Long and variable lags in monetary policy: evaluating uncertainty from simulated data

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Abstract

The paper explores the notion of "long and variable lags, or the relationship between monetary policy decisions and their lag effects on inflation and economic activity." The estimated model of the United States is bootstrapped, and the intricacies and uncertainties are analyzed using the vector autoregressive model and impulse response functions. The findings reveal a significant degree of uncertainty on the inflation side and highlight the need of taking into account the dynamic nature of the Phillips curve as well as potential risks or uncertainties when making monetary policy decisions.

Key Words

Phillips curve, vector autoregression, monetary policy, long and variable lags, bootstrapping

1. Introduction

In his seminal paper, Friedman (1961) introduced the concept of "long and variable lags" in the context of monetary policy interventions in the economy. He argued that the effects of policy changes, such as interest rate adjustments or open market operations, are not immediately observable in economic activity. Instead, there is a significant lag between policy implementation and its discernible effects on the economy. Friedman also argued that these lags are not consistent or predictable, as the timing and magnitude of the effects can vary widely due to various factors. This unpredictability and inconsistency in the manifestation of effects represent the variable component of the lag. This raises questions about monetary policymaking, as policymakers cannot predict the exact magnitude and timing of their interventions. Friedman's insights were based on empirical observations, showing significant delays between monetary interventions and observable changes in economic variables. Since then, macroeconomists have carried out empirical studies to test Friedman's claim about the delayed effects of monetary policy (see Friedman (1990) for the literature review). The actions of monetary policies and their subsequent influence on output and inflation are subject to lengthy and varied delays.

In more recent studies, the effect of monetary policy on output and inflation is calculated using vector autoregression (VAR) models, which are frequently used in the literature on econometrics. Sims (1972) first developed VAR models in 1980, and they have since become one of the most important instruments for examining the dynamic effects of monetary policy on various macroeconomic variables, such as inflation and production. Several studies using VAR models have demonstrated that monetary policy has lasting effects on output and prices. These studies have shown that changes in monetary policy can have both short-term and long-term impacts on the economy. For example, expansionary monetary policy, such as lowering interest rates, can stimulate economic growth in the short run but may also lead to inflationary pressures in the long run. Additionally, VAR models have been used to analyze the transmission mechanisms of monetary policy, shedding light on how changes in interest rates affect variables like investment, consumption, exchange rates, and inflation (see Stock and Watson (2001)).

Scholars and decision-makers have recently discussed the influence of monetary policy on disinflation, particularly considering the inflationary effects that Russia's invasion of Ukraine in 2022 may have on economic activity. To combat these pressures, the US Federal Reserve, for instance, raised interest rates, which may have resulted in a recession and a rise in unemployment. However, monetary tightening has been successful in lowering inflation without strangling growth, a behavior described as "immaculate disinflation" (Decker and Kelly (2023)). Federal Reserve policymakers are unclear about the direction of future policy because this contradicts widely held economic theories. At the outset of the inflationary cycle, it was anticipated that the US interest rate would rise sharply, leading to a decline in the economy and an increase in unemployment. Contrary to conventional presumptions, however, the data show steady GDP growth and low unemployment. Inflation has also decreased, in contrast to what the conventional Phillips curve suggests. As they deliberate on the course of monetary policy for the upcoming months, the Federal Reserve and other central banks are in a challenging situation. They must reevaluate how they determine the current phases of the economic cycle and the long-term and variable effects of previous policy decisions they have made in the past.

What is the likelihood that, even after inflation returns to its normal level, economic activity will not start to slow down following monetary tightening? Since monetary policy's effects are, by their very nature, both long-lasting and unpredictable, their likelihood is uncertain. In addition, the probability is hazier if the Phillips curve, which illustrates the connection between economic activity and inflation, is neither stable nor constant. When this occurs, the effect of monetary policy on economic activity might not be apparent right away or be predictable. A wide range of structural and expectational factors have an impact on the outcome in time-varying ways. In these situations, monetary policy decisions must be carefully thought out considering these uncertainties and potential risks. It is crucial for policymakers to consider the potential lagged effects of monetary policy actions on inflation and economic activity, as well as an unstable Phillips curve.

