$ and $C_{ndur}+C_{serv}$. The output contraction was roughly fifty percent higher than what one would expect from the associated MTC. Moreover, for the given output contraction, the unemployment rate was higher than expected while the drop in nominal wage growth was commensurate with the increase in the unemployment rate. The reduction in inflation was much lower than the drop in nominal wage growth—evidencing some kind of nominal price rigidity at low inflation rates.

In Table 2 we display several financial indicators and measures of financial risk. As compared to the other economic recessions, the most salient indicator is the increase in the measure of credit spread, ΔCS. The small change in the market yield on U.S. Treasury Securities at 10-year constant maturity (*GB10*) and the smaller change in the national financial conditions index (*NFCI*) attest for the severity of the financial crisis (e.g., prospects of low economic growth) together with aggressive fiscal and monetary policies to support the economy. Therefore, these indicators hint at a financial panic from the private sector—rather than from the public sector—mitigated by extensive government intervention.

3.3 Implications for Economic Modeling

Lags in Monetary Policy. Our analysis of the IS-transmission mechanism of monetary policy highlights relevant leading and lagging relations between main macroeconomic aggregates in their response to the *FFR*. Hence, these lags in quantities, nominal wages and prices—as well as the underlying real and financial frictions—should be central ingredients for modeling the transmission mechanisms of monetary policy.

Models of Monetary Economics. Macroeconomic modeling typically builds on certain assumptions such as habit formation in consumption, consumer heterogeneity, monopoly power, price and wage rigidities, and liquidity constraints. The necessity, relevance, and economic meaning of these assumptions has been controversial. As discussed presently, some modeling exercises fail to pick up lead-lag patterns from nominal wage and price rigidities and other built-in frictions, and hence the calibrated parameter values and elasticities could just reflect lagging propagation effects of monetary policy. Various influential models of monetary economics [Christiano, Eichenbaum and Evans (2005), Kaplan, Moll and Violante (2018), and Smets and Wouters (2007)] display a careful representation of the consumption and production sectors, but lump together all forms of consumption, and assume frictionless capital markets for the most part. These models are not well-suited to replicate the IS-transmission mechanism of monetary policy. Investment changes may be augmented by credit frictions for prolonged increases in the interest rate—especially in times of heightened risk. More recent efforts have been directed toward financial intermediation and the ability of the central bank to provide collateral to the private sector and avert a financial crisis [Bianchi and Bigio (2022) and Gertler and Karadi (2011)]. Still, these latter approaches—embedding credit frictions—are in a primitive stage to replicate the dynamics of real and monetary aggregates.

The Elasticity of Intertemporal Substitution. In the microfoundations of New Keynesian models, the elasticity of intertemporal substitution in consumption is a key parameter value. Still, estimates for the degree of habit formation and intertemporal substitution in consumption may just reflect the dynamics of consumer durables rather than other forms of consumption. Besides, the volatility of consumer durables may be affected by financial frictions. Indeed, this elasticity of substitution increased in the financial crisis of 2007-2009. Consumer heterogeneity, liquidity constraints, access to credit, and increased uncertainty may just have a primary impact on consumer durables. Consumer nondurables and services are less volatile than income over these MTCs, while making up for about one-half of the total consumption variation. Models are idealized representations and their parameters will pick a wide variety of effects. Therefore, it is essential to delve into the underlying forces driving these effects.

The Sluggish Response of the Aggregate Price. Nakamura and Steinsson (2013) survey a large literature on granular approaches to the frequency of the price change for generating a sluggish response of the aggregate price. While simple microfounded models with random price changes or menu costs can match sample moments of an ergodic distribution, it is much more challenging to account for the lagging effects of a cumulative *FFR* increase in which inflation may originally go up and then *transit* to a targeted stationary distribution of the price change. In New Keynesian models with nominal rigidities, the price may usually be rewritten as a discounted sum of expected future marginal costs [e.g., Galí and Gertler (1999) and Sbordone (2002)]; hence, the aggregate price would be a leading indicator of the marginal cost. In the Online Appendix, our econometric work shows that the decline in nominal wage growth usually comes before the reduction in inflation.

The modeling of nominal wage and price stickiness to reinforce the propagation effects of interest rate hikes is certainly a topic that requires further consideration [cf., Chari, Kehoe and McGrattan (2000) and Golosov and Lucas (2005)]. Nominal wage and price stickiness *a la Calvo* assumed in New Keynesian models do not seem adequate to replicate these lead-lag patterns for employment, nominal wage growth, and inflation, in which the slope of the Phillips curve may become quite volatile. In these New Keynesian models, price stickiness emerges by letting only a small fraction of agents reset the price at each moment in time.[13] Accordingly, this restricted response of nominal wages and prices is based on a forward-looking updating price mechanism. In the data, nominal wage and price rigidities appear to be part of a *lagged equilibrium adjustment process* giving rise to positive values for the Phillips curve in some phases of the MTC. Besides, forward-looking pricing rules presuppose monopoly power in final goods and labor markets. Monopoly power, however, does not seem a prevailing assumption for the labor supply and many homogeneous good markets, and may

[13]Several other papers have looked into the microfoundations of nominal price and wage rigidities for the dynamics of output and inflation under bargaining and monopoly power. Galí and Gertler (1999) and Sbordone (2002) take as given the paths of labor compensation and *TFP* and search for a best fit for the optimal pricing problem.

only play an auxiliary role in these MTCs.

Financial Frictions. As discussed in our evaluation of the Great Recession of 2007-2009, financial frictions may have substantial real effects because of greater risk and uncertainty which may affect the timing and response of leading and lagging indicators of output. In some MTCs long-term interest rates stay relatively flat and the term spread (*TS*) becomes negative and quite large; see Table 2. On average, only about one-third of the increase of the *FFR* is passed through to the long-term interest rate. Hence, other factors beyond the *FFR* increases may contribute to the drop in credit and investment. Financial frictions may interact with the level of indebtedness of the consumption and production sectors, the health of the banking system, the public debt, and fiscal policy.

4 Sources and Persistence of Inflation

The Fed has vowed to restore its two-percent target for *PCE*-headline *(PCE-HL)* inflation, which peaked at 6.64 percent in the second quarter of 2022. This policy target has to cope with the following sources[14] of inflation persistence.

4.1 Inflation Shocks

(i) *Energy and Food Inflation.* Historically, energy and food have been important cost-push factors of inflation—especially for commodities—and seem to be more persistent than in previous episodes. Usually, energy and food inflation faded after two years but now the geopolitical climate may expand this pricing cycle. Moreover, COVID-19 has increased the cost of durable goods and investment capital with added international trade barriers. Energy and food costs are usually passed through to *CPI*-core (*CPI-C*) inflation and nominal wage growth. Indeed, the following two facts are quite uncommon and signal that inflation may be quite entrenched. First, in the second quarter of 2022 the gap between *CPI*-headline (*CPI-HL*) and *CPI-C* inflation was over 2.5 percentage points, which has only been observed in the 1970s; see Figure 2. And second, *CPI-HL* inflation has outstripped annual nominal wage growth by about 2 percentage points.

(ii) *Wages and Markups.* Several data sources place current nominal wage growth above 5 percent without clear tendency to go down. The Online Appendix illustrates the strong positive effects of nominal wage growth on inflation over our MTCs. COVID-19

[14]The Online Appendix explores these sources of inflation delaying the operation of the propagation channels of monetary policy. A systematic study of all these sources would be a rather ambitious task beyond the scope of this paper.

has contracted the labor supply. Increasing unemployment rates and declining real wage growth have been the norm in the above MTCs. Interest rates and taxes are bound to increase, which will also exert inflation pressures on markups and final prices of goods and services.

(iii) *CPI-Shelter Inflation and Housing Appreciation.* The cumulative increase in national housing rents has been about 25 percent; the estimated annual growth rate peaked at 17 percent in February 2022 [see, e.g., Zillow Observed Rent Index (*ZORI*)]. Housing rents are a sizable part of the *CPI* and will translate into *CPI*-inflation with a lag between six and twelve months [Bolhuis, Cramer and Summers (2022)]. Housing appreciation has traditionally propped up consumption; see the Online Appendix.

