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Effects of Interest Rate Policy on Inflation

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ABSTRACT

This paper analyzes the episodes of high inflation and the efficacy of raising interest rates in reducing inflationary pressures in the U.S. economy. Estimating a Markov-switching regression model, the results show that high inflation frequently occurred from 1975 to 1983 with the most prolonged duration. In the 2000s, there were merely two inflationary months in 2008, but this is too short to call it a period. Then, after a period of low inflation in 2020, inflationary pressure started to build up. From March 2021 to the present, a period of high inflation has been prevailing. The estimation results suggest that the period from 1976 to 1983 is one episode of the high inflation period, and the period from 2016 to 2022 is the second period, which is about equal in length to both periods. A simple sub-period analysis shows that an increase in the federal funds rate lowers future inflation in both periods. A vector autoregression model is then estimated to identify the monetary policy channel via the short-term interest rate together with other variables such as inflation expectations and real economic activity. A one standard deviation increase in the federal funds rate can reduce annual inflation by up to 1.6 percent in the first period and 0.74 percent in the second. The effects on expected inflation are also comparable. The results suggest that interest rate policy has been effective in controlling inflation.

Introduction

In this paper, I quantitatively study the past episodes of high inflation and the efficacy of raising interest rates in lowering inflationary pressure in the US economy. The U.S. economy is currently experiencing high inflation as of 2022. The main method to implement monetary policy is arguably to set targets and control the federal funds rate via open market operations. A natural research question is how effective this practice has been and will be. Inflation is defined as the growth rate of aggregate price level, which is a weighted average of selected commodities' prices. Because the economy uses fiat currency, the U.S. dollar, for transactions and trading, high inflation means that the prices of average consumption and investment goods increase over time. Higher inflation implies that one needs increasingly more money to purchase the same amount of goods as before. Basic economic principle, the quantity theory of money, states that when money supply is too abundant or commodities are in short supply, it is expected that the commodity price will rise if this tendency persists.

Possible reasons for high inflation are listed as follows. First, suppose that the Federal Reserve and banks supply liquidity 'excessively'. Money is more available than commodities in the economy, hence commodities and services eventually become more expensive. Second, inflation arises because the prices of goods and services increase, as firms and producers have to incur larger costs on raw materials, labor, and distributions, etc. This so-called cost-push inflation begins from the production side, yet eventually transmits to consumers and investors, which can lead to stagflation. Third, inflation accelerates due to public expectations regarding future inflation. All three channels may operate interactively with leads and lags in time.

How can the Federal Reserve lower inflation pressure? By raising the short-term interest rate used by economic agents dealing with financing needs of the economy, the Federal Reserve tries to constrain economic activities, tame inflation expectations, and withdraw excessive liquidity from the economy over time. However, this may happen rather slowly and gradually. I explain the mechanism using an important economic equation regarding the relation between the interest rate and inflation, called the Fisher equation The equation dictates that the nominal interest rate, denoted as $r^{\$}$ is approximated to be the sum of the real interest rate (rr) and the expected inflation rate (π^e), or