This paper reconsiders the relationship between monetary policy actions and economic outcomes considering these uncertainties and potential risks. It aims to provide a statistical analysis of the lag effects of monetary policy actions on inflation and economic activity, taking into account the instability of the Phillips curve. After a VAR model is estimated in samples, they simulate joint probability distributions of variables based on their impulse responses to monetary policy shocks. It enhances our understanding of the complex dynamics at play by doing this. By simulating joint probability distributions, researchers can gain insights into the potential range of outcomes and identify the likelihood of different scenarios. This approach helps policymakers make more informed decisions by considering the time-varying uncertainties and risks associated with monetary policy actions and their impact on inflation and economic activity. Additionally, understanding the complex dynamics at play allows for a more nuanced analysis of the lag effects and helps in formulating effective policy responses.

The paper is structured as follows: First, it provides a theoretical foundation for the VAR model that takes into account variables influencing monetary policy outcomes, such as unemployment and inflation rates. The paper then estimates the VAR models, simulating the joint probability distributions of the variables with data from the United States. The simulations make it possible to examine the dynamic interactions between monetary policy, inflation, and economic activity, giving important insights into the transmission mechanism. It concludes by presenting the empirical findings and their policy implications, emphasizing the significance of taking into account both the time-varying effects of monetary policy actions on inflation and economic activity. In general, the analysis provides valuable insights for policymakers devising effective strategies amidst uncertainty and expands our understanding of the relationship between monetary policy and macroeconomic outcomes.

2. VAR Model

The VAR model provides a system-based method for examining the dynamic interrelations between various time series. The VAR model of order p (VAR (p)) with k endogenous variables is denoted mathematically as:

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

where Y_t is a k×1 vector of observations at time t, A_i are k×k matrices of coefficients for i=1…p, and u_t is a k×1 vector of error terms.

The advantage of the VAR model is that it can accurately represent the dynamic feedback interactions in the system. By regressing each variable on both its own lagged values and those of all other variables, VAR can successfully model the interdependencies present in macroeconomic data.

The VAR framework makes it possible to use impulse response functions (IRFs). They show how a single shock to one of the innovations affects the values of the endogenous variables now and in the future. Formally, the following gives the IRF due to a shock at time t for the h periods ahead:

$$IRF(h) = E(Y_{t+h} | u_t = \varepsilon) - E(Y_{t+h})$$

where ε is a one-time shock.

The impact of monetary policy shocks on economic activity will be examined in this paper using the VAR framework and IRFs. Looking at the IRFs can help us understand how a shock to the central bank's interest rate decision affects variables like inflation and unemployment over time. The findings of this investigation will clarify the transmission mechanism of monetary policy and its effects on the entire economy. Interpreting the IRFs, we focus on the standard error bands of the IRFs that measure uncertainty in the trajectories of the reaction to policy shocks. These standard error bands provide valuable insights into the range of possible outcomes and highlight the level of uncertainty surrounding the effects of monetary policy. By considering these bands, policymakers can make more informed decisions and assess the potential risks associated with their interest rate decisions. Additionally, analyzing the standard error bands allows for a more comprehensive understanding of the robustness and reliability of the research findings.

In the context of the VAR model, bootstrapping is a widely adopted technique to ascertain the standard error bands for the IRFs (Chernick (2011)). Upon estimating the VAR on actual data, one obtains the coefficient estimates and the residuals. To maintain the sample size equivalent to the original data's number of observations, residuals are randomly resampled with replacements to generate a new set. Using the coefficient estimates and the resampled residuals, an artificial dataset is constructed. The standard error bands around the median IRF are constructed using the appropriate percentiles from this distribution.

