A Major Shock Makes Prices More Flexible and May Result in a Burst of Inflation or Deflation

Robert E. Hall

Hoover Institution
April 5, 2023

Propositions

1. Cost shocks can cause large increases in price flexibility, in the presence of menu-cost price stickiness

Propositions

1. Cost shocks can cause large increases in price flexibility, in the presence of menu-cost price stickiness

2. The volatility of cost shocks rises in crises, such as the financial crisis and the pandemic

Propositions

1. Cost shocks can cause large increases in price flexibility, in the presence of menu-cost price stickiness

2. The volatility of cost shocks rises in crises, such as the financial crisis and the pandemic

3. Episodes of runaway inflation or deflation may occur in crises if the real interest rates are flexible along with inflation.

.

Cost shocks can cause large increases in price flexibility, with menu-cost price stickiness

.

General principles of the model

The model resembles Golosov-Lucas in its fundamental principles, but the goal is somewhat different.

General principles of the model

The model resembles Golosov-Lucas in its fundamental principles, but the goal is somewhat different.

Firms face a menu cost for any resetting of the product price.

General principles of the model

The model resembles Golosov-Lucas in its fundamental principles, but the goal is somewhat different.

Firms face a menu cost for any resetting of the product price.

They choose the profit-maximizing price when resetting, which is a fixed markup over cost

.

Golosov and Lucas

focus on the choice of the interval between one resetting of the price and the next,

Golosov and Lucas

focus on the choice of the interval between one resetting of the price and the next,

whereas this paper focuses on the choice between a passive sticky-price strategy or an active strategy of resetting prices as input costs vary.

.

Model

Firms produce output q from a single input x with constant returns and unit productivity, so their production functions are $q = x$.

Model

Firms produce output q from a single input x with constant returns and unit productivity, so their production functions are $q = x$.

The input x is available in a competitive market at price c, a random variable.

Model

Firms produce output q from a single input x with constant returns and unit productivity, so their production functions are $q = x$.

The input x is available in a competitive market at price c, a random variable.

Firms sell at price p in differentiated markets facing demand with constant price elasticity of 2:

$$q = \frac{1}{p^2}.$$

Model

Firms produce output q from a single input x with constant returns and unit productivity, so their production functions are $q = x$.

The input x is available in a competitive market at price c, a random variable.

Firms sell at price p in differentiated markets facing demand with constant price elasticity of 2:

$$q = \frac{1}{p^2}.$$

When free of menu costs, firms charge the profit-maximizing reset price

$$p^* = 2c$$

.

Source of sticky prices

Sellers incur a cost κ to make a price change.

Source of sticky prices

Sellers incur a cost κ to make a price change.

The profit net of that cost is

$$\frac{2c - c}{(2c)^2} - \kappa = \frac{1}{4c} - \kappa$$

Source of sticky prices

Sellers incur a cost κ to make a price change.

The profit net of that cost is

$$\frac{2c - c}{(2c)^2} - \kappa = \frac{1}{4c} - \kappa$$

The profit from retaining last period's price $\bar{p}$ when this period's cost, c, may have changed since last period, is the product of margin and volume:

$$\frac{\bar{p} - c}{\bar{p}^2}$$

.

.

Indifference between the two outcomes implies a level of cost, $\hat{c}$, satisfying

$$\frac{1}{4\hat{c}} - \kappa = \frac{\bar{p} - \hat{c}}{\bar{p}^2}$$

Indifference between the two outcomes implies a level of cost, $\hat{c}$, satisfying

$$\frac{1}{4\hat{c}} - \kappa = \frac{\bar{p} - \hat{c}}{\bar{p}^2}$$

This equation is quadratic in $\hat{c}$, so it has two roots.

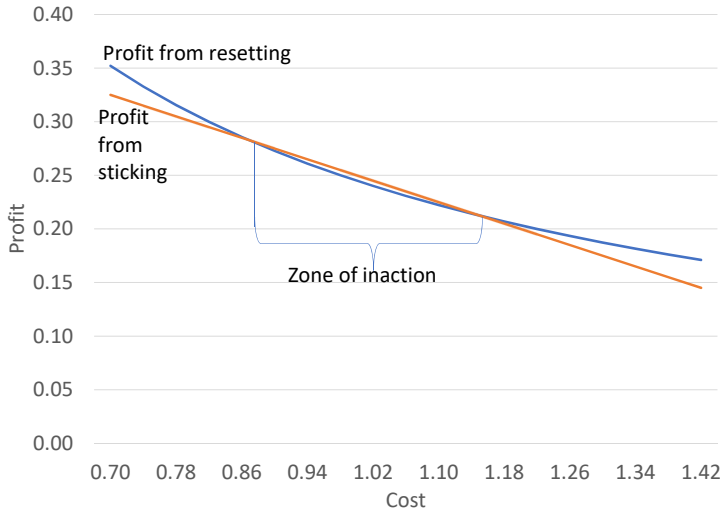
Indifference between the two outcomes implies a level of cost, $\hat{c}$, satisfying