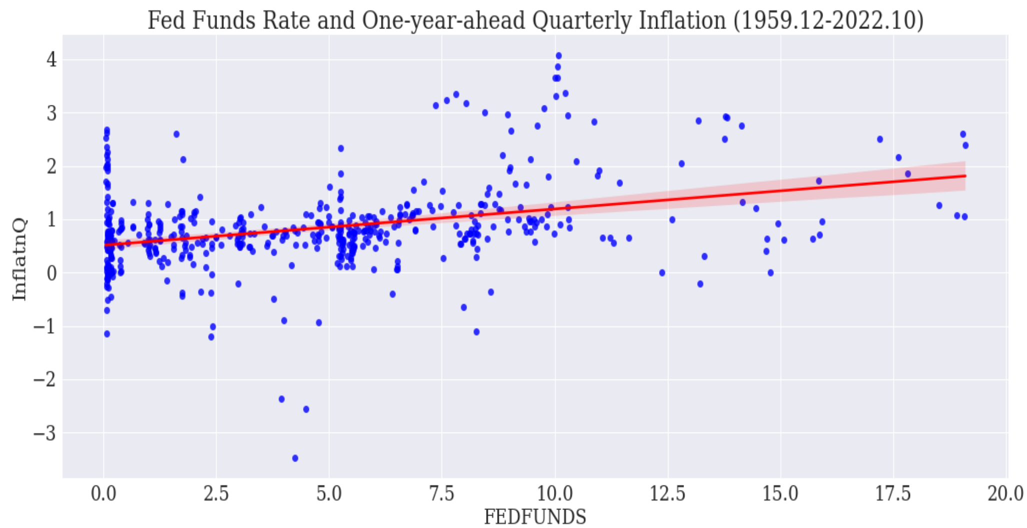

Figure 1. Interest Rate and Future Inflation for the period of 1959.12 to 2022.10. This figure plots the scatterplot between the fed funds rate (FEDFUNDS) and the quarterly inflation rate measured by the quarterly growth rate of consumer price index (CPIAUCLS) available from the St. Louis Fed Data Repository. The figure also displays the linear regression line as well. The estimated intercept and slope parameters are 0.37 and 0.12 with t-statistics of 3.26 and 4.3, respectively.

$r^{\$} = rr + \pi^e$. (See Mankiw (2020) and Jones (2013)). The nominal interest rates are what we normally observe and use. If we save or borrow money from a bank, we will be paid or pay back in dollars. However, the real interest rate refers to the borrowing and lending rate in actual goods and services terms (e.g., barter exchange), and it is directly related to real economic activities and debt burden. If the economy grows by 2 percent per year in real terms, then the real interest rate is likely to be close to 2 percent per year, abstracting from credit risks. The gap between these two rates is the expectation of inflation for a year ($\pi^e = r^{\$} - rr$). If the economy is expected to experience 3 percent inflation and grow by 2 percent next year, the nominal interest rate for one year is likely to be 5 percent, as explained in Lucas (1996).

This implies that the nominal interest rate and inflation or expected inflation will be positively associated with each other on average. Figure 1 confirms this conjecture in that the Federal Funds Rate (FFR) is positively related to quarterly inflation over the period of 1959.12 to 2022.10. The slope of the fitted line via linear regression is around 0.12 with t-statistic of 4.3, suggesting that if FFR increases by one percentage point, quarterly inflation increases by 0.12%, or 0.48% of annual inflation.[1] This positive relation is seemingly alluding that monetary policy of raising FFR is not effective. However, according to the Fisher equation, if the expected inflation (π^e) moves one-to-one with actual inflation (denoted as π) and the real interest rate (rr) do not move when FFR increases, we should observe the slope close to 0.25 so that FFR is moving in one-to-one fashion with inflation. Instead, quarterly inflation increased only by 0.12percent per quarter, suggesting a lower increase in inflation prevails even in terms of the long-term trend. Therefore, as explained earlier, increases in the interest rate can reduce economic activities and increase unemployment by

[1] I also ran another regression showing the relation between the fed funds rate and the expected inflation measured by the university of Michigan (Surveys of Consumers). The results are largely similar to those in Figure 1. A one-percent increase in the fed funds rate corresponds to 4.73 percent increases in the annual expected inflation.

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increasing the real financing costs incurred by firms, which is often called the Phillips curve relation. Can data reflect this? The next section analyzes this issue section with an emphasis on shorter-term evidence, based on the notion of the Phillips curve relation (Jones (2003) and Kim (2022) for explanations). Then I conclude.

