Levels vs Slopes: What Drove the High Inflation in the United States in the 1970s?*

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Abstract

We explore two competing hypotheses regarding the forces behind the inflationary experience in the United States during the 1970s. The first hypothesis, described in Clarida, Gali, and Gertler (2000), explains the inflation rate through a combination of positive and high cost-push shocks, together with a weak response of the policy rate to increases in inflation before Volcker's appointment. The other, described in Gao, Kulish, and Nicolini (2022), points towards exogenous and persistent increases in the policy rate. We show that both hypotheses play a role when considered in isolation, but once the two are jointly estimated, the role of the exogenous increase in the policy rate comes as the clear dominating force. In addition, once the exogenous changes in the policy rate are considered, the evidence pointing to a lower response of the policy rate in the 1970's is very weak.

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1 Introduction

In this paper, we evaluate two alternative views on what accounts for the high inflation of the 1970s in the United States. The first view has been proposed in an influential paper by Clarida, Galí, and Gertler (2000) (CGG from now on). According to that view, during the 1970s, monetary policy did not react enough to shocks that drove inflation up. In terms of the jargon of the literature, the Taylor rule coefficient on inflation was too low. Once Volcker took office, the interest rate responded much more to those shocks, stabilizing inflation closer to its two percent target. In other words, the inflation coefficient of the Taylor rule became much larger following the appointment of Volcker as Fed Chair.

A second, different view, proposed by Gao, Kulish, and Nicolini (2021) (GKN from now), argues that the 1970's correspond to a regime change, in which the Fed became more tolerant to inflation. In terms of the jargon, this is equivalent to an increase in the inflation target. A new regime change occurred in the early 1980's with the appointment of Volcker, which is equivalent to the the Fed changing the target back to a low value.

The two views have different implications regarding the role of the Fed in the high inflation of the 1970s. According to the first view, inflation was the result of a sequence of adverse real shocks, coupled with a weak response of monetary policy. Somewhat lower inflation could have been achieved, but at the cost of reductions in real activity. To keep inflation at bay, could have been very costly.

According to the second view, inflation was the result of a change in the monetary policy regime. This view is consistent with the notion that inflation, as the one observed during the 1970's is a monetary phenomenon, where the Central Bank is the responsible. Inflation could have been avoided without any cost in real activity.

To compare the two hypothesis, we estimate an otherwise totally standard New Keynesian model, allowing for regime changes in both the responsiveness of the policy rule to movements in inflation (the "slope" theory proposed by CGG) and in the exogenous fixed term of the policy rule (the "level" theory proposed by GKN).

We compare three different models: first, we only allow for a change in the level; second, we allow only for a change in the slope; finally, we estimate the model allowing jointly for both a level and a slope change. A comparison of the three models allows us to conclude that, at least within the realm of the small-scale New Keynesian model explored by CGG and GKN, the change in the level appears as the dominant force behind the high average inflation of the 1970s.

CGG followed the tradition in the literature and assumed that monetary policy follows a rule where the nominal interest rate depends on the state of the economy and on a shock

that follows a first-order autoregressive process. The dependence of the policy rule on the state of the economy comes from the endogenous component of the policy. Thus, it can never be on itself, a cause of inflation. In New Keynesian models, if interest rates are positively related to inflation, monetary policy reduces the volatility of inflation, relative to the case in which policy is unresponsive to the state. Thus, shocks that are unrelated to policy must be the force behind inflation, and monetary policy dampened the movements in inflation. CGG argued that this component was not "hawkish" enough during the 1970's. Thus, if a relatively long sequence of bad shocks materializes, inflation can be higher than the target for a long period of time.

Under the rule estimated by CGG, the only source of exogenous variation of monetary policy comes from the first-order autoregressive process that governs the stochastic component of policy. This specification very much limits the role of exogenous changes in monetary policy in the estimation. Importantly, such a specification for policy rules out the possibility that the central bank shifts the unconditional mean of the nominal variables in the economy by construction.

If an econometrician were to use data to estimate a model assuming such a policy rule but using a sample in which monetary policy shifted the unconditional mean of nominal variables, the estimation would have no choice but to rely on other real shocks to account for the fluctuations in the data brought about by this change in regime. In the particular case of inflation, the estimation will force the other real shocks to follow more persistent processes in order to explain more persistent deviations from what should be regarded as a deceptive sample mean. And it may also bias down the slope coefficients so as to allow for inflation in the data to go up for several periods.

More specifically, if one were to study cases in which persistent changes to the implicit inflation target of the policy rule played an important role, the estimation using the standard practice would be misspecified and would overstate the role of other shocks in the economy.

To address this issue, GKN allow for other forms of exogenous changes to monetary policy, in a way that we make very precise. These shocks to the regime imply changes in the unconditional expectation of the nominal interest rate and, therefore, in the unconditional expectation of inflation. We then let the data inform us about the role of these alternative policy regime shocks. Our results strongly favor a model in which the target changes over time, and this regime change explains a large share of the ups and downs in inflation from the late 1960's to the late 1980's in the United States.

We label those regime changes in the unconditional mean of inflation "monetary forces", since they correspond to the movements rationalized by the quantity theory of money, as

defined in Lucas (1980).

The role of monetary forces in driving inflation has been widely documented for cases of large inflation stabilization episodes, where there is ample independent evidence of large regime changes, like in the classic study of Sargent (1982) as well as in Calvo and Végh (1999) or in Kehoe and Nicolini (2021). This set of studies has convincingly created a consensus about the role of purely monetary forces in creating and stopping very high inflation. On the other hand, in discussing periods of very low inflation, these forces are typically ignored.

This is so, in spite of a series of papers that provide substantial evidence for episodes involving moderate inflation rates, like the high inflation period in many developed economies in the '70s and '80s, like Lucas (1980), Ireland (2007), Benati (2009), and Sargent and Surico (2011) . More recently, Uribe (2022) makes a very convincing case of the role of monetary forces by allowing for permanent shocks to the policy rate. The closest paper to ours is Gao, Kulish, and Nicolini (2021), who follow up on Lucas (1980) by studying a series of OECD countries, and by embedding the monetary forces in an estimated small scale DSGE model for the great inflation period in the United States, as a way to justify filtering techniques of the type discussed in Lucas (1980).

The paper proceeds as follows. In Section 2 we revisit the reduce-form estimates of the Taylor rule discussed in CGG, where they argue that the estimated slope coefficients were smaller in the pre-Volcker period.

Our main discussion centers around the behavior of the short-term interest rate during most of the twentieth century. We argue that beyond the short-term movements in the policy rate, the ones we typically identify as cyclical monetary policy, there is a clear low frequency component that, after the second great war, exhibits an increasing trend that reverts by 1980.

Based on the distinctive effects of permanent versus temporary policy changes clearly documented in Uribe (2022) we propose a statistical separation of the data into a cyclical component and a trend. We show that the reduced-form results in CGG are quite sensitive to removing the low-frequency component of the series. This exercise provides motivation for the regime change that we propose to add to an otherwise standard New Keynesian model in Section 3, which we estimate in Section 4. Section 5 provides some concluding comments.

2 Empirical Estimates of the Interest Rate Rule

To illustrate the potential misspecification of ignoring changes in the trend in a simple way, we show in Table 1 the result of estimating Taylor rules and checking the stability of its coefficients pre- and post- the appointment of Volcker as the Fed Chair.