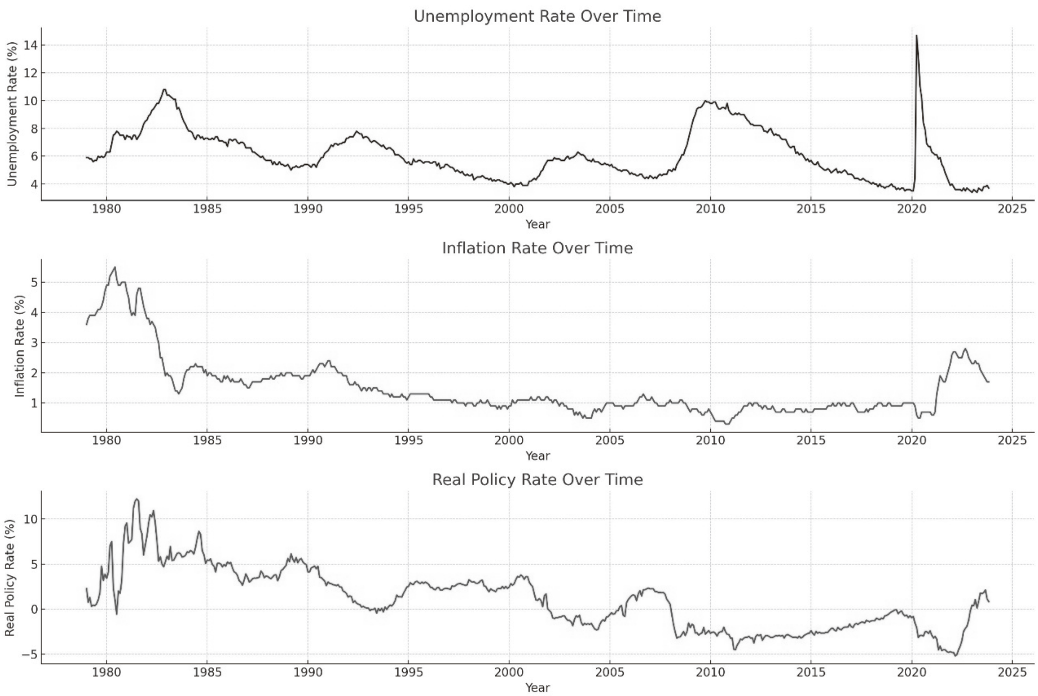
3. Data

The VAR model is estimated using the unemployment rate, the inflation rate, and the real policy rate. We utilize the US Bureau of Labor Statistics' published series for the unemployment rate. The inflation rate is calculated as the annual percentage change in the consumer price index for all urban consumers of all goods, excluding food and energy. The real policy rate is defined as the monthly average of the Federal Funds rate minus the expected inflation rate from the University of Michigan. This data set includes a monthly

Table1　Descriptive statistics of the variables in the VAR model

	unemployment rate	inflation rate	real policy rate
mean	6.11	1.50	1.03
std	1.78	1.00	3.39
min	3.40	0.30	-5.20
25%	4.75	0.90	-1.97
50%	5.70	1.10	0.97
75%	7.20	1.90	3.14
max	14.70	5.50	12.24

Figures 1　The unemployment rate, the inflation rate and the real policy rate in the sample period



series from January 1979 to December 2023. Table 1 describes the data, and Figure 1 plots the series over time.

4. Empirical Results

The stationarity of the data is statistically tested using the augmented Dickey-Fuller (ADF) statistics prior to estimating the VAR model. The ADF statistics and corresponding p values are displayed in Table 2. Because their ADF statistics are below the critical values and their p-values are less than 0.05, the unemployment and inflation rates are stationary at the 5% significance level. Given that its p-value is higher than 0.05, the real policy rate is non-stationary. The series must be differenced and retested for stationarity because the real policy rate is non-stationary. The ADF statistic of the first-differenced real policy rate is in Table 2. The very low p-value and an ADF statistic that is lower than the critical values show that the differenced real policy rate series is stationary.

The VAR model is estimated with the original series of the unemployment rate and the inflation rate as well as the first-differenced

Table 2　The ADF statistics of the variables in the VAR model

original	ADF	p value
unemployment rate	-2.974	0.037
inflation rate	-3.805	0.003
real policy rate	-2.294	0.174