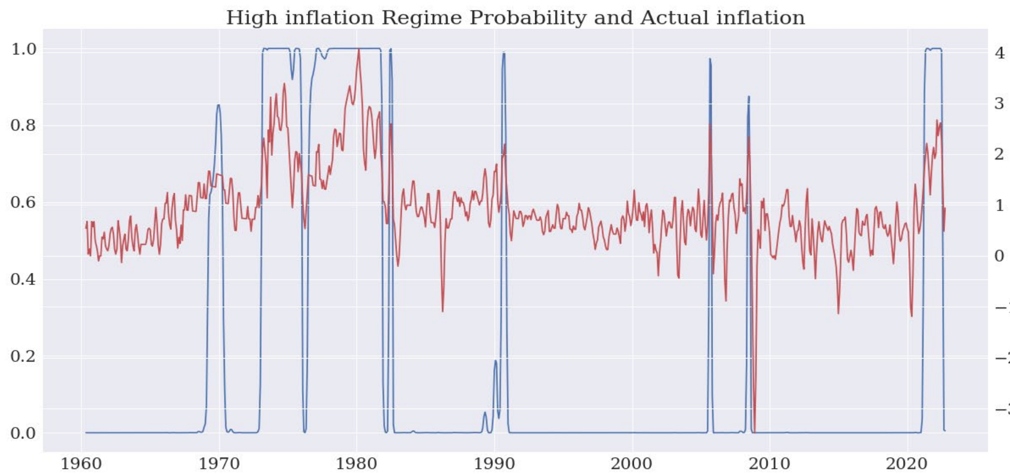


Figure 2. Inflation and High Inflation Regimes. This figure displays the quarterly inflation (red line and right axis in percentage terms) and the estimated probabilities of the high inflation regime (blue line and left axis in decimal). Statsmodels module in python is used to estimate the Markov switching autoregressive regression. Two regimes (high and low) are imposed.

Main Results and Discussions

This section explains the main results and interprets policy implications. First, data series used in the paper are introduced, then I estimated the high inflation regimes using a Markov switching regression model using the data. Based on the identified high inflation regimes, I study dynamic interactions of the key macroeconomic variables using a vector autoregression estimator.

Data

All data series come from the Federal Reserve Bank of St. Louis (https://fred.stlouisfed.org). For the short-term interest rate, I use the federal funds effective rate (FEDFUNDS). For the unemployment rate and aggregate price level, this paper used the UNRATE and CPIAUCLS series respectively. The inflation rate is computed as the quarterly growth rates of the consumer price index (INFLATNQ). I also use the Inflation Expectation data from the Surveys of Consumers: University of Michigan (MICH). All data series are of monthly frequency, ranging from January 1959 to October 2022, except for the inflation expectation measure beginning in November 1978.

Identification of High Inflation Periods

For the period of 1960 to 2022, the most conspicuously high inflation other than 2021-2022 would be the period of 1979-1982. To rigorously identify which periods belong to a high inflation regime, I use a Markov-switching regression model to estimate a two-regime inflation model. The Markov switching regression model allows researchers to statistically identify latent regimes based on observable variables pioneered by Hamilton (1989). Specifically, I assume that a high and a low inflation regime exist with switching likelihoods, though increasing the number of regimes should be a straightforward extension. Markov property implies that only the current state affects the next-period transition to a different regime. In terms of equations, based on Hamilton (1989) and the online manual of the **statsmodels** (https://www.statsmodels.org/devel/vector_ar.html#impulse-response-analysis), it is assumed that inflation depends on the statistical regime and an error term. In particular, the following equation describes the dynamics of inflation over time.

$$\pi_t = a_{regime(t)} + \varepsilon_t, \quad \varepsilon_t \sim Normal(0, \sigma^2),$$

where $regime(t)$ denotes the inflation regime, which can be either high (H) or low inflation (L), and $a_{regime(t)}$ is the inflation value in each regime at time t, and ε_t is the unexpected shock in inflation at time t, randomly drawn based on the normal distribution of zero mean and the standard deviation of σ, and the regime transition probability is dictated by the following transition probability matrix.

$$\begin{bmatrix} p_{LL} & 1-p_{LL} \\ p_{HL} & 1-p_{HL} \end{bmatrix},$$

where p_{LL} refers the probability staying in the low inflation, and p_{HL} is the probability shifting from high inflation to low inflation. I estimate the probabilities of the US economy in a high inflation regime using the Python module, **statsmodels.**

Figure 2 shows the result displaying the high regime probabilities (i.e., blue line reaching the probability of one) in each month together with historical quarterly inflation data. According to the estimation, high inflation prevailed frequently in 1975 to 1983 with the longest duration. In the 2000s, only two inflationary months in 2008 existed but it is too short to call it a period. Then, after a low inflation period, in 2020, inflationary pressure started building up to reach a high inflation period from March 2021 to now. Based on the results, I choose the period of 1976 to 1983 as one episode of high inflation period, and the period of 2016 to 2022 as the second period matching the length of both periods, in order to answer the research question.