(iv) *Monetary and Fiscal Policy.* *PCE-HL* inflation went up to over 6 percent while the *FFR* was still hitting the lower bound [e.g., Blanchard (2022)]. Negative real interest rates over long-time periods, stimulus checks and other forms of money creation generate inflation pressures through asset appreciation, increasing investment, and consumption expenditure. Historical levels of government transfers together with social distancing constraints boosted households' savings—resulting in more resilient balance sheets—adding to the rise and persistence of inflation; e.g., Aladangady *et al.* (2022). Government debt increased significantly without observable effects on the credit spread.

Observe that (i)-(ii) are aggregate negative supply shocks and (iii)-(iv) are aggregate positive demand shocks. This constellation of shocks may lessen and delay the various propagation channels of the IS-transmission mechanism of monetary policy. For instance, a negative labor supply shock will increase nominal wage growth, while a positive wealth effect will sustain consumption demand.

4.2 The Conventional Model of Inflation

Headline inflation will refer to *CPI*-inflation. Core inflation refers to *CPI*-inflation less food and energy. In the past, core inflation has hovered around 2 percent, and only in some short periods has deviated from headline inflation; see Figure 2. Since headline inflation depends on external sources (energy and food data), we will focus on core inflation.[15]

[15]The *PCE* price index is the Fed's preferred inflation measure since 2000 [Board of Governors of the Federal Reserve System (2000)]. The *PCE* price index is quite similar to the *CPI*, but they differ in some respects. While expenditure weights in the *PCE* price index are continuously updated to take into account changes in the consumption bundle, these weights are adjusted periodically in the *CPI*. Both energy and

What we term *the conventional or traditional model of inflation* is just a view as to how inflation has evolved from *the Great Moderation* since the late 1980s: (1) controlled inflation for services, (2) low or negative inflation for commodities, (3) some acute but relatively short fluctuations in energy and food prices, and (4) nominal wage growth keeping up with core inflation plus *TFP* growth but losing against headline inflation in some time periods.
As compared to commodities, services are usually non-tradable, labor intensive, and tend to experience less productivity growth. Hence, services should be more inflationary than commodities based on *capital-biased technological progress* and competition from international trade. Energy and food prices are fairly volatile, but usually peak within two or three years; then, they sharply go down. In spite of computerization, the U.S. share of labor compensation in *GDP* at current national prices remained constant over the last decade at around 59.50 percent (e.g., see FRED).
Inflation. Services account for about 60 percent of *CPI*-inflation, and commodities for 40 percent. Within these categories, food items make up for over 13 percent of the *CPI*, and energy items make up for about 8 percent. Between January 2000 and December 2019, inflation in services less energy averaged 2.76 percent, and inflation in commodities less food and energy averaged 0.01 percent; see Table 3. Energy inflation peaked at about 30 percent in the energy crises of 2003-2006 and 2007-2008, but both price cycles were relatively short to awaken fears of entrenched inflation. Between January 2000 and December 2019, energy inflation averaged 4.27 percent, and food inflation averaged 2.30 percent. All in all, average *CPI-C* inflation for quarterly data averaged 2.10 percent over the twenty-year period, and *CPI-HL* inflation averaged 2.17 percent. *PCE-C* inflation averaged 1.75 percent and *PCE-HL* inflation 1.86 percent.
COVID-19 broke apart this conventional model of inflation—a stronghold for anchoring inflation expectations. After the COVID-19 outburst, prices for commodities were the first to jump. These prices are still in their two-year upward trajectory (see Table 3) because of supply chain disruptions, energy costs, and higher wages. Moreover, food and energy costs have skyrocketed, and are not expected to go down so soon because of global geopolitical political turbulence and labor shortages. Therefore, two solid pillars of the conventional model of inflation to anchor price expectations [(2)-(3) above] have been shaken. COVID-19 also brought in continued expansionary monetary and fiscal policies rising housing wealth and aggregate expenditure. Housing rental prices have gone up over 25 percent [Zillow Observed

housing costs make up for a larger share of the basket of items included in the *CPI*. Therefore, *CPI*-inflation tends to be higher and more volatile.

Rent Index *(ZORI)*]. The S&P/Case-Shiller U.S. National Home Price Index went from 215 in March 2020 to 308 in June 2022.

Wages and Price Markups. Table 3 reports four measures of wage growth. Between January 2000 and December 2019, average wage growth from all these measures was around 3 percent, whereas *TFP* growth averaged 0.76 percent. Hence, an average worker was able to secure core inflation plus *TFP* gains. Between December 2021 and December 2022, average wage growth was about 5.5 percent, core inflation about 5.44 percent, and annual *TFP* growth about -0.16 percent. Therefore, an average worker is still securing core inflation together with *TFP* growth, but is losing from headline inflation (7.77 percent). Average wages are usually more volatile than core inflation, and hence it is common (i.e., one-year observations) to see deviations of the average wage from core inflation plus *TFP*. The unemployment rate has been around 3.4 percent, which is quite low by historical accounts. The low unemployment rate has been related to a drop in the labor force participation and to relative high expenditure as exemplified in the ratio $(C_{dur} + I)/Y$; see Figure 1b. After extrapolating past trends, some estimates show that about 5M workers have withdrawn from labor participation. Labor shortages have been observed at the aggregate and sectoral levels and can become quite persistent [e.g., Ball, Leigh and Mishra (2022), Bauer, Edelberg and Estep (2022), and Blanchard, Domash and Summers (2022)], but average nominal wage growth so far fits within the conventional model of inflation—matching up core inflation plus *TFP* growth.

At this descriptive level, we can furthermore review trends in profits and markups. From Table 3, profits have increased at an annual rate of 7.15 percent between January 2000 and December 2019. The general level of markups may have increased by 10 percent [Nekarda and Ramey (2021), Table 2] over the last decade. While the labor income share has been quite stable, some other factors have been blamed for the evolution of profits. First, there has been a relative drop in the price of capital goods, and hence there is some room for the increase in profits coming from capital-biased technological progress. And second, Smolyansky (2022) computes that two thirds of the growth in profits over sales can be attached to drops in the interest and tax expenses. Again, these computations should be taken as a mere accounting exercise—without considering their indirect effects on economic activity.

To conclude, because of these inflation shocks it seems quite hard to bring inflation down below 3 percent.[16] Given the downward rigidity of nominal wages and prices of services at

[16] A rather concerning issue is inflation in services less shelter (SRV-LS). This component represents 27.58 percent of the *CPI* and 35 percent of *CPI-C*. Currently, annual *SRV-LS*-inflation is 6.68 percent, and it is highly correlated with nominal wage growth. Assuming inflation in food to be around 9 percent, inflation in energy around 5 percent, and inflation in commodities around 1 percent, a significant reduction in inflation

very low inflation rates, the Fed should be willing to accept temporarily inflation levels well over the two-percent benchmark rate. In the aftermath of COVID-19, commodity prices (including energy and food) have surged—challenging conventional inflation patterns. Inflation in services and salaries no longer can be around 3 percent to meet the two-percent inflation target. Nominal wage growth is not exerting downward pressure on inflation; moreover, some inflation pass-through may be expected from higher costs from capital goods, taxes, and interest rates.

4.3 Monetary Aggregates, Asset Appreciation, and Inflation

From Table 3, between January 2000 and December 2020, average annual growth for *M2* and bank credit was around 6 percent. Hence, broad money over nominal *GDP* has been growing consistently; see Wolf (2022). The long-trend slowdown of the money velocity conforms with declining interest rates since the 1980s—converging to the zero lower bound. Growth of monetary aggregates has been greater than asset price inflation.[17] More importantly, this expansion of monetary aggregates has been disconnected from the conventional model of inflation and wage growth. A broad set of long-term inflation expectation measures have been aligned with the conventional model of inflation, which may arise from trust and confidence that the Fed will keep core inflation at bay and preserve these inflation patterns. The link between broad monetary aggregates and inflation is observed to be stronger at higher inflationary levels; see Borio, Hofmann and Zakrajsek (2023).
With stimulus checks and further expansionary monetary and fiscal measures, COVID-19 witnessed the highest increase in monetary aggregates—again pushing consumption and government expenditures. The Fed announced that it would begin to "taper" its large-scale asset purchases in November 2021, and started moving the *FFR* in March 2022. But there was solid evidence much before that the persistence of inflation could become a serious policy issue [e.g., Druckenmiller (2021) and Summers (2021)]. After COVID-19, housing prices have grown faster than bank credit and the money supply; see Table 3. The Online Appendix documents that housing appreciation has significant effects on consumer durables, and to a lesser extent in consumer nondurables and services. Indicators of credit risk and delinquency still display low values; see, however, *IMF* (2023). The credit spread *CS* was 2.16 percent

in services would be necessary to reach the two-percent target for *PCE-HL* inflation. Even if we assume a shelter inflation of 3 percent, inflation in *SRV-LS* should be about -2.00 percent.