As in CGG, we consider the following rule for the federal funds rate:

$$i_t^* = i^* + \beta \left(\mathbb{E} \left\{ \pi_{t,k} | \Omega_t \right\} - \pi^* \right) + \gamma \left(\mathbb{E} \left\{ x_{t,k} | \Omega_t \right\} \right) \tag{1}$$

where $\pi_{t,k}$ denotes inflation between t and $t+k$ in annual terms, π^* is the inflation target, $x_{t,k}$ denotes the average output gap between t and $t+q$, i^* is the steady-state nominal interest rate, and Ω_t is the information set at period t. Allowing for interest rate smoothing and specifying the following relationship between the actual federal funds rate i_t and the target i_t^*:

$$i_t = \rho(L) i_{t-1} + (1-\rho) i_t^*, \tag{2}$$

where $\rho(L) = \rho_1 + \rho_2 L + \ldots + \rho_n L^{n-1}$. Combining (1) and (2), we arrive at the set of orthogonality conditions

$$\mathbb{E}_t \left[\left\{ i_t - (1-\rho(1)) \left(r^* - (\beta - 1)\pi^* + \beta \pi_{t,k} + \gamma x_{t,q} \right) - \rho(L) i_{t-1} \right\} \mathbf{z}_t \right] = 0, \tag{3}$$

where r^* is the steady-state real interest rate and $\mathbf{z}_t$ collects the set of instruments known when i_t is set. As in CGG, we conduct a Generalized Method of Moments estimation on (3) and use the same set of instruments, including four lags of the federal funds rate, inflation, the output gap, the spread between the 10-year Treasury yield and the 3-month Treasury yield, commodity price inflation, and the growth rate of M2.[1]

Following CGG, we will report results for the GDP price deflator, and in addition will report results using core CPI inflation, which we use in the estimation below. We will use one-quarter target horizons for both inflation and the output gap ($k = q = 1$), and two lags of the interest rate (so that $\rho(L) = \rho_1 + \rho_2 L$).

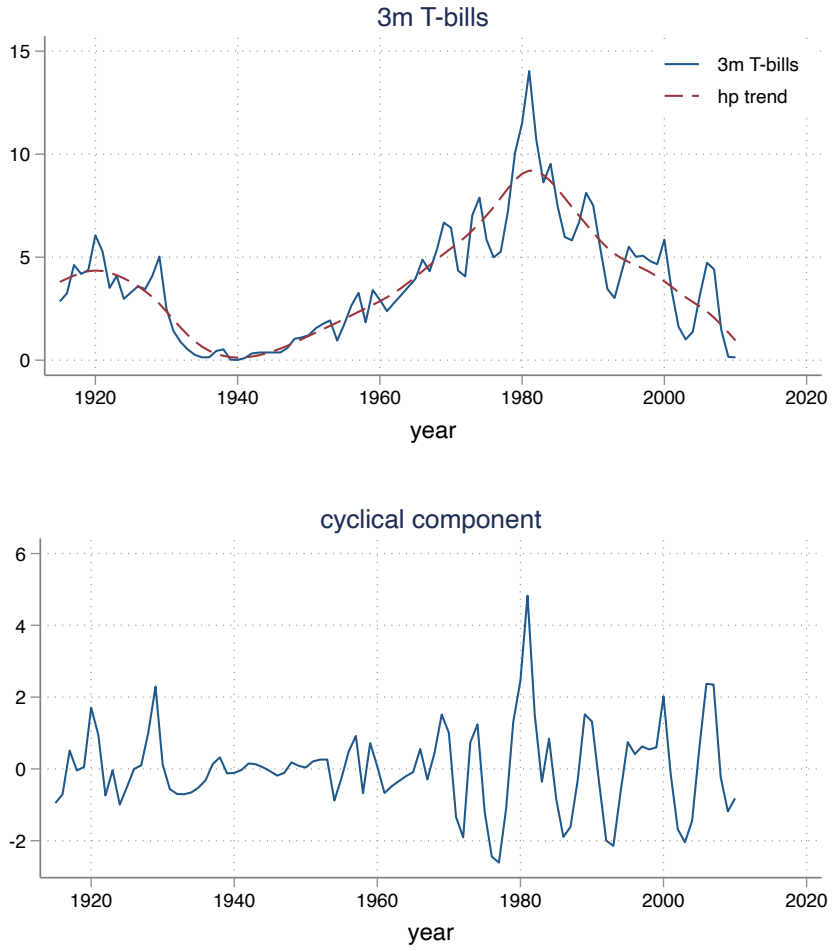
Implicit in equation (3) is the assumption that the target of inflation is constant over time, since π^* is time invariant.

Given that the New Keynesian model has been designed to study business cycle fluctuations and it is typically solved by log-linearizing the model, this is the right choice from a theoretical point of view.

However, given that the application covers the period from 1960 till 2000, the assumption

[1] We detail in the Appendix the construction of these series.

Figure 1: Interest Rates



Notes: HP Filter with a smoothing parameter of 100.

appears controversial. The reason is provided in Figure 1, which shows the time series of the short-term interest rate and its trend, using the Hodrick-Prescott filter.

The Figure shows a clear slow-moving upward trend from the end of the second great war until 1981, followed by a decreasing slow-moving trend til the end of the sample. The amplitude of this cycle is orders of magnitude the typical tightening cycle in monetary policy, so one may want to remove it in the estimation of the policy rule.

In light of the previous discussion, in addition to reporting results for the specification (3), we also consider a case where the inflation target is time-varying and thus use the following specification:

$$\mathbb{E}_t \left[\left\{ i_t - (1-\rho(1)) \left(r^* - (\beta-1)\pi_t^* + \beta \pi_{t,k} + \gamma x_{t,q} \right) - \rho(L) i_{t-1} \right\} \mathbf{z}_t \right] = 0. \tag{4}$$

Table 1: GMM Estimates of the Interest Rate Rule

	Panel A. GDP Deflator				*Panel B. Core CPI*			
	62:1–79:2	79:3–96:4	62:1–79:2	79:3–96:4	62:1–79:2	79:3–96:4	62:1–79:2	79:3–96:4
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ρ_1	1.096***	0.863***	1.182***	0.543	1.070***	0.942***	1.117***	−0.849
	(0.119)	(0.139)	(0.110)	(1.776)	(0.120)	(0.160)	(0.126)	(1.579)
ρ_2	−0.402***	−0.0198	−0.397***	−0.494	−0.383***	−0.0631	−0.383***	0.818
	(0.102)	(0.112)	(0.0967)	(1.752)	(0.110)	(0.129)	(0.106)	(1.552)
β	0.876***	2.010***	0.252	1.374***	0.787***	1.816***	0.571*	1.207***
	(0.0790)	(0.420)	(0.298)	(0.240)	(0.0602)	(0.427)	(0.260)	(0.236)
π^*	4.047*	3.287***			3.728***	4.085***		
	(1.717)	(0.480)			(0.815)	(0.954)		
γ	0.414**	0.624	0.222	0.194*	0.432***	0.678	0.205	−0.0850
	(0.139)	(0.351)	(0.134)	(0.0779)	(0.130)	(0.631)	(0.107)	(0.134)
N	66	70	66	70	66	70	66	70

Notes: Standard errors in parentheses. Specifications (1), (2), (5), and (6) estimate a time-invariant inflation target π^* and use the moment condition in equation (3). Specifications (3), (4), (7), and (8) use the HP-filtered cyclical components of the federal funds rate and inflation to estimate the parameters of the interest rate rule. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

For columns (1), (2), (5), and (6), we use (3), and so estimate a sample specific constant inflation target π^*, in addition to ρ_1, ρ_2, β, and γ. In specifications (3), (4), (7), and (8), we allow for a time-varying inflation target π_t^* and thus will only estimate parameters ρ_1, ρ_2, β, and γ. For both specifications, we will report estimates for two subsamples, 1962:q1–1979:q2, and 1979:q3–1996:q4.[2] For all estimations, where appropriate, we will use the subsample averages of the ex-post real interest rate for r^*.

The results are presented in Table 1. Columns (1) and (2) are similar to those presented in CGG.[3] A constant target is assumed across the two sub-samples. As it can be seen, the coefficient on inflation is more than twice in the second sub-sample. Columns (3) and (4) report the results of the regression when the nominal interest rates and the inflation rate are de-trended using a standard HP filter. We identify the low-frequency component as the moving target in equation (4). This is an arbitrary interpretation and is based on a statistical decomposition of the data. A better, theoretically-based alternative will be provided below. Once the trend component is removed, the slope estimates are substantially lower for both sub-periods, while they two coefficients are no longer statistically different.

Columns (5) to (8) reproduce the results for core CPI, the measure we use in estimating

[2]CGG use as their first subsample 1960:q1–1979:q2. We start two years later due to data availability.
[3]There are small differences that can be due to revisions in the data

the model below. The conclusions are even more striking.