Interest Rates and Future Inflation: A Vector Autoregression Analysis

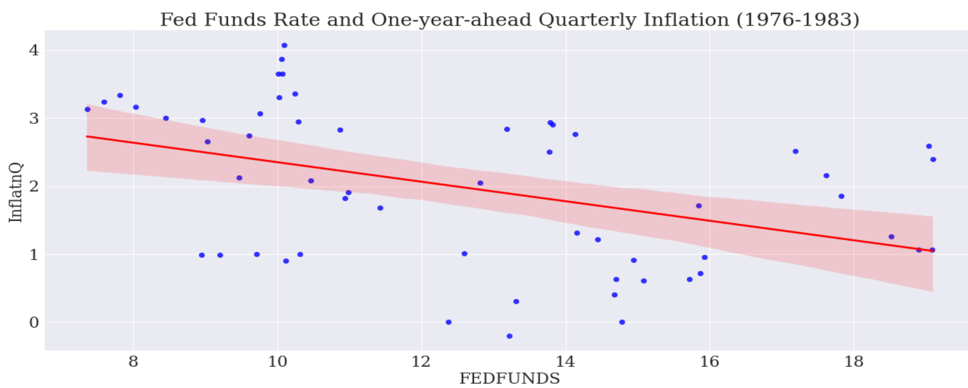
First, I repeat drawing Figure 1 with the two periods including high inflation. The results in Figure 3 show a stark contrast to that of Figure 1. The slope is significantly '**negative**', suggesting that increasing the interest rate lowers future inflation! Despite the stable positive association between the short-term interest rate and future inflation consistent with the long-run economic fact, higher interest rates lead to lower future inflation, hinting at the effectiveness of monetary policy. The slope for the first episode is around -0.15, suggesting that a one-percent increase in interest rate is correlated with 0.15 percent decrease in inflation by quarter, or 0.6 percent in one year. For the second episode, the estimated coefficient is around -0.7, meaning that one percent increase in the federal funds rate can predict up to 2.8 percent decreases in inflation in one year.

The results are encouraging but there are caveats in this analysis. First, it is possible inflation was going to decrease regardless of policy movements by the Federal Reserve. Second, other variables such as unemployment rate or the inflation expectation moves first, then this impacts the federal funds rate and inflation over time. To alleviate the concerns, I adopt an econometric method called the vector autoregression (VAR) pioneered by Sims (1980), in which multiple variables with their lags are used as explanatory variables to summarize economic variables and to evaluate macroeconomic models statistically. To illustrate this statistical model, denoting the vector of the variables of interest (labeled as $1, \ldots k$), $Y_t = (Y_{1,t}, \ldots, Y_{k,t})$, a VAR with p lags is written as:

$$Y_t = A_1 Y_{t-1} + \cdots + A_p Y_{t-p},$$

where $A_1, \cdots, A_p$ are coefficient matrices to be estimated. A major advantage of using the VAR approach is that one can estimate dynamic impulse responses of the variables of interest to an economic shock.

Thus, dynamic responses to a shock in FFR can be estimated in this context, controlling for other variables. I form a *VAR(p=4)* model containing unemployment rate, growth rate of industrial production, producer price index inflation, consumer price index inflation, the federal funds rate, and the expected inflation to estimate using a Python module available in **statsmodels** again from Python. In doing so, I use the Cholesky decomposition of the estimated error covariance matrix of the model to orthogonalize the shocks. This implies that the order of shocks matter in that variables stacked latter are more endogenously related to the variables located in the front. VAR models results are known to be sensitive to the order of variables, though it turns out that the results in this model are rather robust. The federal funds rate and the expected inflation variables were located at the end of the variable vector to take into account that the federal reserve banks are likely to set the interest rate target with all possible information, and the public forms expectations observing policy actions by the federal reserve banks. However, changing the order of the two variables barely affects the impulse responses.