$$\frac{1}{4\hat{c}} - \kappa = \frac{\bar{p} - \hat{c}}{\bar{p}^2}$$

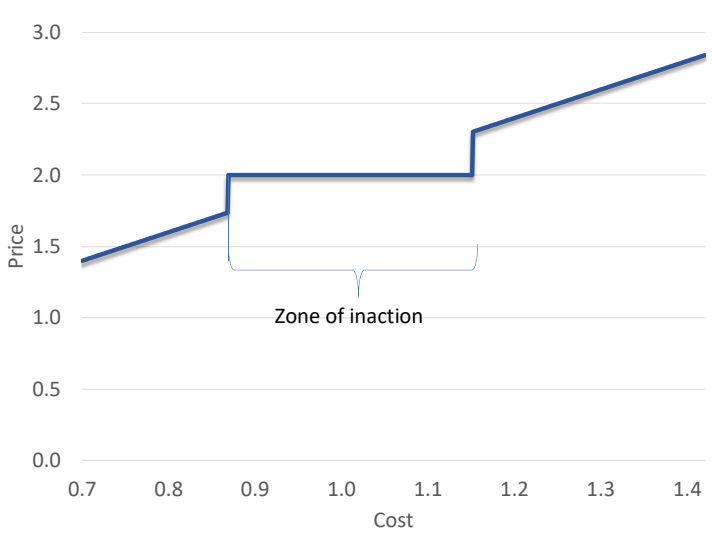
This equation is quadratic in $\hat{c}$, so it has two roots.

If the price elasticity of demand differs from 2, the results in this analysis still hold, but the reasoning is less transparent.

.



Profit Levels as a Function of Cost, and the Resulting Zone of Inaction, with $\kappa = 0.005$



Price as a Function of Cost

This paper

explores the behavior of the price when volatility rises to high levels.

This paper

explores the behavior of the price when volatility rises to high levels.

The relation between the volatility of the cost shock and the flexibility of the price level is the subject of the rest of this paper.

.

The cost shock in the model

is an iid draw from a uniform distribution on the interval $[1-\delta, 1+\delta]$.

The cost shock in the model

is an iid draw from a uniform distribution on the interval $[1-\delta, 1+\delta]$.

The parameter δ controls a mean-preserving spread of the cost shock around the mean, which is 1.

The cost shock in the model

is an iid draw from a uniform distribution on the interval $[1-\delta, 1+\delta]$.

The parameter δ controls a mean-preserving spread of the cost shock around the mean, which is 1.

A seller chooses to *reset* the price if

$$\frac{1}{4c_t} - \kappa > \frac{p_{t-1} - c_t}{p_{t-1}^2}$$

or *stick* otherwise.

The cost shock in the model

is an iid draw from a uniform distribution on the interval $[1-\delta, 1+\delta]$.

The parameter δ controls a mean-preserving spread of the cost shock around the mean, which is 1.

A seller chooses to *reset* the price if

$$\frac{1}{4c_t} - \kappa > \frac{p_{t-1} - c_t}{p_{t-1}^2}$$

or *stick* otherwise.

The price is $p_t = 2c_t$ for *reset* and $p_t = p_{t-1}$ for *stick*.

.

Characterization of the behavior of prices according to the model

The model has the general form

$$p_t = f(p_{t-1}, c_t),$$

which implies a recursive Markovian conditional probability density $g(p'|p)$ that yields an ergodic distribution for p, which in turn yields the ergodic distribution of interesting statistics, such as the fraction of time that that the price is reset.

Characterization of the behavior of prices according to the model

The model has the general form

$$p_t = f(p_{t-1}, c_t),$$

which implies a recursive Markovian conditional probability density $g(p'|p)$ that yields an ergodic distribution for p, which in turn yields the ergodic distribution of interesting statistics, such as the fraction of time that that the price is reset.

Monte Carlo calculations show that the distribution is ergodic.

Characterization of the behavior of prices according to the model

The model has the general form

$$p_t = f(p_{t-1}, c_t),$$

which implies a recursive Markovian conditional probability density $g(p'|p)$ that yields an ergodic distribution for p, which in turn yields the ergodic distribution of interesting statistics, such as the fraction of time that that the price is reset.

Monte Carlo calculations show that the distribution is ergodic.

The calculations reveal a critical point that separates zero resetting (purely sticky prices) from low frequencies of resetting.

.

Passive sticky price versus active variable pricing

If the support of the distribution of cost is entirely within the zone of inaction, the firm will either stick with the initial price from the start (if the starting cost is within the zone) or change the price to 2 times the starting cost and stick with that price for the rest of time.