Notice finally that the estimates for the constant target in columns (1) and (2) (and in columns (5) and (6)) are remarkably similar, so one could conclude that the constant target assumption is quite reasonable. However, this hides the evolution of inflation over time.

Take a new look at the trend component of inflation from 1962 until 1999 in Figure 1. What appears in comparing columns (1) and (2) a relatively stable target is revealed in the Figure as a symmetric inverted U-shape. When forcing a constant target before and after the peak, the estimation delivers approximately equal left-side and right-side averages.

3 A Model with Monetary Regime Changes

In this section, we introduce regime changes in monetary policy to the workhorse New Keynesian model used by Ireland (2004).[4]

Building upon Clarida, Galí, and Gertler (2000) and Gao, Kulish, and Nicolini (2021) we allow for regime changes in the monetary policy rule.

3.1 The model

The model is composed of the familiar Euler equation (also known as the Fisher equation), the New Keynesian Phillips curve, and the Taylor rule shown below:

$$x_t = (z - \ln\beta) - (i_t - \mathbb{E}_t\pi_{t+1}) + \mathbb{E}_t x_{t+1} + (1-\omega)(1-\rho_a)a_t \tag{5}$$

$$\pi_t = (1-\beta)\pi^s + \beta\mathbb{E}_t\pi_{t+1} + \psi x_t - e_t \tag{6}$$

$$i_t = i_t^* + \rho_i\left(i_{t-1} - i_{t-1}^*\right) + \phi_\pi\left(\pi_t - \pi_t^*\right) + \phi_x x_t + \varepsilon_{i,t}. \tag{7}$$

In the above equations, x_t is the output gap, π_t is the log of the gross rate of inflation, and i_t is the log of the gross nominal interest rate. To allow for a regime change in the slope coefficients, we let ϕ_π and ϕ_x to be regime dependent. To allow for a regime change in the level, we let the inflation target, π_t^*, and the corresponding target for the nominal interest rate i_t^* to depend on time, as shown in Equation (7).

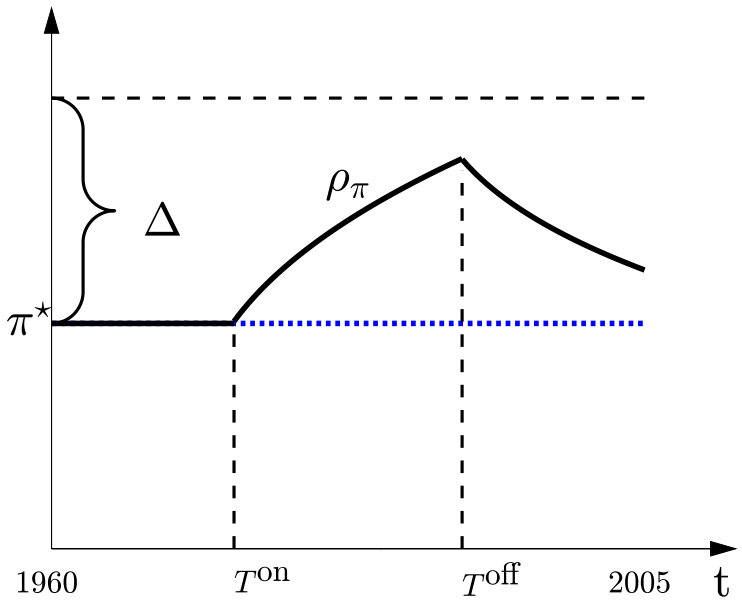
Specifically, we assume that

$$\pi_t^* = (1-\rho_\pi)\pi^s + \rho_\pi\pi_{t-1}^* \tag{8}$$

$$i_t^* = z - \ln\beta + \pi_t^*. \tag{9}$$

[4]Details of the non-linear model can be found in Ireland (2004).

Figure 2: Graphic Illustration of Inflation Target Evolution



According to equation (9), the implied target for the nominal interest rate, i_t^*, is determined by the steady state real interest rate, $z - \ln \beta$, and the inflation target, π_t^*. The variable z is the steady state growth rate of labor-augmenting productivity, which follows in logs a unit root with drift z, and β is the household's discount factor. The inflation target, π_t^*, follows a regime-dependent AR(1) process in which $\mathbb{I}^s$ is an indicator variable that is turned on at T^{on} and then turned off at T^{off}; that is,

$$\mathbb{I}^s = \begin{cases} 1 & \text{for } t \in [T^{\text{on}}, T^{\text{off}}) \\ 0 & \text{otherwise.} \end{cases} \tag{10}$$

At the start of the sample (1960Q1), we set $\mathbb{I}^s = 0$ and $\pi^s = 0.005$, which is equivalent to an inflation target of annually 2%. Before T^{on}, shocks to the inflation target are turned off, and the model is a standard New Keynesian model with a constant inflation target.

At T^{on}, $\mathbb{I}^s = 1$, so we allow, but do not require, the long-run inflation target – that is, π^s – to change from $\pi^s = 0.005$ to $\pi^s = 0.005 + \Delta_\pi$, and Δ_π is to be estimated. Thus, at time T^{on}, the inflation target is subject to a permanent shock, Δ_π, until T^{off}. Notice that because of the persistence of the inflation target process, ρ_π in equation (8), the long-run inflation target is reached gradually. Finally, at time T^{off}, the policy returns to its original regime; that is, $\mathbb{I}^s = 0$ and $\pi^s = 0.005$. Figure 2 presents a graphic illustration of the process of π_t^* as in Equation (8).

Finally, we also allow in estimation for the hypothesis in Clarida, Galí, and Gertler

(2000)—that the lack of a strong response of the policy rate to inflation in the '70s could explain the high inflation during the period. Therefore, we let the policy responsiveness parameters ϕ_π and ϕ_y, to be regime dependent, i.e.

$$i_t = i_t^* + \phi_\pi(\mathbb{I}^s)(\pi_t - \pi^*) + \phi_y(\mathbb{I}^s)(y_t - y^*) + \varepsilon_t^i,$$

where the evolution of responsive parameters follows:

$$\phi_\pi(0) = \phi_\pi, \quad \phi_\pi(1) = \phi_\pi^*, \quad \phi_y(0) = \phi_y, \quad \phi_y(1) = \phi_y^* \tag{11}$$

Besides the monetary policy shocks, the economy is also subject to the following non-policy shocks: a preference shock, a_t; a markup shock, e_t; and a technology shock, z_t. These are governed by the equations below:

$$a_t = \rho_a a_{t-1} + \varepsilon_{a,t} \tag{12}$$

$$e_t = \rho_e e_{t-1} + \varepsilon_{e,t} \tag{13}$$

$$z_t = z + \varepsilon_{z,t}. \tag{14}$$

3.2 Model discussion

Our choice of regime change in inflation target as in Figure 2 allows for a potentially slow-moving component that pushes up inflation, with a reversion to the original 2 percent per year inflation rate. In estimating the model, we let the data choose the values for the four key parameters for the inflation target shock process, $\Delta_\pi, \rho_\pi, T^{\text{on}}, T^{\text{off}}$, in equation (8); and the four key parameters for the regime change in the slope parameters, $\{\phi_\pi, \phi_y, \phi_\pi^*, \phi_y^*\}$.

We are not the first to consider a time-varying inflation target. But our modeling approach is different from others proposed in the literature. In the Markov-switching (MS) specification proposed in Liu, Waggoner, and Zha (2011), the inflation target follows a Markov-switching process in which the target jumps between a high and a low value with non-absorbing transition probabilities. Although the inflation target in the policy rule changes, these changes are not permanent. As a result, the MS model is consistent with an ergodic (steady state) rate of inflation. In the MS model, agents expect the regime to switch with some probability in every period, but long-run inflation and long-run inflation expectations stay anchored at the ergodic mean. An advantage of our approach is that the steady state of nominal variables can shift. When a change in π^s takes place, long-run inflation and long-run inflation expectations adjust. In our case, there are two permanent shocks to the inflation target, Δ_π when the economy shifts towards the high inflation regime

and then $-\Delta_\pi$ when the economy reverts back to the 2% regime. The target, π_t^*, gradually adjusts, as shown in Figure 2, towards its new long-run value.