first difference	ADF	p value
real policy rate	-6.475	0.000

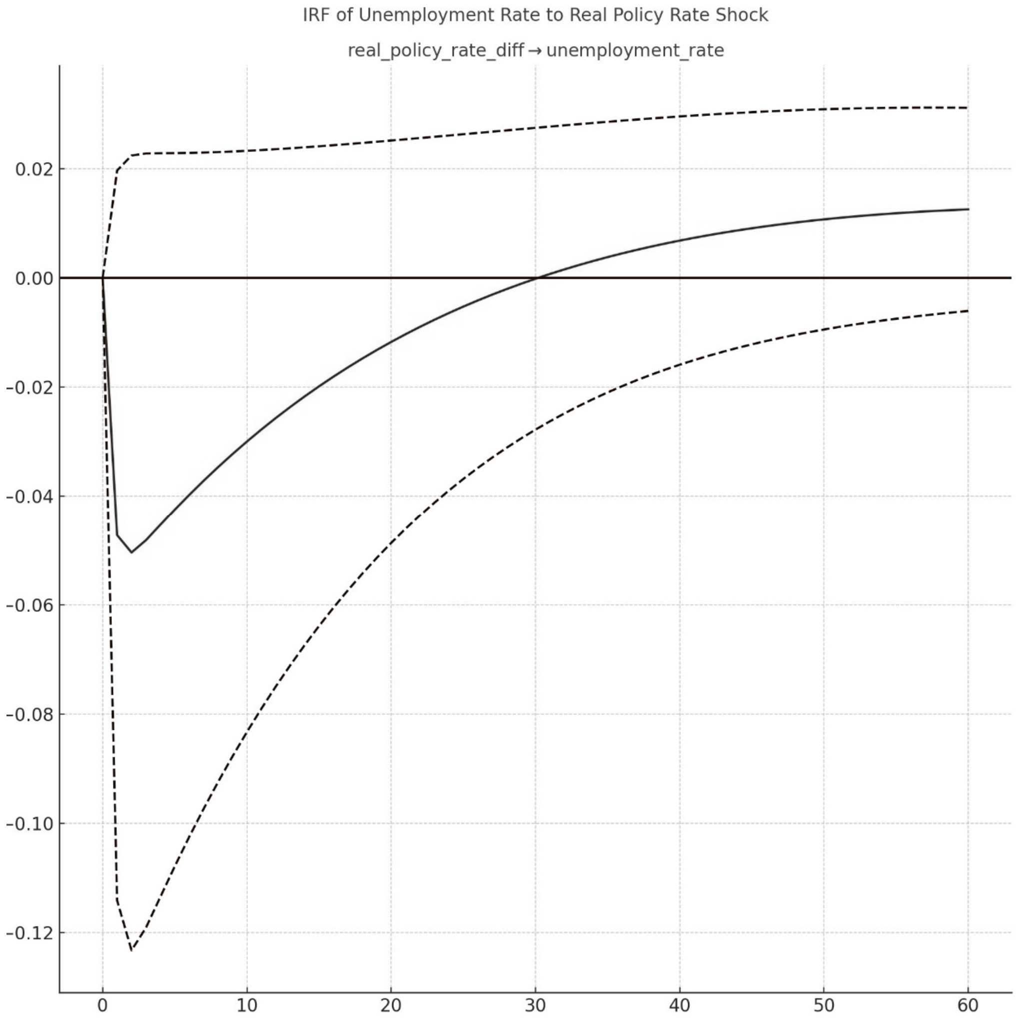
Table 3　The estimated coefficients of the VAR model

unemployment rate	estimate	p value
constant	0.190	0.017
unemployment rate	0.958	0.000
inflation rate	0.041	0.060
real policy rate	-0.047	0.166

inflation rate	estimate	pvalue
constant	0.045	0.007
unemployment rate	-0.006	0.028
inflation rate	0.990	0.000
real policy rate	0.022	0.002