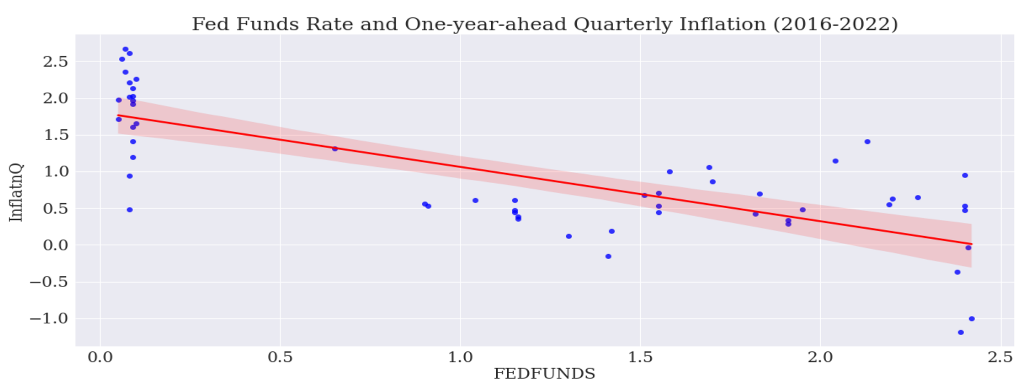


Figure 3. Interest Rate and Future Inflation with High Inflation Periods. This figure plots the scatterplots between the fed funds rate (FEDFUNDS) and the one-year-ahead quarterly inflation rate for the periods identified to include the high inflation regime. The figure also displays the estimated linear regression lines as well. The linear regression for the first period results in the intercept of 3.79 and the slope parameter of -0.15 with the t-statistics of 4.9 and -2.5, respectively. For the second period, the estimates of the intercept and slope are 1.71 and -0.698 with the t-statistics of 9.25 and -5.05, respectively.

Figure 4 reports the impulse response of FFR to inflation. The left panel figures show the movement of FFR, whereas the right panel figures show the responses of inflation against a shock in FFR. The left panels show that the FFR shocks have different dynamics between the first high inflation period and the second one. Unexpectedly large increases in the federal funds rate occur over a shorter interval, compared to the second period, and this is consistent with the anti-inflationary monetary policy implemented by the Federal Reserve and the Chairman, Mr. Paul Volcker (Board of Governors of the Federal Reserve System (1979)).

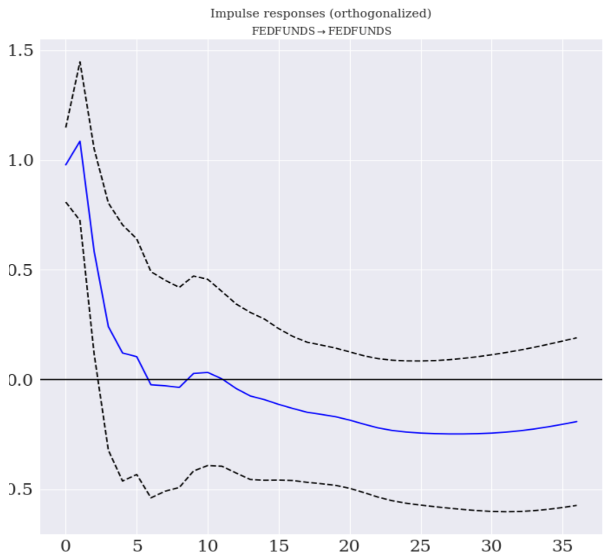
Indeed, inflation starts decreasing, reacting to a FFR shock, after a few months and continues decreasing for the next 24 months or so in case of the first period, and the result holds for both periods of high inflation, confirming the results in Figure 3. In case of the latter episode, high inflation is still high as of 2022, and the impulse responses show ongoing decreases after twelve months or so. With the estimated confidence intervals, it is clear to infer that decreases in inflation are statistically significant, suggesting that monetary policy via federal funds rate increases is quantitatively effective. Impulse response results are often interpreted in terms of the size of the standard deviation of the shock and the contribution of the shock to a dependent variable of interest by multiplying the estimated coefficient. The standard deviations of the federal funds rate are 3.34% for the first period and 1.03% for the second period, respectively. Figure 4 depicts that quarterly inflation decreases after 5 to 6 months with the coefficients of 0.12 and 0.18 for each period and the effects last at least for a year or so. Thus, the yearly effects on annual inflation can be computed roughly as $3.34\% \times 0.12 \times 4\ quarters = 1.60\%$ for the first period, and $3.34\% \times 0.12 \times 4\ quarters = 0.74\%$ for the second period.