Our approach is also different from that of Ireland (2007) and Uribe (2022), in which there are no regime changes, but the single regime is characterized by permanent shocks to the target in every period. This distinction will be key in our model simulations. Our posterior estimates imply only positive values for the parameter Δ_π and very high values for the persistence parameter ρ_π. Thus, in simulating the model, as we do in Section 4.3, the distributions of the simulations will be centered on an inverse U-shaped function, as it is in the data. Had we assumed permanent shocks, the simulations would all be centered on a flat line given by the sum of the initial condition of the permanent component and the mean of the transitory one.

4 Estimation

4.1 Estimation strategy

We estimate the dates of the regime change, T^{on} and T^{off}, alongside the structural parameters, following the method described by Kulish and Pagan (2017). The model is estimated with five observable series: real GDP per capita growth; the federal funds rate; core inflation as measured by the CPI, excluding food and energy; and the Michigan survey measure of inflation expectations.

The equations linking the observable variables—output growth g_t to the endogenous variables are given by

$$g_t = \hat{y}_t - \hat{y}_{t-1} + z_t \tag{15}$$

$$x_t = \hat{y}_t - \omega a_t \tag{16}$$

$$\mathbb{E}_t^{\text{obs}} \pi_{t+1} = \frac{1}{4}\left(\sum_{j=1}^{4} \mathbb{E}_t \pi_{t+j}\right) + v_t, \tag{17}$$

where $\hat{y}_t$ is the percentage deviation of stochastically de-trended output, Y_t/Z_t, from its steady state. We use the Surveys of Consumers from the University of Michigan as the measure of inflation expectations, $\mathbb{E}_t^{\text{obs}} \pi_{t+1}$, and allow for measurement error v_t.

In steady state, $\pi_t = \pi_t^* = \pi^s$, $i_t = i^s$, $g_t = z$, and $i^s = \pi^s + z - \ln \beta$; all other variables (including the output gap) settle at zero. The reason nominal variables are left in levels, as opposed to percentage deviations from the steady state, is that in estimation, we allow for changes in the steady states of these variables.

We estimated the model treating the regime changes as unanticipated. This seems to us a reasonable choice, particularly for the shock T^{on}: it is conceivable that the breakdown of the Bretton Woods system and the inflation that ensued took most by surprise. It is less plausible that the disinflation shock, T^{off}, was a surprise. However, we allow the change in target to be very slow moving by allowing the autoregressive component in (8). A high value for ρ_π implies that the economy slowly approaches the new long-run target. The estimation does deliver a very high value for ρ_π, so although Δ_π is unanticipated, the transition path that it triggers for π_t^* towards its new steady state is anticipated.

To guard against the possibility that our proposed policy regime change captures the higher macroeconomic volatility before the Great Moderation, we use a parsimonious specification and introduce the parameter κ, which multiplies the standard deviations of all structural shocks before T_κ. That is, the standard deviation of the structural shock i is given by $\kappa\sigma_i$ before T_κ and shifts to σ_i at T_κ. The standard deviations of all shocks change by the same proportions. By adding this "great moderation" shock, the estimation is free to rely on shocks other than the inflation target shock to account for the increased volatility in the earlier part of the sample.

The parameters that determine the steady state of output growth, the nominal interest rate, and inflation are set prior to estimation. In particular, we set $\beta = 0.9975$, $z = 0.0044$, and $\pi^s = 0.005$. Jointly, they imply a mean growth rate of real GDP per capita of 1.8% in annual terms, a mean nominal interest rate of 4.75%, and an inflation rate of 2% in annual terms. We set the slope of the NK Phillips curve to $\psi = 0.3$, which in our model depends on a quadratic price adjustment cost. One way to interpret this slope is to consider a version of the NK model with a Calvo price friction. With log-utility and linearity in hours worked, a value of $\psi = 0.3$ in the standard NK model would correspond to a parameter ζ of 0.6, consistent with the findings of Fitzgerald, Jones, Kulish, and Nicolini (2020).[5]

4.2 Model with regime change: the level

We start with the baseline case considered in Gao, Kulish, and Nicolini (2021), with an estimated regime change in the inflation target, but no regime change in the responsiveness parameter.

The two parameters characterizing the policy regime change are the persistence parameter ρ_π and the change in the inflation target between regimes Δ_π. The prior on ρ_π is a beta distribution with a mean of 0.5 and a standard deviation of 0.2. The estimated posterior mode for ρ_π is 0.98, which implies a very slow adjustment of the target to its newer, higher

[5] ζ refers to the fraction of sticky firms.

value. We use a wide uniform prior for Δ_π that ranges from -8% to 24% in annual terms. At the mode, Δ_π is estimated at roughly 0.018, which in annual terms amounts to a jump in the target of approximately 7.2% per year.

For date breaks, T^{on} and T^{off}, we use uniform priors but restrict T^{off} to lie between 1979Q4 and 1983Q4, the quarters corresponding to the Volcker disinflation. In turn, T^{on} is restricted to take place simply before 1979Q4. Importantly, while the estimation allows for changes in the policy regime, these changes are not imposed. The estimation is free to choose $\Delta_\pi = 0$ if it so desires.

The data strongly favor a specification in which the increase in inflation in the '70s is in large part interpreted as permanent, with π^s smoothly increasing from 2% to roughly 9% at the mode and very precisely estimated. The date breaks are precisely estimated, with the inflationary regime beginning in the late '60s and ending in the early '80s. The estimates of the policy rule parameters are in line with those found in the literature. In the interest of space, the full set of estimates of the structural parameters and date breaks appears in the Appendix.

In terms of the time-varying size of the shocks, we estimate a value for κ of 2.3 at the mode, which implies that the volatility of structural shocks halved after T_κ, which at the mode is estimated precisely around 1983Q1. Table 2 presents the prior and posterior distribution of the inflation target level and persistence, policy responsiveness parameters, as well as the timing of regime change.

To gauge the contribution of structural shocks to inflation fluctuations, we conduct the following two exercises.

In our first exercise, we simulate the estimated model, setting the inflation target to its estimated values while setting the value for all other shocks to zero, as shown in Figure 3(a). In our second exercise, we repeat the exercise but set the target to two percent for the whole period and set all other shocks to their estimated values, as shown in Figure 3(b). We show the corresponding counterfactuals as dashed blue lines in Figure 3(a) and Figure 3(b), respectively. For ease of comparison, we also show the values for inflation in the United States during the period with solid red lines. Figure 3(a) makes clear that changes in the target alone can do a very good job tracking the evolution of the long-run component of inflation in the data. All other shocks only add to short-run inflation fluctuations but fail in capturing the high inflation from the mid '60s to early '90s, as shown in Figure 3(b).

An estimation of the model without inflation target would put a higher weight on other shocks in explaining the inflation. To illustrate this, we also estimate the model assuming a constant inflation target. We obtained the parameters and shocks, and computed the counterfactual simulation of inflation when we feed in the estimated markup shocks but set

Table 2: Estimation Results: Deterministic Inflation Target Only Using Core CPI

	Prior distribution			Posterior distribution			
	Shape	Mean	Std Dev.	Mode	Mean	5%	95%
Standard deviations							
$100 \times \sigma_i$	Inv. Gamma	1	2	0.11	0.11	0.09	0.13
$100 \times \sigma_a$	Inv. Gamma	1	2	1.23	1.30	1.05	1.63
$100 \times \sigma_e$	Inv. Gamma	1	2	0.11	0.11	0.09	0.13
$100 \times \sigma_z$	Inv. Gamma	1	2	0.43	0.43	0.38	0.48
$100 \times \sigma_\tau^{obs}$	Inv. Gamma	1	2	0.25	0.41	0.16	1.23
κ	Normal	2	0.3	2.28	2.30	2.10	2.49
κ_m	Normal	2	0.3	1.33	1.38	1.15	1.61
Structural parameters							
ρ_i	Beta	0.5	0.2	0.85	0.85	0.81	0.89
ϕ_π	Normal	2	0.5	2.42	2.45	1.82	3.09
ϕ_x	Normal	0.125	0.05	0.35	0.35	0.29	0.41
$10 \times \omega$	Normal	0.5	0.1	0.54	0.54	0.38	0.69
η	Normal	0.5	0.05	0.44	0.43	0.35	0.52
ρ_m	Beta	0.5	0.2	0.92	0.92	0.87	0.96
ρ_a	Beta	0.5	0.2	0.87	0.86	0.82	0.90
ρ_e	Beta	0.5	0.2	0.55	0.55	0.46	0.64
ρ_τ	Beta	0.5	0.2	0.83	0.84	0.76	0.91
ρ_π	Beta	0.5	0.2	0.97	0.97	0.97	0.98
Δ_π	Uniform	[-2 , 6]		1.72	1.72	1.47	1.98

all other shocks to 0. The result is presented in Figure 4(a). In Figure 4(b), we repeat the same exercise for the model with inflation target shocks.