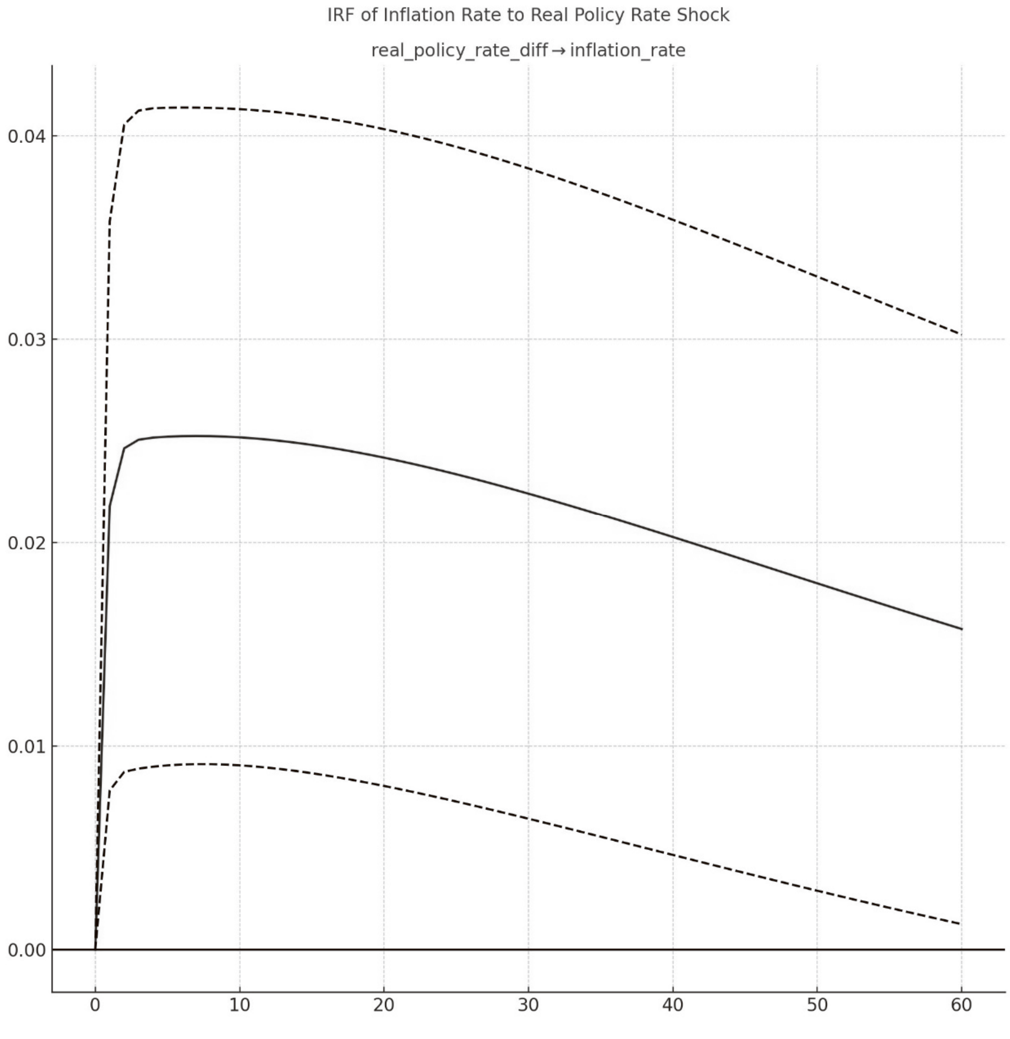
real policy rate	estimate	pvalue
constant	0.050	0.617
unemployment rate	-0.016	0.291
inflation rate	0.033	0.229
real policy rate	0.128	0.003

Figures 2 The IRS of the unemployment rate and the inflation Rate to a real policy shock



series of the real policy rate. The Bayesian information criteria (BIC) and the Akaike information criteria (AIC) indicate 1 and 13 lags, respectively. We use one lag in the model's estimation and follow BIC for parsimony. In Table 3, the estimated coefficients and corresponding p-values are displayed.

Figure 2 shows the inflation and unemployment rates' impulse responses (the deviations from the unconditional means) to a shock of one standard deviation to the real policy rate at period 0. The impulse responses are bootstrapped with replacement over more than a thousand iterations. The bold lines represent the means for the intervals of 0 to 60 months. The standard error benchmarks show the simulated responses' 2.5 and 97.5 percentiles. The means of the IRFs demonstrate that the rates of inflation and unemployment follow the policy shock right away, despite the large standard error bands. Similar to previous