[17] Asset appreciation is fairly sensitive to the chosen initial date. Between January 2000 and December 2020, annual housing appreciation has averaged 4.17 percent while the S&P 500 has averaged about 5.30 percent, and NASDAQ about 8.59 percent; see Table 3. In spite of low economic growth, in the past two decades asset appreciation has overshadowed inflation of goods and services.

in March of 2023. Hence, in our computations below for the IS-transmission mechanism we assume that the risks of a financial meltdown are quite moderate. The Fed seems ready to rescue failing financial institutions, which may inadvertently delay the contractionary effects of monetary policy.

5 Lessons for Managing Monetary Policy in the Post COVID-19 Era

All our efforts so far have focused on a detailed account of the IS-transmission mechanism of monetary policy under systematic increases of the *FFR* based on the empirical evidence gleaned from the above four U.S. MTCs. We now offer some policy prescriptions based on current economic conditions and our estimates for the propagation effects of the IS-transmission mechanism of monetary policy.

Macroeconomic Laws for Major MTCs. As discussed in Section 3 and the Online Appendix, *systematic FFR* changes may have stronger effects on economic activity and inflation. We highlight these empirical regularities in Table 4 as macroeconomic laws for major MTCs intended to quantify some propagation channels. *(i) Output and the FFR:* The *FFR* semi-elasticity of our *BP*-filtered measure of real *GDP* is less than 1 (in absolute value), although it may jump over 1 in a financial meltdown. In the IS-transmission mechanism the output contraction is driven by the semi-elasticities of durable goods and investment with respect to the cumulative interest rate hike together with a much softer response of consumer nondurables and services. Because investment and durable goods are about 26 percent of nominal output, these semi-elasticities are not high enough to generate an output contraction greater than the change in the *FFR*. *(ii) Output, Unemployment, and Wages:* The percentage output contraction is generally greater than the increment in the unemployment rate; i.e., Okun's Law. Moreover, the drop in nominal wage growth is commensurate to the increase in the unemployment rate. *(iii) Inflation and Wages:* Nominal wage growth tends to keep up with core inflation plus *TFP* growth. Real wage growth declines at advanced stages of the recession—prompting the reduction in inflation. Nominal wage growth may lose against headline inflation. Finally, *(iv) Inflation and Output:* It follows from all these facts in Table 4 that the reduction in inflation is smaller than the percentage output contraction. This usually applies to both core and headline inflation—unless there is a large, sudden drop in energy and food inflation. For instance, over the above four monetary tightening cycles the average cumulative increase for the *FFR* was 775 basis points resulting in an average reduction in *PCE-C* inflation of 3.78 percentage points, while the average output contraction for our *BP*-filtered measure of output was 5.66 percentage points. In fact, the cumulative drop in *PCE-C* inflation is 0.48 of the cumulative change in the *FFR*. Hence, for a peak value for annual *PCE-C* inflation of roughly 5.30 in January 2022, the required cumulative increment in the *FFR* would be about 700 basis points to reach the two-percent inflation target.

Lags in the Propagation Effects of Monetary Policy. For each macroeconomic aggregate, Table 5 pins down the date of the maximum response upon an *FFR* increase, while the Online Appendix tracks down the whole time interval of these lagging effects. Roughly, the main response of real economic aggregates occurs within $s = 4$ and $s = 8$ quarters after the interest rate increase, and the main response of nominal variables may occur within $s = 10$ and $s = 12$ quarters. Interestingly, Table 5 illustrates that these patterns for the timing of the lagging effects of monetary policy can be observed in a variety of scenarios—over both systematic policy changes and in arbitrary time periods—excluding the MTC of the financial crisis of 2007-2009.

Bounds for Systematic Increases in the FFR. (i) Upper bound: By an upper bound[18] for the *FFR*, we want to refer to the maximum cumulative *FFR*-increase compatible with acceptable drops in investment, real output, and employment—without risking a financial meltdown. From Figure 1b we observe that the ratio $(C_{dur} + I)/Y$ has never been below 0.20. Hence, letting $(C_{dur} + I)/Y$ go from the recent peak of 0.27 to 0.22 may increase credit risk substantially and may lead to an output contraction of over 6.5 percentage points. From our discussion in footnote 8, a contraction in our filtered measure of *GDP* of over 6.5 percent would correspond to a negative average annual growth rate in real *GDP* for over 8 quarters. Therefore, it seems reasonable for the ratio $(C_{dur} + I)/Y$ to stay above 0.23. Then, the cumulative *FFR* increase should be about 550 basis points. As we report in Table 6, Scenario 1, from all our MTCs, the total contraction for our filtered measure of output would then range between 4.40 and 5.34 percentage points, the unemployment rate could reach between 6.92 and 7.67 percent, inflation between 1.83 and 2.69 percent, and nominal wage growth between 1.83 and 2.74 percent. These are very conservative estimates under present sources of inflation persistence. Indeed, given the actual contraction in the labor force originated from COVID-19, the estimate for the unemployment rate should be adjusted to about 5 percent, which is just below our estimates in Panels B and C of Table 6. These latter two panels report estimates for the expected impact of *FFR* on our economic aggregates based on average semi-elasticities computed from our MTCs excluding the 2007-2009 financial crisis. Of course, in this case we obtain lower estimates for the output contraction but higher (and possibly more realistic) estimates for inflation. Under these new estimates, a cumulative

[18] The following computations for both the upper and lower bounds rely on page 44 of the Online Appendix.

increase in the *FFR* of about 550 basis points would generate a contraction in our filtered measure of *GDP* of over 3.8 percent, which would translate into a negative average annual growth rate in real *GDP* for about 5 quarters. Hence, even under our recommended upper bound for the *FFR*, there would be a significant, long decline in economic activity while the expected reduction in inflation would surely be short of the two-percent policy mark.

(ii) Lower bound: By a lower bound for the *FFR*, we want to refer to the minimum *FFR*-increase to restore the two-percent inflation target. In the second quarter of 2022, annual *PCE-HL* inflation peaked at 6.64 percent and *CPI-HL* inflation peaked at 8.56, while *PCE-C* inflation peaked at 5.33 in the first quarter of 2022, and *CPI-C* inflation peaked at 6.32 percent. From the above baseline elasticity values characterizing the IS-channel in Section 3, we get that a cumulative hike of at least 700 basis points for the *FFR* is necessary to bring down *PCE-HL* inflation (and the other inflation indexes) to about the two-percent target. As documented in Table 6, Scenario 2, for a cumulative increase in the *FFR* of 700 basis points the output contraction may range between 5.60 and 6.79 percentage points, the unemployment rate could reach between 7.88 and 8.83 percent, and nominal wage growth between 0.42 and 1.57 percent. Again, our estimate of the unemployment rate should be adjusted for the current state of the labor market. Current developments in the labor market and resilient households' balance sheets make inflation more persistent than in previous episodes.

Prescriptions for Monetary Policy. As these two bounds for the interest rate encompass regions with empty intersection, inflation cannot get down to desired levels without a marked economic slowdown or the so touted *hard landing.* The economy, however, cannot be pushed to a financial crisis. We posit that 550 basis points for the *FFR* is a red line not to be surpassed. From the IS-transmission mechanism, output is driven by the ratio $(C_{dur} + I)/Y$, which in turn could be a major source of financial risk. In the Great Recession of 2007-2009 the credit spread *CS* went up to 600 basis points and the unemployment rate to above 10 percent. Based on our MTCs excluding the Great Recession, in the Online Appendix we try to picture the dynamic responses to an *FFR* hike of 550 basis points for inflation, unemployment, and output. We get that *PCE-C* inflation below 3 percent will be reached by 2025-Q4, and below 2 percent by 2026-Q3. As already pointed out in footnote 4, this relatively slow response of inflation will come at the cost of an economic recession in 2024 with an overall output contraction of over 3.8 percentage points as a deviation from trend.