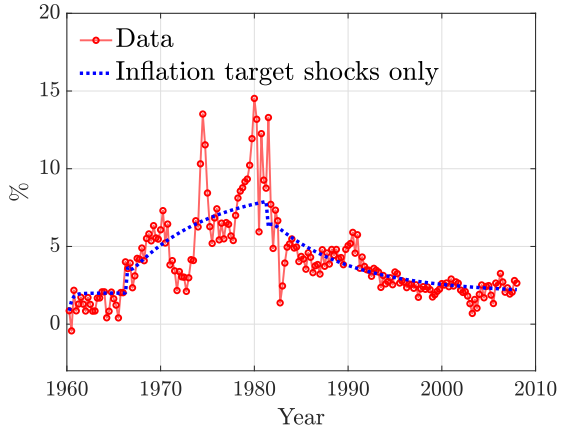
A comparison of the two figures makes clear that not accounting for regime changes in monetary policy may mistakenly assign inflation fluctuations to other shocks, leading to biases in the estimates. By imposing a constant target, the econometrician is ruling out the possibility of the common policy shock that is implied by the Fisher equation and that is evident in cross-country comparisons.

These results are in contrast to the findings of Galí and Gertler (1999) and Smets and Wouters (2007), who assume a fixed inflation target and find that wage and price markup shocks play a dominant role in explaining inflation fluctuations. Without a regime change of the inflation target, they find that monetary policy shocks explain a small part of the federal funds rate and inflation fluctuations.

Our results are also in contrast with the MS model of Liu, Waggoner, and Zha (2011), which ascribes the rise and fall of inflation more to shocks than to changes in the monetary

Figure 3: Role of Inflation Target: Simulation of Model with Det. Inflation Target Only

(a) Policy target shocks only



(b) All shocks but policy target shocks

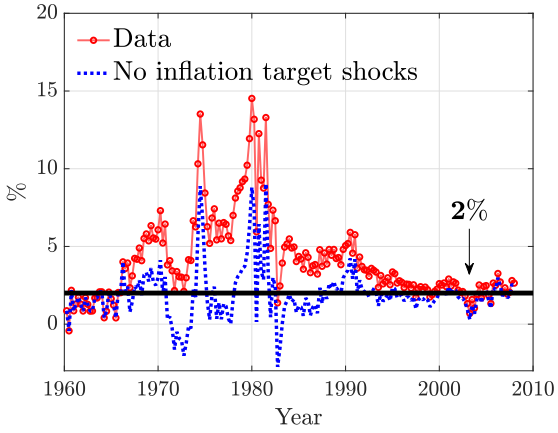
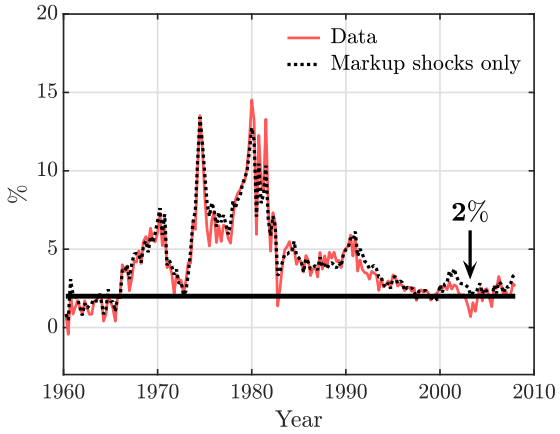
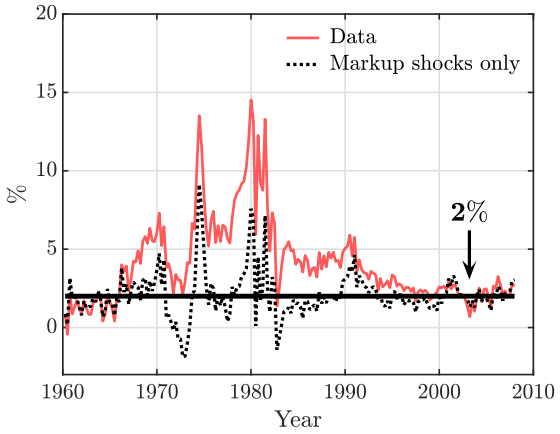


Figure 4: Role of Markup Shocks: Estimation with and without Inflation Target

(a) No regime in inflation target



(b) Deterministic inflation target



policy regime. In their case, the high inflation target regime and the probability of switching to that regime explain some of the first increase in inflation of the mid 1970's. But their counterfactual path under the permanently low inflation target tracks the actual path of inflation almost perfectly. As we argue above, their MS model is consistent with an unconditional mean (steady state) rate of inflation, while in our model, the unconditional mean of inflation *changes* with the monetary regime. This is a subtle, but crucial difference. In our case, as can be seen in Figure 3(a), the lion's share of the rise and subsequent fall in inflation is explained by the change in regime.

Actual inflation in our sample is accounted for by both shocks and regime changes. To get a sense of how important regime changes are in accounting for actual inflation, we simulate a counterfactual economy under Δ_π and $\varepsilon_{\pi,t}$ but set all other shocks to zero. We take the ratio of the standard deviation of the inflation under the counterfactual to that of the data and find that the regime change accounts for about 80% of the observed standard deviation.

4.3 Model with regime change: the slope

In this subsection, we consider a regime switch on the responsiveness of the interest rate policy rate to inflation and output gap deviations. This case corresponds to the hypothesis laid out in Clarida, Galí, and Gertler (2000). Specifically, we allow for a regime change in the policy slope parameter as specified in Equation (11). In this subsection, in order to evaluate the role of this regime change on itself, we maintain the assumption in Clarida, Galí, and Gertler (2000) that the inflation target is constant over time.

In Table 3 we present the prior and posterior distributions of the key parameters. We use the same uniform priors for the regime change dates. We also use the same priors for the slope parameters in different regimes, which are also the same as the prior in the estimation without a change in slope in Section 3.2.

As Table 3 shows, even though we impose common priors, the data strongly prefer a very different slope parameter for inflation. In particular, ϕ_π in the first regime is estimated to be 3.72 at the mode, while ϕ_π^* drops sharply to only 1.61. This is consistent with the argument of Clarida, Galí, and Gertler (2000) and Sargent and Surico (2011) that the second regime, which covers the time window between the '70s and '80s, features smaller policy responsiveness, in particular, the responsiveness to inflation. Table 3 also shows that there is no significant difference across periods in the slope coefficient on the output gap. Thus, from now on, we will focus only on the slope parameter on inflation.