Figure 5 shows that the impulse responses of other variables fluctuate in line with the conjecture explained. It is often argued that managing inflation expectation is the key to success in anti-inflation policy, and the right panels in Figure 5 show that inflation expectations (MICH) become tamed down in response to increases in the federal funds rate. The quantitative effects on inflation expectation (MICH) are comparable though the effects appear to prevail more slowly, suggesting that inflation expectations can be sticky as pointed out by prior studies (Jones (2013) for a brief survey of the literature) and yet the expectation management has been also effective.[2]

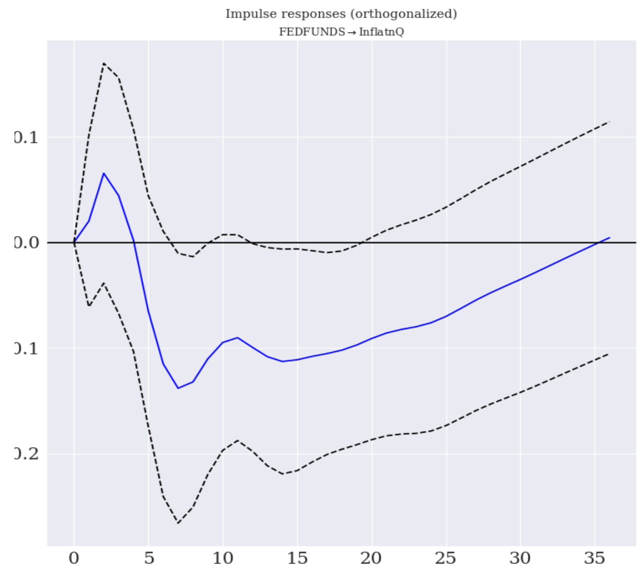
Finally, the dynamic responses of real economic activities measured by unemployment rate (UNEMP) are reported in the left panels of Figure 5. In the case of the first episode (1976-1983), unemployment rate (UNRATE) significantly increases by 20% of the one standard deviation shock in FFR, or $0.2 \times 3.34\% \approx 0.67\%$, about 10 months after the federal funds rate increases, as expected in the short-run Phillips curve relation.

However, during the second period of 2016-2022, an increase in the federal funds rate leads to decreases in the unemployment rate, which is somewhat puzzling. The effect is rather short-lived because the responses become insignificant after a quarter, but the magnitude is nontrivial ($0.97 \times 1.02\% \approx 0.99\%$). At face value, this means that a tightening monetary policy movement lowers inflation and its expectation without negatively affecting real activity. Is this plausible? Returning back to the right panels of Figure 4, I find that the initial responses of inflation are somewhat inflationary or at best very muted. Therefore, in the beginning of rate hikes, either due to slow and delayed responses of the economy or insufficient increases in the nominal interest rates render the economy inflationary, real economic activities show positive reactions temporarily. Given the sharp contrast of the two periods in terms of the speed of interest rate increases, I suspect that the latter channel appears to be a more appealing justification, though more rigorous analyses would be necessary.

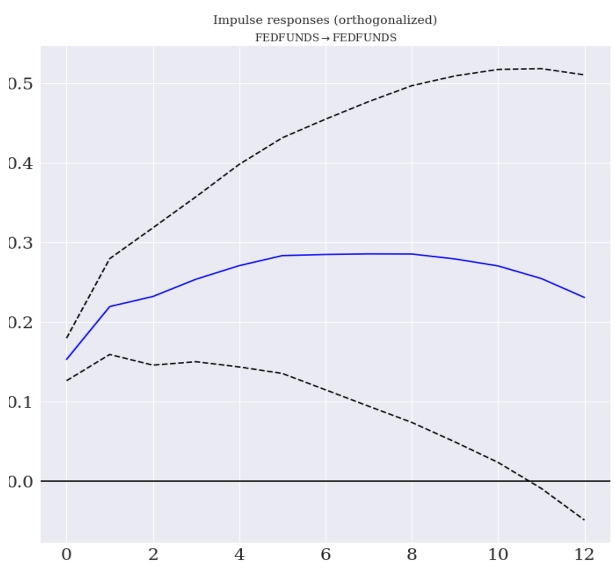
[2] It is possible that expectations regarding future inflation can come from current and future liquidity demand shocks. Kim & Subramanian (2006, 2009) study new Keynesian models to show that optimal monetary policy is related to the asset demand shocks associated with changes in transactions technology. For the second period of high inflation, emerging new transactions technology such as blockchain and crypto currencies could have contributed to inflation and its expectation. Consistent with this conjecture, as the Federal reserve raises the interest rates, the prices of cryptocurrencies experienced significant downfalls.