6 Concluding Remarks

This paper contributes to three related areas of monetary policy. First, we study in depth the impact of some monetary tightening cycles (MTCs) on economic activity and inflation: the lagging effects of monetary policy could be magnified under systematic monetary interventions. Second, the evidence fits well with a refined variant of the IS-transmission mechanism to mimic the propagation effects of monetary policy. We study the quantitative impact on economic activity and inflation of the various propagation channels conforming the IS-transmission mechanism. We highlight the heterogeneous dynamic response of main macroeconomic aggregates to the interest rate. Most economic models are not intended to replicate this transmission mechanism propelled by the multiplying effects of investment on economic activity upon an interest rate change. We portray the dynamics of nominal wage growth and inflation under an unstable Phillips curve reflecting lead-lag patterns of this transmission mechanism for employment, wages, and prices. In some phases of a prototypical MTC, the slope of the Phillips curve becomes positive. And third, we discuss some prescriptions for monetary policy under various inflation shocks and the current state of the economy. Most professional forecasts about inflation tend to be more optimistic than our projections supported by the evidence gleaned from previous MTCs. Today's inflation originates from an unprecedented mix of shocks associated with COVID-19, which have clearly been overlooked, and will certainly delay and weaken the propagation channels of monetary policy.

It is typical to appeal to *VAR* methods over arbitrarily chosen time periods to sort out the dynamic effects of monetary policy on economic activity and inflation. Because of the long lags involved in the dynamics of output and inflation, these propagation effects may be lessened by changing agents' expectations and further government's responses to contemporaneous economic conditions. Over our MTCs, the magnitude of the average response to the *FFR* of the various *GDP* components, employment, wages and inflation tends to be three times greater than over a whole extended period stretching over these MTCs. Therefore, our analysis underscores the *stronger effects of systematic monetary policy.*

Several important lessons emerge from the IS-transmission mechanism of monetary policy. First, an increase in the *FFR* will eventually generate a contraction in output and a later reduction in inflation. There is then an important role for countercyclical monetary policy. Inflation lags output, and hence monetary policy can be time-inconsistent. Second, an MTC may risk a severe economic downturn because of the involved high output cost to quell inflation. Under our benchmark estimates, the variations in both investment, I, and total consumption, C, contribute equally to the output contraction, while the variations in consumer durables, C_{dur}, and consumer nondurables and services, $C_{ndur} + C_{srv}$, contribute equally to the loss in total consumption, C. Third, in the short term the slope of the Phillips curve does not reflect the aforementioned output-inflation tradeoff. Rather, this slope varies with the lead-lag patterns in employment, wages, and inflation involved in the IS-transmission mechanism. And fourth, for the present economic situation we still have not observed the decline in nominal wage growth that usually occurs before the reduction in inflation.

Macroeconomists have long debated about the relative importance of real and monetary forces driving the business cycle. These primary forces interact with the Fed's attempts to stabilize the economy. This poses an identification problem: Fed's interventions greatly affect high-frequency economic fluctuations and asset values though the transmission mechanisms of monetary policy. In the last decades the Fed has leaned towards predictable rules to monitor real output growth and inflation. Then, cross-correlations of economic aggregates and related empirical regularities (e.g., the Phillips curve) may just echo the actions of economic policies. Understanding the transmission mechanisms of monetary policy should therefore contribute to the study of the business cycle.

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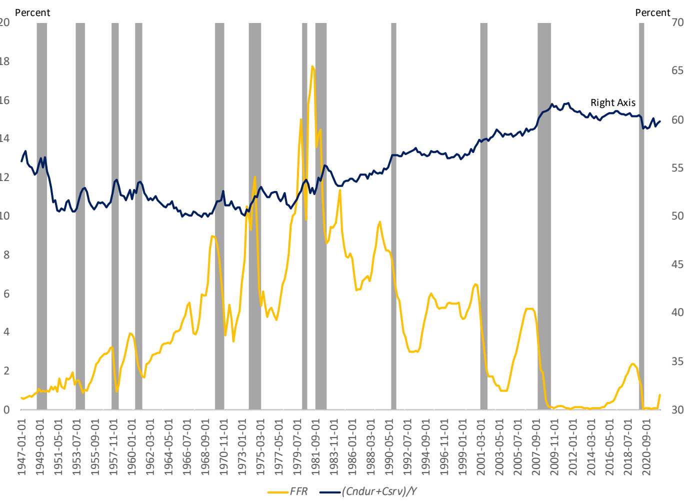
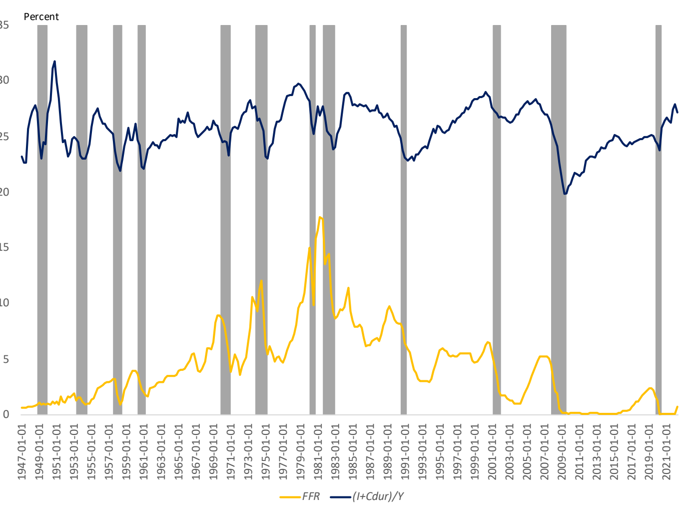
Figure 1: *GDP* Share of Consumption and Investment, and the *FFR*