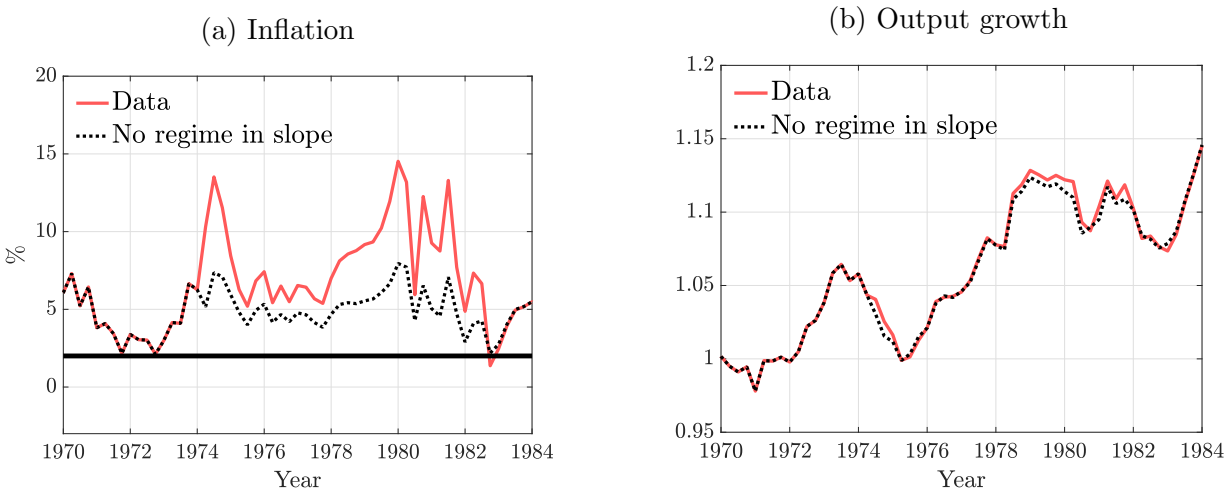
To gauge the role of the regime change in the slope parameter in affecting the aggregates,

Table 3: Estimation Results of Model with Regime Change in Slope Only

	Prior distribution			Posterior distribution			
	Shape	Mean	Std Dev.	Mode	Mean	5 %	95 %
ϕ_π	Normal	2	0.5	3.50	3.66	3.15	4.22
ϕ_x	Normal	0.125	0.05	0.20	0.20	0.15	0.25
ϕ_π^*	Normal	2	0.5	1.52	1.62	1.28	2.05
ϕ_x^*	Normal	0.125	0.05	0.15	0.15	0.09	0.22
T^{on}	Uniform	[1960Q1 , 1979Q3]		1974Q2			
T^{off}	Uniform	[1979Q4 , 1983Q4]		1982Q3			

we simulate the model by setting the policy responsive parameters in regime 2 to be the same as in other regimes, and plot the counterfactual inflation and output series in Figure 5.

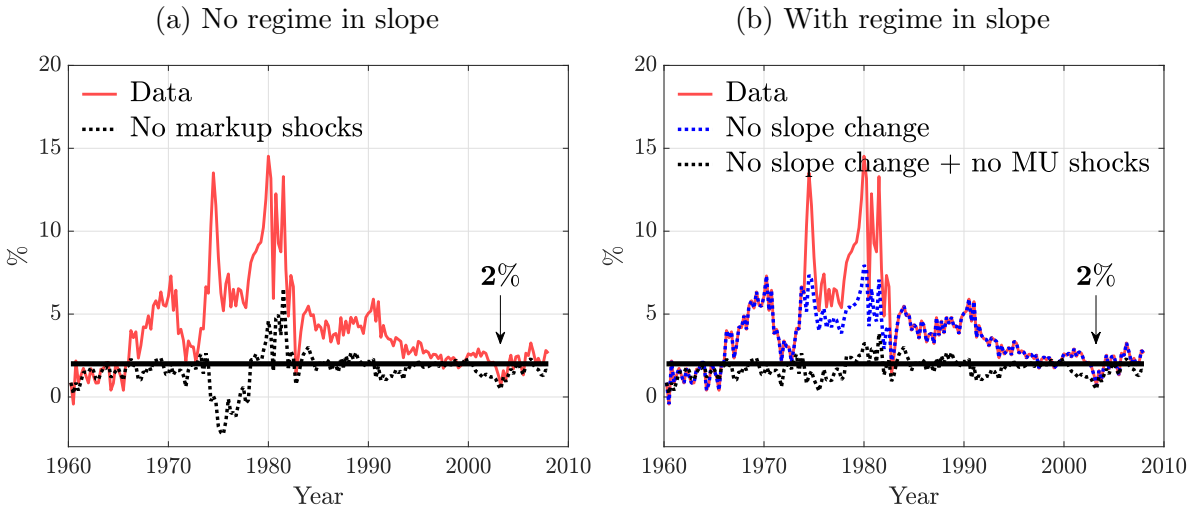
Figure 5: Counterfactual Simulation without Regime Change in Slope



Notes: (i) Output is normalized to be 1 in 1970.

As can be seen from Figure 5(a), the slope parameter indeed explains a large share of the increase in inflation between 1974 and the 1982. Average inflation during the regime two period (1974Q2 to 1982Q3) in the data is 8.3%, while it is only 5.2% in the counterfactual. Thus, according to the estimated model, the lower slope coefficient accounts for an average of 3.1 percent per year, which is a sizable amount. On the other hand, Figure 5(b) shows that the change in the slope parameter barely affects the fluctuations in output. This is likely the result of the relatively low value for the Calvo parameter in our calibration.

Figure 6: Role of Markup Shocks: Model with Regime Change in Slope Only



In Figure 6(a), we simulate the model by shutting down the markup shocks and compare it with the data. As Figure 6(a) shows, as in the conventional New Keynesian model (Figure 4(a)), markup shocks play a very important role in explaining inflation fluctuations. In Figure 6(b), we first simulate the economy by set policy responsiveness parameters in regime 2 as the same of those in regime 1, which replicates the results in Figure 5(a), which corresponds to the dotted blue line. Under the same scenario with no slope change, we further shut down the markup shocks and plot the simulated series as the dotted black line. Not surprisingly, this further attenuates the variation in inflation relative to the blue line. What is more informative is that when we compare the black lines on both panels of Figure 6, the inflation rate between 1974 and 1982 is way less volatile when we shut down the regime change in the slope, which means that the regime change in slope propagates the effects of markup shocks in this time window.

4.4 Model with Regime Change: Level and Slope

To disentangle the relative importance of the levels and slopes, in this section, we allow for a regime change where both the inflation target and the policy responsiveness are allowed to change. We consider the case in which the stochastic inflation target shocks are allowed as well as the case in which the stochastic component is shut down.

In estimating the model, we use the same priors of the inflation target process as in Section 3.2 and the same priors of the slope parameters as in Section 3.3. We also use the same uniform priors of the regime change dates as in the previous sections.

Table 4: Estimation Results: Regime Change in Slope and Deterministic Inflation Target

	Prior distribution			Posterior distribution			
	Shape	Mean	Std Dev.	Mode	Mean	5%	95%
Standard deviations							
$100 \times \sigma_i$	Inv. Gamma	1	2	0.11	0.11	0.11	0.12
$100 \times \sigma_a$	Inv. Gamma	1	2	1.23	1.24	1.24	1.12
$100 \times \sigma_e$	Inv. Gamma	1	2	0.11	0.11	0.11	0.10
$100 \times \sigma_z$	Inv. Gamma	1	2	0.43	0.43	0.43	0.45
$100 \times \sigma_\tau^{obs}$	Inv. Gamma	1	2	0.09	0.09	0.09	0.10
κ	Normal	2	0.3	2.24	2.26	2.06	2.47
κ_m	Normal	2	0.3	1.36	1.38	1.16	1.62
Structural parameters							
ρ_i	Beta	0.5	0.2	0.85	0.85	0.81	0.88
ϕ_π	Normal	2	0.5	2.71	2.78	2.18	3.43
ϕ_x	Normal	0.125	0.05	0.27	0.27	0.21	0.33
$10 \times \omega$	Normal	0.5	0.1	0.51	0.53	0.36	0.69
η	Normal	0.5	0.05	0.42	0.43	0.35	0.52
ρ_m	Beta	0.5	0.2	0.92	0.91	0.87	0.95
ρ_a	Beta	0.5	0.2	0.86	0.86	0.82	0.89
ρ_e	Beta	0.5	0.2	0.59	0.59	0.51	0.67
ρ_τ	Beta	0.5	0.2	0.84	0.84	0.76	0.91
ρ_π	Beta	0.5	0.2	0.97	0.97	0.96	0.98
$100 \times \Delta_\pi$	Uniform	[-2 , 6]		1.67	1.69	1.46	1.94
ρ_i^*	Beta	0.5	0.2	0.82	0.82	0.76	0.88
ϕ_π^*	Normal	2	0.5	2.13	2.15	1.43	2.99
ϕ_x^*	Normal	0.125	0.05	0.27	0.28	0.22	0.34