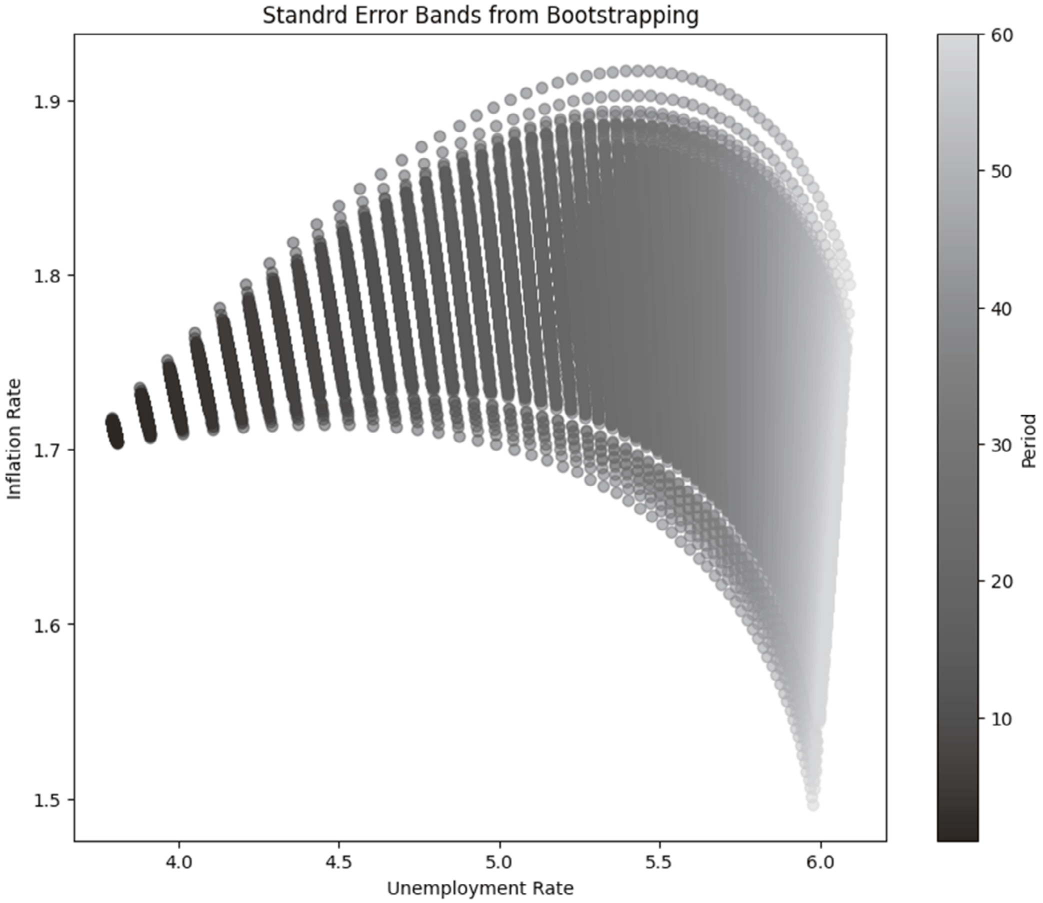
macroeconomic studies that have used VAR models, the impulse responses display hump-shaped behaviors of the variables. Monetary policy's effects on inflation have a longer half-life than its effects on unemployment, which fade after 30 periods.

Figure 3 displays a cross-plot of the standard error bands obtained from bootstrapping samples for the unemployment rate and inflation rate. The figure indicates that the unemployment rate will rise right away after the policy shock, even though inflation will not even start to decline for a few years. Moreover, the bands' higher verticality than horizontality makes it clear that there is uncertainty on the inflation side.

5. Concluding Remarks

This paper has investigated the intricate relationship between monetary policy decisions, their lag effects on inflation, and their

Figure 3 The cross-plot of the unemployment rate and the inflation rate from bootstrapping



effects on economic activity. We've looked at the idea of "long and variable lags," a term used by Milton Friedman to highlight how erratic and time-varying these lags are. Our research uses VAR models and impulse response functions to shed light on the complexities. We use bootstrapping the joint probability distributions of the variables based on their responses to monetary policy shocks to provide a nuanced understanding of the possible outcomes and the associated uncertainties. We find uncertainty about inflation and variable lags. Our results emphasize how crucial it is to consider both the Phillips curve's dynamic nature and variable and long-lasting lag effects as central banks around the world attempt to develop successful monetary policy plans. When making decisions, policymakers must always be cautious and take into account any potential risks or uncertainties.

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