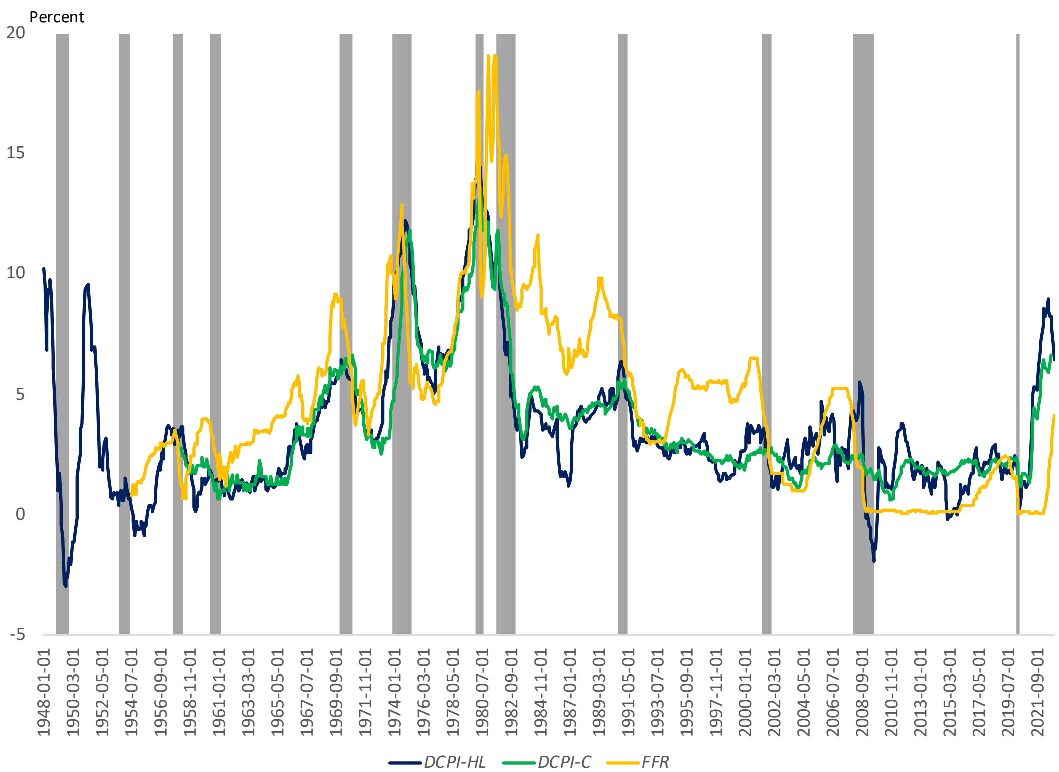
(a) Nondurable Consumption and Services



(b) Durable Consumption and Investment

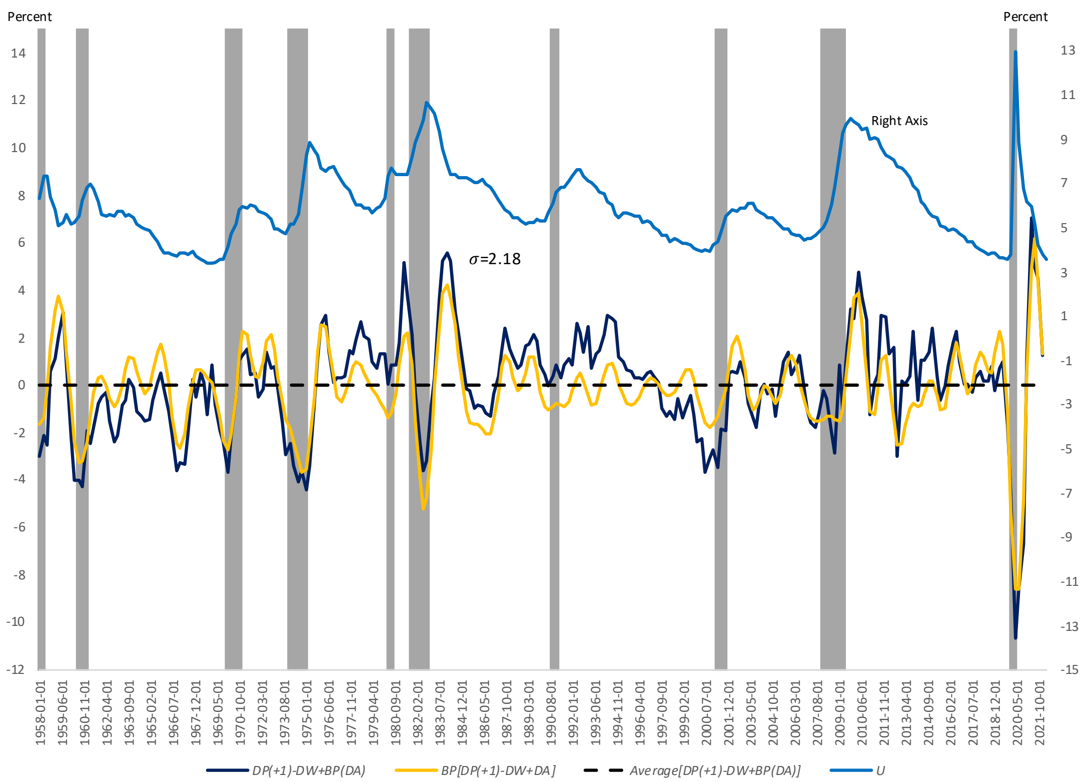
Notes: The figure depicts the evolution of the *FFR* and the ratios $(C_{ndur} + C_{srv})/Y$ and $(I + C_{dur})/Y$, where $\boldsymbol{FFR}$ is the federal funds effective rate, $\boldsymbol{C_{ndur}}$ is nominal personal consumption expenditures of nondurable goods, $\boldsymbol{C_{srv}}$ is nominal personal consumption expenditures of services, $\boldsymbol{I}$ is nominal gross private domestic investment, $\boldsymbol{C_{dur}}$ is nominal personal consumption expenditures of durable goods, and $\boldsymbol{Y}$ is nominal gross domestic product. Shaded areas represent periods of *NBER*-dated recessions. All variables are measured in percentage points. Quarterly data. For further definitions and data sources see the Online Appendix.

Figure 2: The *FFR*, and Headline and Core *CPI* Inflation



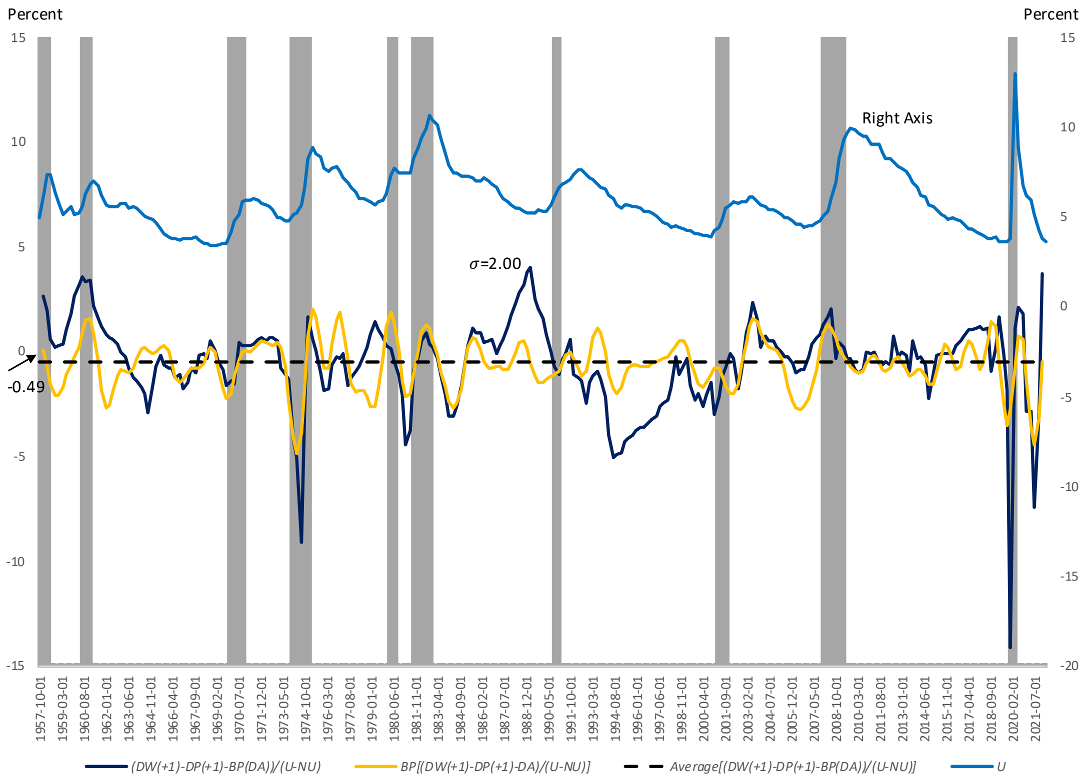
Notes: The figure depicts the evolution of the *FFR*, *CPI-HL* inflation, and *CPI-C* inflation, where ***FFR*** is the federal funds effective rate, ***DCPI-HL*** is annual *CPI*-headline inflation, and ***DCPI-C*** is annual *CPI*-core inflation (excluding food and energy). Shaded areas represent periods of *NBER*-dated recessions. All variables are measured in percentage points. Monthly data. For further definitions and data sources see the Online Appendix.

Figure 3: Dynamics of Unemployment, and Inflation minus Growth of Labor Costs



Notes: The figure depicts the evolution of U, *DP(+1)-DW+BP(DA)* and its average, and filtered *DP(+1)-DW+DA*, where ***U*** is the unemployment rate, ***DP(+1)*** is annual *CPI*-core inflation in the next period, ***DW*** is the annual growth rate of hourly compensation for all employed persons in the business sector (HCOMPBS), ***DA*** is annual *TFP* growth, ***BP(DA)*** is filtered *DA*, and ***BP[DP(+1)-DW+DA]*** is filtered *DP(+1)-DW+DA*. Filtering procedure: Band-pass filter isolating frequencies between 6 and 32 quarters. Shaded areas represent periods of *NBER*-dated recessions. All variables are measured in percentage points. Quarterly data. For further definitions and data sources see the Online Appendix.