4.4.1 Impact on parameter estimation

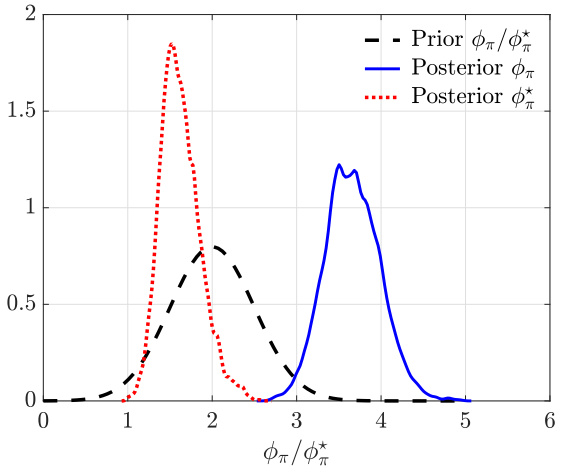
As Table 4 shows, we are able to identify a regime change in both the inflation target and .the policy responsiveness. To be more specific, $\Delta\pi = 1.68\%$ at the mode, which is almost identical as the estimate when the regime change in slope is not allowed. Comparing Table 3 and Table 4, we find that the gap between ϕ_π and ϕ_π^* is much smaller than when inflation target shocks are allowed.

We report in Figure 7 the prior and posterior distributions of the inflation responsive parameters when we allow for the regime change in slope parameter but use different assumptions of the inflation target. As can be seen in Figure 7, the presence of the inflation target weakens the identification of the gap between the slope parameters.

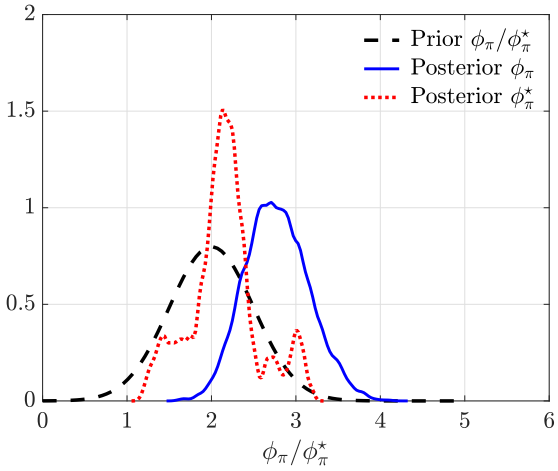
On the other side of the coin, estimation with the presence of regime change in slope has no effect in the posterior distributions of the inflation target shock process, including

Figure 7: Estimated Regime Change in Slope ϕ_π, ϕ_π^* by Inflation Target Structure

(a) No inflation target regime



(b) Deterministic inflation target



the target level change Δ_π and its persistence ρ_π as shown in Figure 8.

4.4.2 Relative importance of levels and slopes

We now analyze, using the same tools that we have discussed so far, the relative roles of the regime change in the level of the policy rate versus the regime change in the slope coefficients of the policy rate.

In order to do so, we simulate the estimated model, using the estimated shocks, but we shut down, one at a time, the two estimated regime changes.

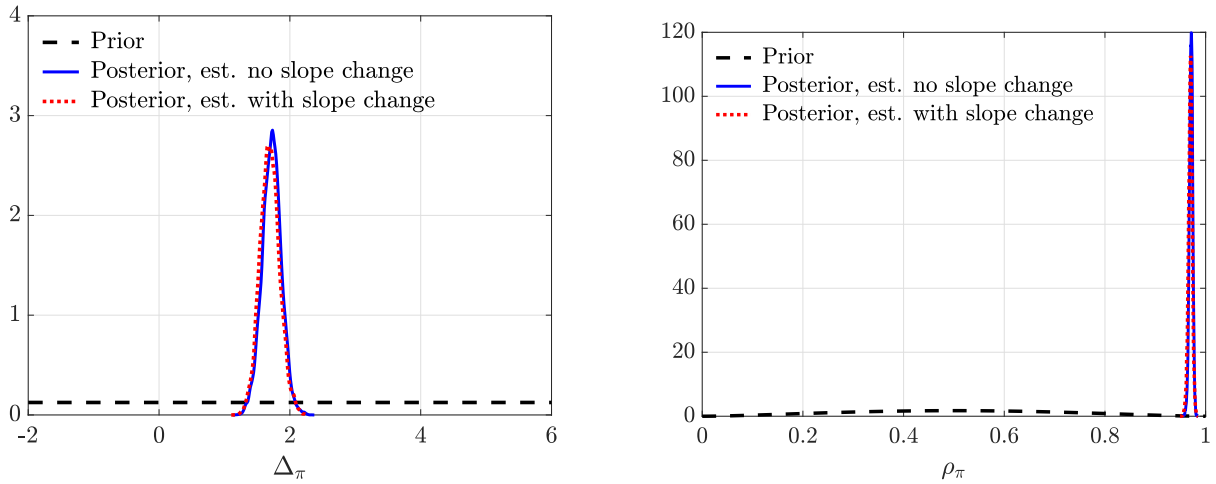
Figure 9(a) plots the data together with the simulation of the model when we assume that the slope coefficients are, for all periods, those estimated for the beginning and end of the sample. As can be seen from the figure, the two curves are almost indistinguishable. Thus, we conclude that the role of the changing coefficients is negligible.

In fact, the average inflation in the data for the regime 2 period (1965Q1 to 1981Q3) is equal to 6.1%, while the average inflation for the same period in the counterfactual where the slope parameters in regime 2 are set equal to the ones estimated for regime 1 is equal to 6.2%. Thus, the difference in the slope coefficient explains less tan half of a percentage point of inflation on average.

This result contrasts with Figure 5(a), where the differential (lower) slope on inflation deviations explained more than 3 percentage points.

As we show below, the main reason for this differential behavior is that once the regime change in the level of the policy rate is allowed in estimation, the change in the slopes becomes substantially smaller, consistent with the simple evidence presented in

Figure 8: Estimation of Deterministic Inflation Target by the Presence of Slope Change



(a) Δ_π (b) ρ_π

the Introduction. As shown in Figure 9(b), when we allow for a time-varying slope but shut down the regime switching in the inflation target, the simulation misses most of the medium-term fluctuations in inflation.

For the estimated break dates, average inflation in the data is 6.1%, while the model without the target shock only delivers an average of 2.08%, very close to the 2%, the calibrated target of the sample in regime 1.

4.4.3 The role of cost-push shocks

In Figure 10(a), we simulate the model by shutting down the markup shocks and compare it with the data. Once the inflation target shock is allowed, markup shocks play little role in explaining the inflation fluctuations. In Figure 10(b), we further simulate by setting the policy responsiveness parameters in regime 2 as the same as those in regime 1, which again shows the small role that markup shocks contributed to the fluctuations in inflation. In sharp contrast to Figure 6, Figure 10 illustrates that markup shocks, with or without the propagation of regime change in slope parameters, cannot explain the fluctuations in inflation.

4.4.4 Back to the reduced form

Because of the equilibrium selection that is typical in New Keynesian models, the estimation posteriors restrict the slope parameter in inflation to be higher than one. The advantage of estimating just the Policy rule is that no such restriction needs to be imposed.