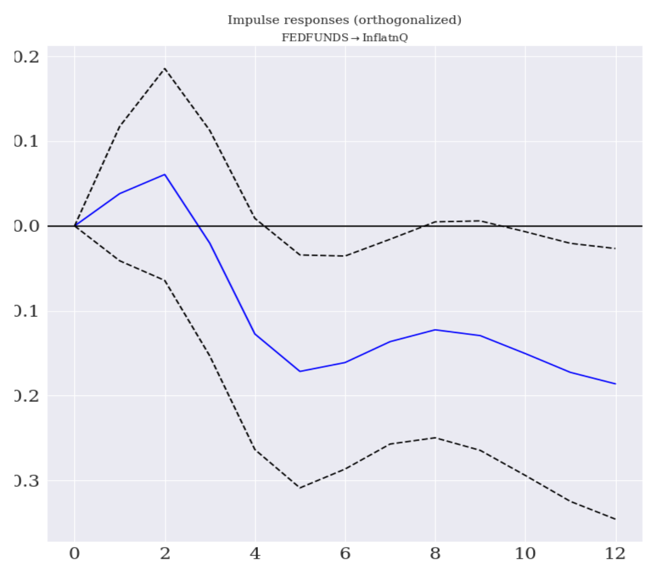
FFR ($r^{\$}$) to FFR ($r^{\$}$)) (1976-1983)



FFR ($r^{\$}$) to INFLATION ($\pi$) (1976-1983)

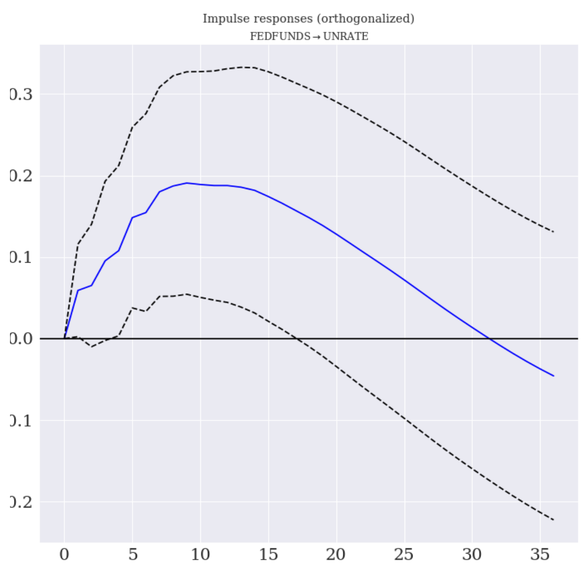


FFR ($r^{\$}$) to FFR ($r^{\$}$)) (2016-2022)

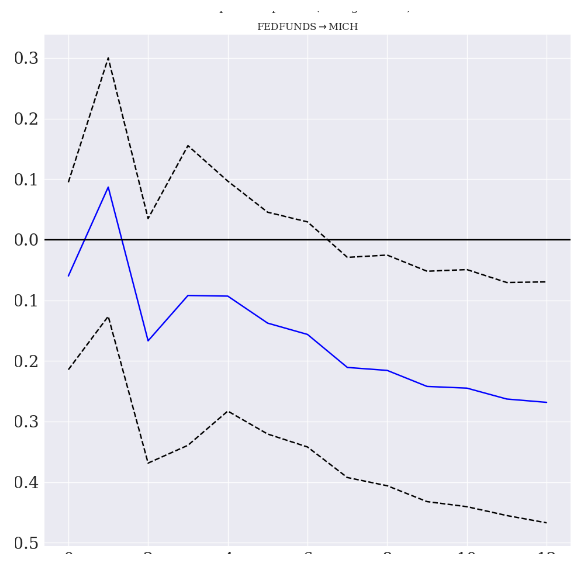


FFR ($r^{\$}$) to INFLATION ($\pi$) (2016-2022)