Figure 4: Dynamics of Unemployment and the Slope of The Phillips Curve



Notes: The figure depicts the evolution of *U*, the ratio *(DW(+1)-DP(+1)-BP(DA))/(U-NU)* and its average, and the filtered ratio *(DW(+1)-DP(+1)-DA)/(U-NU),* where ***U*** is the unemployment rate, ***NU*** is the noncyclical rate of unemployment, ***DP(+1)*** is annual *CPI*-core inflation in the next period, ***DW(+1)*** is the annual growth rate of hourly compensation for all employed persons in the business sector (HCOMPBS) in the next period, ***DA*** is annual *TFP* growth, ***BP(DA)*** is filtered *DA*, and ***BP[(DW(+1)-DP(+1)-DA)/(U-NU)]*** is the filtered ratio *(DW(+1)-DP(+1)-DA)/(U-NU)*. An interpolation method described in the Online Appendix is used for periods in which the unemployment gap *(U-NU)* is close to zero. Filtering procedure: Band-pass filter isolating frequencies from 6 to 32 quarters. Shaded areas represent periods of *NBER*-dated recessions. All variables are measured in percentage points. Quarterly data. For further definitions and data sources see the Online Appendix.

Table 1: Monetary Tightening Cycles (I)

	1967-Q3–1969-Q3	1972-Q1–1974-Q3	1977-Q1–1981-Q2	2004-Q2–2006-Q3
ΔFFR	5.09	8.54	13.12	4.24
		GDP		
$\Delta BP(GDP)$	-3.43	-7.67	-6.85	-4.69
	(1968-Q4–1970-Q3)	(1973-Q2–1975-Q2)	(1979-Q2–1982-Q4)	(2008-Q1–2009-Q2)
$\Delta HP(GDP)$	-4.96	-7.57	-8.35	-5.12
	(1969-Q1–1970-Q4)	(1973-Q2–1975-Q2)	(1978-Q4–1982-Q4)	(2007-Q4–2009-Q2)
$\Delta DGDP$	-0.64	-2.45	-0.55	-4.00
	(1969-Q3–1970-Q1)	(1973-Q4–1975-Q2)	(1980-Q1–1982-Q3)	(2008-Q2–2009-Q2)
		TFP		
$\Delta BP(A)$	-3.18	-7.51	-4.25	-4.28
	(1968-Q3–1970-Q2)	(1973-Q1–1975-Q1)	(1978-Q4–1982-Q3)	(2006-Q1–2009-Q1)
ΔDA	-4.68	-9.70	-6.90	-6.26
	(1968-Q3–1970-Q1)	(1973-Q1–1974-Q4)	(1977-Q3–1982-Q3)	(2004-Q1–2008-Q4)
		Labor Market		
ΔU	2.63	4.10	4.97	5.50
	(1968-Q4–1971-Q3)	(1973-Q4–1975-Q2)	(1979-Q2–1982-Q4)	(2006-Q4–2009-Q4)
ΔDW	-3.42	-5.16	-7.21	-5.41
	(1970-Q1–1971-Q4)	(1975-Q1–1976-Q2)	(1980-Q4–1983-Q4)	(2007-Q3–2009-Q1)
$\Delta DW\text{-}DP$	-3.59	-4.75	-3.94	-4.39
	(1968-Q4–1970-Q4)	(1973-Q3–1974-Q4)	(1977-Q3–1981-Q3)	(2007-Q3–2009-Q1)
$\Delta DW\text{-}DP\text{-}BP(DA)$	-6.01	-8.49	-5.38	-7.44
	(1970-Q1–1971-Q1)	(1974-Q2–1976-Q1)	(1979-Q3–1984-Q1)	(2008-Q4–2010-Q2)
		Inflation		
$\Delta DPCE\text{-}HL$	-1.73	-6.38	-7.30	-5.12
	(1970-Q1–1972-Q3)	(1974-Q4–1976-Q4)	(1980-Q1–1983-Q4)	(2008-Q3–2009-Q3)
$\Delta DCPI\text{-}HL$	-3.20	-6.86	-11.90	-6.86
	(1970-Q1–1972-Q3)	(1974-Q4–1976-Q4)	(1980-Q2–1983-Q3)	(2008-Q3–2009-Q3)
$\Delta DPCE\text{-}C$	-2.23	-4.13	-6.84	-1.94
	(1970-Q1–1973-Q1)	(1975-Q1–1976-Q2)	(1980-Q4–1987-Q1)	(2006-Q3–2009-Q3)
$\Delta DCPI\text{-}C$	-3.63	-5.41	-10.05	-2.17
	(1970-Q4–1973-Q1)	(1975-Q1–1977-Q1)	(1980-Q2–1983-Q3)	(2006-Q3–2010-Q4)
		Money Supply and Credit		
$\Delta BP(M2)$	-5.18	-7.34	-4.09	-6.25
	(1968-Q4–1971-Q3)	(1972-Q4–1975-Q1)	(1977-Q3–1982-Q2)	(2009-Q2–2010-Q4)
$\Delta BP(BCR)$	-8.08	-8.55	-5.58	-5.44
	(1968-Q4–1970-Q2)	(1974-Q2–1976-Q4)	(1979-Q3–1983-Q1)	(2008-Q4-2011-Q3)

Notes: For each variable, we calculate the peak to trough (or trough to peak) change after the start of the monetary tightening cycle. $\boldsymbol{\Delta}$***FFR***: Change in the federal funds effective rate. $\boldsymbol{\Delta}$***BP(GDP)***: Change in filtered real *GDP*. $\boldsymbol{\Delta}$***HP(GDP)***: Change in filtered real *GDP* under the Hodrick-Prescott filter. $\boldsymbol{\Delta}$***DGDP***: Change in the annual growth rate of real *GDP*. $\boldsymbol{\Delta}$***BP(A)***: Change in filtered *TFP*. $\boldsymbol{\Delta}$***DA***: Change in the annual growth rate of *TFP*. $\boldsymbol{\Delta}$***U***: Change in the unemployment rate. $\boldsymbol{\Delta}$***DW***: Change in the annual growth rate of hourly compensation for all employed persons in the business sector (HCOMPBS). $\boldsymbol{\Delta}$***DW-DP***: Change in the annual growth rate of *HCOMPBS* less *CPI*-core (excluding food and energy) inflation. $\boldsymbol{\Delta}$***DW-DP-BP(DA)***: Change in the annual growth rate of *HCOMPBS* less *CPI*-core inflation and filtered *TFP* growth. $\boldsymbol{\Delta}$***DPCE-HL***: Change in annual headline inflation from the *PCE* deflator. $\boldsymbol{\Delta}$***DCPI-HL***: Change in annual headline inflation from the *CPI*. $\boldsymbol{\Delta}$***DPCE-C***: Change in annual core inflation from the *PCE* deflator. $\boldsymbol{\Delta}$***DCPI-C***: Change in annual core inflation from the *CPI*. $\boldsymbol{\Delta}$***BP(M2)***: Change in filtered *M2* money stock. $\boldsymbol{\Delta}$***BP(BCR)***: Change in filtered bank credit for all commercial banks. Filtering procedure (except for Δ*HP(GDP)*): Band-pass filter isolating frequencies from 6 to 32 quarters. All variables are measured in percentage points. Quarterly data. For further definitions and data sources see the Online Appendix.

Table 2: Monetary Tightening Cycles (II)