Figure 9: Role of Levels vs Slopes: Model with Regime Change in Slope and Infl. Target

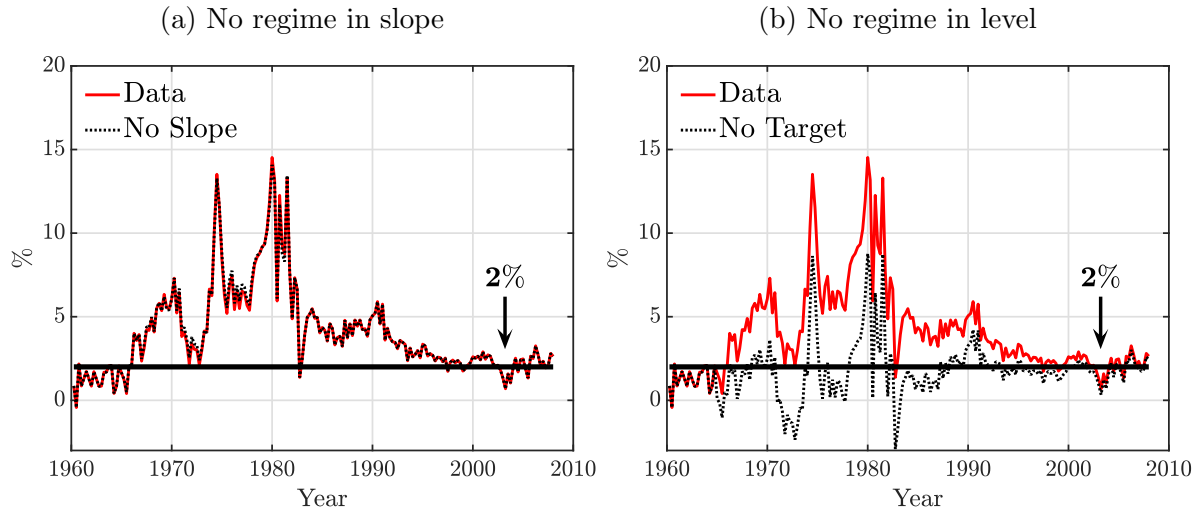


Figure 10: Role of Markup Shocks: Model with Regime Change in Both Slope and Inflation Target

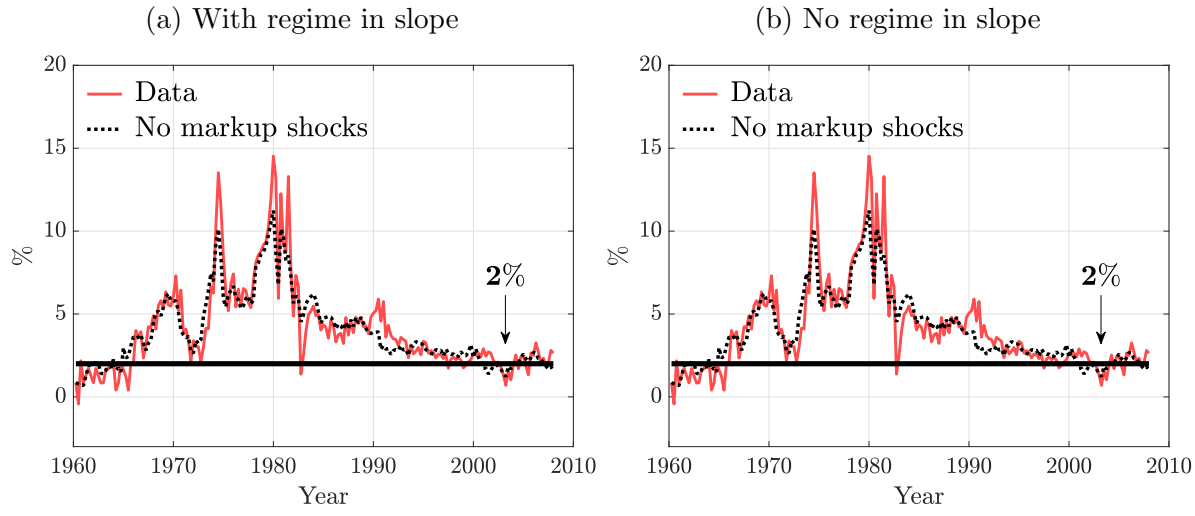


Table 5: GMM Estimates of the Interest Rate Rule, Core CPI

	Panel A. Raw Data		*Panel B. π_t^*-Adjusted*	
	62:1–79:2	79:3–96:4	62:1–79:2	79:3–96:4
	(1)	(2)	(3)	(4)
ρ_1	1.070***	0.942***	1.135***	1.105***
	(0.120)	(0.160)	(0.121)	(0.159)
ρ_2	−0.383***	−0.0631	−0.371***	−0.208
	(0.110)	(0.129)	(0.105)	(0.151)
β	0.787***	1.816***	0.424*	0.693
	(0.0602)	(0.427)	(0.193)	(0.796)
π^*	3.728***	4.085***		
	(0.815)	(0.954)		
γ	0.432***	0.678	0.555***	0.832*
	(0.130)	(0.631)	(0.130)	(0.417)
N	66	70	66	70

Notes: Standard errors in parentheses. Specifications (1) and (2) estimate a time-invariant inflation target π^* and use the moment condition in equation (3). Specifications (3) and (4) use the time-varying inflation target π_t^* estimated from the model and the moment condition in equation (4). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We end this Section revisiting the reduced form estimation of the policy rule we discussed in Section 2. The reason for doing so is that we now have an estimate of π_t^*. Thus, we can estimate equation (4) using our estimate of the time-varying target, instead of relying on the statistical decomposition we used in Section 2.

The results are reported in Table 5. We used core CPI as our measure of inflation. The first two columns report the results when we assume that the target in each subsample is constant; these results were reported in Section 2. The last two columns show the results when we use in estimation the time varying target we obtained in estimating the structural model. The results are starker than when using the statistical trend: The sensitivity of the policy rate to inflation in the second subperiod is not statistically different from zero.

5 Conclusions

What was the role of monetary policy in driving the high inflation rates of the 1970's in the United States? In this paper, we estimate a small scale New Keynesian model in order to address this question. We follow the tradition in the New Keynesian literature in assuming

that monetary policy is implemented by controlling a short-run nominal interest rate. More specifically, we estimate, as is customary, a linear rule for the policy rate that depends on deviations of endogenous variables from exogenously specified targets.

The main innovation of our approach is to allow, in estimation, for changes over time in the exogenous component of the rule. This is in contrast with most of the literature, that assumes that exogenous component to be time invariant. By allowing for this possibility, we allow for two distinct channels by which monetary policy can affect inflation. First, we allow for changes over time in the parameters that control the sensitivity of the monetary policy rule to endogenous variables (the slope parameters), as proposed in Clarida, Galí, and Gertler (2000). Second, we allow for changes over time on the exogenous component of policy (the level parameter).

We find that, as in CGG, if only the slope parameters are allowed to change, the difference between the estimated value during the high inflation period and the rest is quite high: there is almost no overlap between the supports of the posteriors of the estimator of the sensitivity of inflation for both sub-periods . And in the counterfactual in which we assume the slope coefficient in the high inflation period to be the ones estimated for the low inflation period, average inflation is close to 3 percentage points lower.

We also find that if only the level parameter is allowed to change, a high (around 7 percentage points) and significant change is detected during the high inflation period.

Finally, when allowing for both the slope and the level parameters to change, the difference in the slope parameters between the two subperiods is substantially lower than when only the slope parameters are allowed to change.

In contrast, the estimated change in the level parameter is the same as when only the level parameter is allowed to change. Our counterfactual exercises in this case show that while the level parameter explains a large share of the increase—and further decrease—of inflation during the 1970's, the contribution to inflation of the change in the slopes is very small, around 0.04 percentage points on average.

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Appendix

Not for Publication

A Data for GMM Estimation

FRED codes and data construction.

- GDP deflator: 400*(GDPDEF(t) - GDPDEF(t-1))
- Core CPI: 400*(CPILFESL(t) - CPILFESL(t-1))
- M2: 400*(M2SL(t) - M2SL(t-1))
- Federal funds rate: FEDFUNDS
- Output gap: 100*(GDPC1 - GDPPOT)/GDPPOT
- 10Y - 3M spread: DGS10 - DTB3
- Commodity price inflation: 100*(PPIACO-PPIACO(t-4)), where PPIACO is the Producer Price Index by Commodity: All Commodities. We use the 4-quarter growth rate of PPIACO to account for seasonal components.

Figure A.1: Data used in GMM Estimation