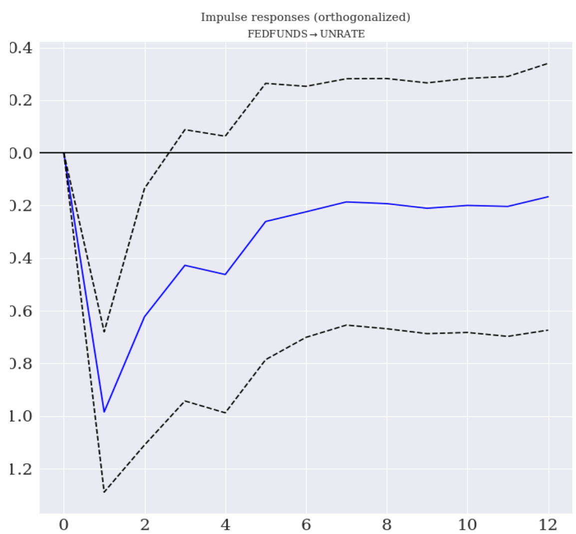
Figure 4. Impulse Responses of the Federal Funds Rate to Inflation. This figure plots the impulse responses of the federal funds rate and inflation estimated using the VAR model. The results show how a one-time shock in the fed funds rate leads to changes in the fed funds rate (left panels) and inflation (right panels), controlling for the effects from own past realizations of the variables used in the estimation. The upper panel is the estimation result for the first period of high inflation, and the lower panel shows the second period. Dotted lines represent asymptotic standard errors at the 95% significance level. All impulse response functions are plotted in orthogonalized form using the Cholesky decomposition of the estimated error covariance matrix.



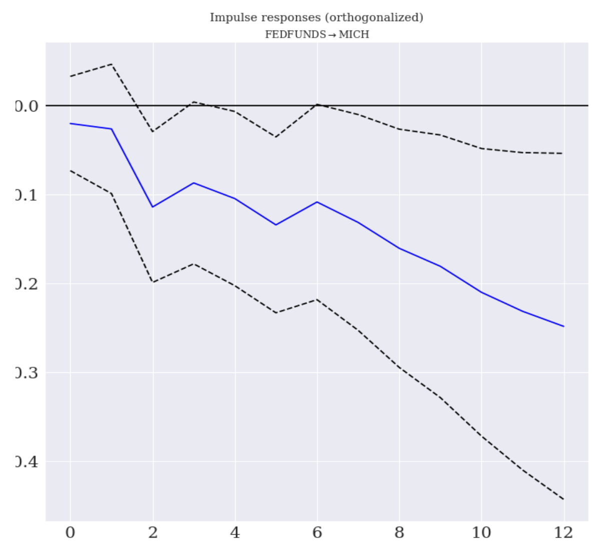
FFR ($r^{\$}$) to UNRATE
(1976-1983)



FFR ($r^{\$}$) to MICH ($\pi^e$)
(1976-1983)



FFR ($r^{\$}$) to UNRATE
(2016-2022)



FFR ($r^{\$}$) to MICH ($\pi^e$)
(2016-2022)

Figure 5. Impulse Responses of FFR to Unemployment & Inflation Expectation. This figure plots impulse responses of the federal funds rate, unemployment, and inflation expectation estimated using the VAR model. The results show how a one-time shock in the fed funds rate leads to changes in the fed funds rate (left panels) and inflation (right panels), controlling for the effects from the past realizations of the variables used. The upper panel is the estimation result for the first period of high inflation, and the lower panel shows the second period. Dotted lines represent asymptotic standard errors at the 95% significance level. All impulse response functions are plotted in orthogonalized form using the Cholesky decomposition of the estimated error covariance matrix.

Conclusion

Is interest rate policy important for controlling inflation? Quantitative evidence suggests that interest rate policy is very effective in controlling inflation. Analyzing the U.S. post 1970s altogether appears to show weak results due to the long-run neutrality between inflation and real economic variables, as documented by Lucas (1996). However, by identifying the two periods of high inflation in the U.S. economy between 1960 and 2022, I show that increases in the federal funds rate lead to significant reductions in both inflation and expected inflation over the next twelve to twenty-four months. Including other macroeconomic variables such as inflation using producer price index, unemployment rate do not affect the main results. In addition, the results are robust to changing economic structures generating different types of endogeneity.

Effects on real activities somewhat diverge between the two episodes, especially in the short-run. In the more recent episode, the pace of rate increases is slower, but the overall effect is comparable to the first episode, in which the Federal Reserve raised the rate much more rapidly. It is possible that the Federal Reserve is now more transparent and provides timely information to financial markets, allowing policymakers and market participants to better coordinate. However, both international and domestic economic concerns can quickly affect the cost side of the economy, leading to stagflation. Whether interest rate policy can effectively deal with such stagflation when it occurs is still an open question. Related, coordination between monetary policy and fiscal policy is becoming an important issue, which is left as future research.

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