	1967-Q3–1969-Q3	1972-Q1–1974-Q3	1977-Q1–1981-Q2	2004-Q2–2006-Q3
ΔFFR	5.09	8.54	13.12	4.24
		GDP		
$\Delta BP(GDP)$	-3.43	-7.67	-6.85	-4.69
	(1968-Q4–1970-Q3)	(1973-Q2–1975-Q2)	(1979-Q2–1982-Q4)	(2008-Q1–2009-Q2)
		Expenditures over GDP		
$\Delta(C_{dur}/Y)$	-1.18	-1.62	-2.05	-1.90
	(1968-Q3–1970-Q4)	(1973-Q1–1974-Q4)	(1978-Q2–1981-Q4)	(2004-Q2–2008-Q4)
$\Delta(I/Y)$	-2.04	-4.24	-4.68	-7.18
	(1969-Q1–1970-Q4)	(1973-Q2–1975-Q2)	(1978-Q4–1982-Q4)	(2006-Q1-2009-Q3)
$\Delta[(C_{ndur}+C_{srv})/Y]$	2.59	2.92	4.46	3.19
	(1969-Q1–1970-Q4)	(1973-Q2–1975-Q2)	(1978-Q4–1982-Q4)	(2006-Q1-2009-Q3)
$\Delta(G/Y)$	0.29	1.73	1.81	2.44
	(1969-Q4–1970-Q4)	(1973-Q4–1975-Q1)	(1979-Q1–1982-Q4)	(2006-Q3–2009-Q3)
$\Delta(NX/Y)$	0.38	2.17	2.31	3.16
	(1969-Q2–1971-Q1)	(1972-Q1–1975-Q2)	(1978-Q1–1980-Q3)	(2005-Q4–2009-Q2)
		Investment and Durable Consumption		
$\Delta BP(I^r)$	-11.37	-33.00	-29.60	- 26.99
	(1969-Q2–1970-Q3)	(1973-Q2–1975-Q2)	(1979-Q2–1982-Q4)	(2008-Q1–2009-Q2)
$\Delta BP(I^r_{res})$	-19.66	-47.92	-48.56	-18.10
	(1969-Q1–1970-Q2)	(1973-Q1–1975-Q2)	(1979-Q2–1982-Q2)	(2007-Q4-2009-Q2)
$\Delta BP(I^r_{nres})$	-8.19	-19.09	-19.15	-21.68
	(1969-Q3–1971-Q1)	(1973-Q4–1975-Q4)	(1979-Q2–1983-Q1)	(2008-Q1-2009-Q3)
$\Delta BP(C^r_{dur})$	-9.04	-23.41	-16.09	-13.44
	(1968-Q4–1970-Q3)	(1973-Q1–1975-Q2)	(1979-Q2–1982-Q2)	(2007-Q4–2009-Q2)
		Consumption of Non-Durables and Services		
$\Delta BP(C^r_{ndur})$	-1.37	-6.72	-3.42	-3.86
	(1969-Q1–1970-Q2)	(1973-Q1–1975-Q1)	(1979-Q3–1982-Q3)	(2007-Q2–2009-Q2)
$\Delta BP(C^r_{srv})$	-1.06	-3.10	-3.36	-1.85
	(1968-Q4–1971-Q2)	(1973-Q1–1975-Q4)	(1979-Q1–1982-Q2)	(2008-Q2–2009-Q3)
		Public Deficit		
$\Delta DEF/Y$	2.30	3.54	4.17	6.38
	(1969–1971)	(1974–1976)	(1979–1983)	(2004–2009)
		Financial Indicators		
ΔCS	1.45	1.85	2.76	3.97
	(1969-Q1–1971-Q1)	(1973-Q3–1975-Q1)	(1978-Q4–1982-Q4)	(2007-Q1–2008-Q4)
$\Delta NFCI$	–	4.84	4.02	3.14
		(1972-Q4–1974-Q3)	(1977-Q1–1982-Q3)	(2007-Q1–2008-Q4)
ΔTS	-3.60	-6.62	-6.72	-4.21
	(1967-Q4–1969-Q3)	(1972-Q1–1974-Q3)	(1977-Q1–1981-Q2)	(2004-Q2–2006-Q4)
$\Delta GB10$	2.63	2.40	7.66	1.45
	(1967-Q2–1970-Q3)	(1971-Q4–1975-Q3)	(1976-Q4–1981-Q3)	(2003-Q2–2006-Q2)

Notes: For each variable, we calculate the peak to trough (or trough to peak) change after the start of the corresponding monetary tightening cycle. $\boldsymbol{\Delta FFR}$: Change in the federal funds effective rate. $\boldsymbol{\Delta BP(GDP)}$: Change in filtered real *GDP*. $\boldsymbol{\Delta(C_{dur}/Y)}$: Change in the ratio of nominal personal consumption expenditures of durable goods over gross domestic product multiplied by 100. $\boldsymbol{\Delta(I/Y)}$: Change in the ratio of nominal gross private domestic investment over gross domestic product multiplied by 100. $\boldsymbol{\Delta[(C_{ndur}+C_{srv})/Y]}$: Change in the ratio of nominal personal consumption expenditures of nondurable goods and services over gross domestic product multiplied by 100. $\boldsymbol{\Delta(G/Y)}$: Change in the ratio of government consumption and investment expenditures over gross domestic product multiplied by 100. $\boldsymbol{\Delta(NX/Y)}$: Change in the ratio of nominal net exports of goods and services over gross domestic product multiplied by 100. $\boldsymbol{\Delta BP(I^r)}$: Change in filtered real gross private domestic investment. $\boldsymbol{\Delta BP(I^r_{res})}$: Change in filtered real private residential fixed investment. $\boldsymbol{\Delta BP(I^r_{nres})}$: Change in filtered real private nonresidential fixed investment. $\boldsymbol{\Delta BP(C^r_{dur})}$: Change in filtered real personal consumption expenditures of durable goods. $\boldsymbol{\Delta BP(C^r_{ndur})}$: Change in filtered real personal consumption expenditures of non-durable goods. $\boldsymbol{\Delta BP(C^r_{srv})}$: Change in filtered real personal consumption expenditures of services. $\boldsymbol{\Delta DEF/GDP}$: Change in the federal fiscal deficit as percentage of the gross domestic product. $\boldsymbol{\Delta CS}$: Change in Moody's seasoned *Baa* corporate bond yield relative to the yield on 10-Year Treasury constant maturity. $\boldsymbol{\Delta NFCI}$: Change in the Chicago Fed's national financial conditions index. $\boldsymbol{\Delta TS}$: Change in 10-year Treasury constant maturity minus *FFR*. $\boldsymbol{\Delta GB10}$: Change in market yield on U.S. Treasury securities at 10-year constant maturity. Filtering procedure: Band-pass filter isolating frequencies from 6 to 32 quarters. All variables are measured in percentage points. Quarterly data. For further definitions and data sources see the Online Appendix.

Table 3: Inflation Indicators

	Periods		
	2000-Q1–2019-Q4	2020-Q1–2021-Q3	2021-Q4–2022-Q4
		Inflation Measures	
DPCE-HL	1.86	2.12	6.15
DCPI-HL	2.17	2.43	7.75
DPCE-C	1.75	2.06	4.96
DCPI-C	2.01	2.30	5.92
DCPI-ENERGY	4.27	3.00	26.53
DCPI-FOOD	2.30	3.37	9.13
DCPI-SHELTER	2.69	2.38	5.46
DCPI-SERVICES	2.76	2.29	5.71
DCPI-SER-LS	2.84	2.15	5.94
DCPI-SER-LEN	2.76	2.27	5.20
DCPI-DURCOM	-0.91	4.41	10.85
DCPI-COM-LFE	0.01	2.35	8.08
		Financial Variables	
DBCR	5.89	7.79	8.84
DM2	6.13	18.52	6.81
DCASE-SHILLER	4.17	10.46	15.83
DS&P500	5.30	20.50	3.39
DNASDAQ	8.59	36.03	-5.51
DPROFITS	7.15	17.60	12.29
		Wages	
DAHE-PNS	2.82	4.77	6.38
DECI	2.60	2.92	5.00
DW	3.17	6.58	4.84
DATL	3.38	3.55	5.81
DULC	1.24	2.99	5.94
		Real Growth	
DGDP	2.09	1.08	2.81
DA	0.76	1.67	-0.16
DA-UT	0.84	1.13	0.23

Notes: Average annual percentage growth rates. ***DPCE-HL***: Headline inflation from the *PCE* deflator. ***DCPI-HL***: Headline inflation from the *CPI*. ***DPCE-C***: Core inflation from the *PCE* deflator. ***DCPI-C***: Core inflation from the *CPI*. ***DCPI-ENERGY***: Energy inflation from the *CPI*. ***DCPI-FOOD***: Food inflation from the *CPI*. ***DCPI-SHELTER***: Shelter inflation from the *CPI*. ***DCPI-SERVICES***: Services inflation from the *CPI*. ***DCPI-SER-LS***: Services less rent of shelter inflation from the *CPI*. ***DCPI-SER-LEN***: Services less energy services inflation from the *CPI*. ***DCPI-DURCOM***: Durable commodities inflation from the *CPI*. ***DCPI-COM-LFE***: Commodities less food and energy commodities inflation from the *CPI*. ***DBCR***: Bank credit growth rate, all commercial banks. ***DM2***: Growth rate of the money stock *M2*. ***DCASE-SHILLER***: Growth rate of the S&P/Case-Shiller U.S. National Home Price Index. ***DS&P500***: Growth rate of the *S&P500* stock price index. ***DNASDAQ***: Growth rate of the *NASDAQ* composite stock price index. ***DPROFITS***: Growth rate of corporate profits before taxes. ***DAHE-PNS***: Growth rate of average hourly earnings of production and nonsupervisory employees. ***DECI***: Growth rate of the total compensation for private industry workers in all industries and occupations, employment cost index. ***DW***: Growth rate of the hourly compensation for all employed persons in the business sector (HCOMPBS). ***DATL***: Growth rate of the Atlanta Fed's wage growth tracker, unweighted overall. ***DULC***: Growth rate of the unit labor costs for all workers, business sector. ***DGDP***: Growth rate of real gross domestic product. ***DA***: Growth rate of total factor productivity. ***DA-UT***: Growth rate of utilization-adjusted total factor productivity. Data for *DECI* starts on 2002-Q1. Data for *DPROFITS* ends on 2022-Q3. Quarterly data. For further definitions and data sources see the Online Appendix.

Table 4: Systematic Monetary Policy: Macroeconomic Laws for Major Monetary Tightening Cycles

(i) Output and the *FFR*:	$\lvert\Delta BP(GDP)\rvert < \lvert\Delta FFR\rvert$
(ii) Output, Unemployment, and Wages:	$\lvert\Delta U\rvert < \lvert\Delta BP(GDP)\rvert$ (Okun's Law) $\lvert\Delta DW\rvert \approx \lvert\Delta U\rvert$
(iii) Inflation and Wages:	$DP_C \approx DW - DA$
(iv) Inflation and Output:	$\lvert\Delta DP_{HL}\rvert < \lvert\Delta BP(GDP)\rvert$

Notes: For each variable, Δ denotes the peak to trough (or trough to peak) change after the start of the monetary tightening cycle. $\boldsymbol{BP(GDP)}$: Filtered real *GDP*. $\boldsymbol{FFR}$: Federal funds effective rate. $\boldsymbol{DP_{HL}}$: Headline inflation. $\boldsymbol{DP_C}$: Core (excluding food and energy) inflation. $\boldsymbol{U}$: Unemployment rate. $\boldsymbol{DW}$: Annual growth rate of hourly compensation for all employed persons in the business sector (HCOMPBS). $\boldsymbol{DA}$: Annual growth rate of *TFP*. Filtering procedure: Band-pass filter isolating frequencies from 6 to 32 quarters. Quarterly data. For further definitions and data sources see the Online Appendix.

Table 5: Lagging Effects of Monetary Policy

s=2	*s=3*	*s=4*	*s=5*	*s=6*	*s=7*	*s=8*	*s=10*	*s=11*	*s=12*	*s=13*
Panel A: 1954-Q3–2022-Q4										
		$BP(I^r_{res})$	$BP(P^r_h)$	*BP(GDP)*	*BP(U)*		*BP(DCPI-HL)*		*BP(DW)*	*BP(PCE-C)*
		$BP(C^r_{dur})$	$BP(C^r_{ndur})$	$BP(I^r)$			*BP(PCE-HL)*		*BP(DCPI-C)*	
		BP(A)		$BP(C^r_{srv})$						
Panel B: Monetary Tightening Cycles										
	$BP(P^r_h)$		*BP(A)*	$BP(I^r_{res})$	*BP(GDP)*	*BP(U)*		*BP(DCPI-HL)*	*BP(DCPI-C)*	
				$BP(C^r_{dur})$	$BP(I^r)$			*BP(PCE-HL)*	*BP(PCE-C)*	
				$BP(C^r_{srv})$	$BP(C^r_{ndur})$			*BP(DW)*		
Panel C: Monetary Tightening Cycles, Excluding the 2007-2009 Financial Crises										
$BP(P^r_h)$		$BP(I^r_{res})$	*BP(GDP)*	*BP(U)*			*BP(DCPI-HL)*	*BP(PCE-HL)*	*BP(DCPI-C)*	
		$BP(C^r_{dur})$	$BP(I^r)$				*BP(DW)*		*BP(PCE-C)*	
		$BP(C^r_{srv})$	$BP(C^r_{ndur})$							
		BP(A)								
Panel D: 2007-2009 Financial Crises										
					$BP(P^r_h)$	*BP(A)*	$BP(C^r_{ndur})$	$BP(C^r_{srv})$	*BP(DCPI-HL)*	*BP(U)*
								BP(PCE-HL)	*BP(DCPI-C)*	$BP(I^r_{res})$
								BP(DW)	$BP(I^r)$	*BP(PCE-C)*
									$BP(C^r_{dur})$	
									BP(GDP)	

Notes: For each macroeconomic aggregate, this table reports the date s of the maximum response upon an *FFR* increase, based on methods discussed in the Online Appendix. ***BP(A)***: Filtered *TFP*. $\boldsymbol{BP(P^r_h)}$: Filtered *CPI-HL* deflated S&P/Case-Shiller U.S. National Home Price Index. $\boldsymbol{BP(C^r_{ndur})}$: Filtered real personal consumption expenditures of non-durable goods. ***BP(GDP)***: Filtered real *GDP*. $\boldsymbol{BP(I^r)}$: Filtered real gross private domestic investment. $\boldsymbol{BP(C^r_{srv})}$: Filtered real personal consumption expenditures of services. ***BP(U)***: Filtered unemployment rate. ***BP(DCPI-HL)***: Filtered change in annual headline inflation from the *CPI*. ***BP(DPCE-HL)***: Filtered change in annual headline inflation from the *PCE* deflator. ***BP(DW)***: Filtered annual growth rate of hourly compensation for all employed persons in the business sector (HCOMPBS). ***BP(DPCE-C)***: Filtered annual core inflation from the *PCE* deflator. ***BP(DCPI-C)***: Filtered annual core inflation from the *CPI*. Filtering procedure: Band-pass filter isolating frequencies from 6 to 32 quarters. All variables are measured in percentage points. Quarterly data from 1954-Q2–2022-Q4 for all variables except for core inflation that starts on 1960-Q1. For further definitions and data sources see the Online Appendix.

Table 6: Quantifying The Impact of the FFR on the Percentage Output Contraction [$\Delta BP(GDP)$], and Projected Ending Values for the Unemployment Rate (U), Nominal Wage Growth (DW), and Core Inflation ($DPCE\text{-}C$), over our MTCs

	Scenario 1: ΔFFR=550	Scenario 2: ΔFFR=700
Panel A: Estimates from Average FFR Semi-Elasticities, All MTCs		
$\Delta BP(GDP)$	(-5.34, -4.40)	(-6.79, -5.60)
U	(6.92, 7.67)	(7.88, 8.83)
DW	(1.83, 2.74)	(0.42, 1.57)
$DPCE\text{-}C$	(1.83, 2.69)	(0.88, 1.97)
Panel B: Estimates from Average FFR Semi-Elasticities, MTCs Excluding the 2007-2009 Financial Crisis		
$\Delta BP(GDP)$	(-4.44, -3.85)	(-5.66, -4.89)
U	(5.92, 6.40)	(6.61, 7.22)
DW	(2.97, 3.65)	(1.87, 2.74)
$DPCE\text{-}C$	(2.06, 2.65)	(1.18, 1.93)
Panel C: Estimates from the Highest and lowest FFR Semi-Elasticities, MTCs Excluding the 2007-2009 Financial Crisis		
$\Delta BP(GDP)$	(-4.94, -2.87)	(-6.29, -3.65)
U	(5.48, 6.24)	(6.05, 7.02)
DW	(3.30, 3.98)	(2.30, 3.15)
$DPCE\text{-}C$	(2.43, 2.89)	(1.65, 2.23)

Notes: Projected effect of economic aggregates from cumulative FFR increases from estimates and methods discussed in the Online Appendix. $\boldsymbol{\Delta BP(GDP)}$: Change in filtered real GDP. $\boldsymbol{U}$: Unemployment rate. $\boldsymbol{DW}$: Annual growth rate of hourly compensation for all employed persons in the business sector (HCOMPBS). $\boldsymbol{DPCE\text{-}C}$: Core inflation from the PCE deflator. Filtering procedure: Band-pass filter isolating frequencies from 6 to 32 quarters. All variables are measured in percentage points. For further definitions and data sources see the Online Appendix.