Passive sticky price versus active variable pricing

If the support of the distribution of cost is entirely within the zone of inaction, the firm will either stick with the initial price from the start (if the starting cost is within the zone) or change the price to 2 times the starting cost and stick with that price for the rest of time.

The ergodic state will be fully sticky.

Passive sticky price versus active variable pricing

If the support of the distribution of cost is entirely within the zone of inaction, the firm will either stick with the initial price from the start (if the starting cost is within the zone) or change the price to 2 times the starting cost and stick with that price for the rest of time.

The ergodic state will be fully sticky.

Otherwise, there can be a mixture of periods with reset pricing and periods with sticky pricing.

Passive sticky price versus active variable pricing

If the support of the distribution of cost is entirely within the zone of inaction, the firm will either stick with the initial price from the start (if the starting cost is within the zone) or change the price to 2 times the starting cost and stick with that price for the rest of time.

The ergodic state will be fully sticky.

Otherwise, there can be a mixture of periods with reset pricing and periods with sticky pricing.

And it is possible that all periods will be flexible, if the menu cost is close enough to zero.

.

Calculation

Demonstrate the relation between the shock size δ and the frequency of the *reset* action.

Calculation

Demonstrate the relation between the shock size δ and the frequency of the *reset* action.

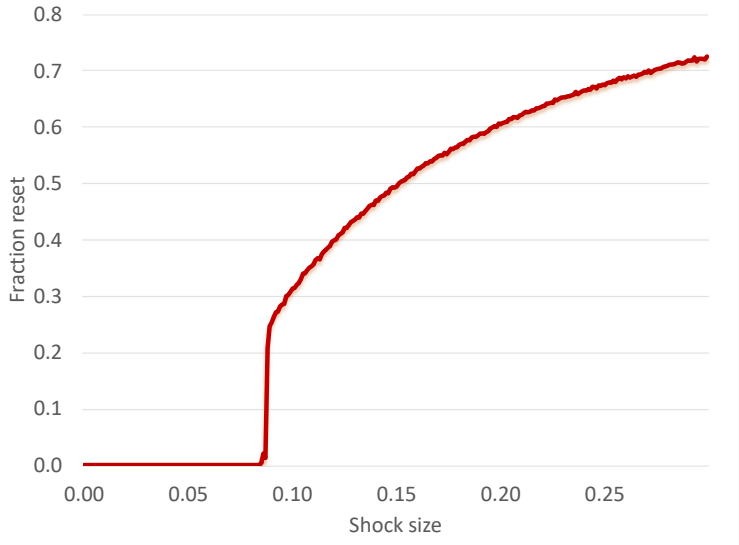
For each of 300 values of δ from zero to 0.3, calculate one million observations of the time series p_t, and tabulate the fraction of the actions that are *reset*.

Calculation

Demonstrate the relation between the shock size δ and the frequency of the *reset* action.

For each of 300 values of δ from zero to 0.3, calculate one million observations of the time series p_t, and tabulate the fraction of the actions that are *reset*.

.



Relation between Shock Size and Fraction of Periods with Resets

Findings

In an economy with small shocks, up to $\delta = 0.0855$, it never pays to reset.

Findings

In an economy with small shocks, up to $\delta = 0.0855$, it never pays to reset.

Above that critical value, it begins to pay to reset.

Findings

In an economy with small shocks, up to $\delta = 0.0855$, it never pays to reset.

Above that critical value, it begins to pay to reset.

There is no discontinuity—the limit from the right of the critical value is zero, like the limit from the left—but the curve becomes infinitely steep from the right (the derivative from the right is discontinuous).

Findings

In an economy with small shocks, up to $\delta = 0.0855$, it never pays to reset.

Above that critical value, it begins to pay to reset.

There is no discontinuity—the limit from the right of the critical value is zero, like the limit from the left—but the curve becomes infinitely steep from the right (the derivative from the right is discontinuous).

To the right of the critical value, it rises steeply up to a reset fraction of 0.25 and then follows a smooth concave path.

.

Price flexibility

If the reset fraction is one, prices are fully flexible, and responsive to current conditions.

Price flexibility

If the reset fraction is one, prices are fully flexible, and responsive to current conditions.

At a shock value of $\delta = 0.3$, flexible pricing would occur about 70 percent of the time.

Price flexibility

If the reset fraction is one, prices are fully flexible, and responsive to current conditions.

At a shock value of $\delta = 0.3$, flexible pricing would occur about 70 percent of the time.

Below a shock value of 0.0855, pricing is fully sticky, independent of current conditions.

.

Fully sticky prices

There is a critical configuration of the model such that at lower values of the of the cost volatility δ, the price is a constant over time—resetting never occurs

Fully sticky prices

There is a critical configuration of the model such that at lower values of the of the cost volatility δ, the price is a constant over time—resetting never occurs

except possibly to bring the price into the zone of inaction at the beginning of time.

.

Key finding

The surprising implication of this investigation is that a small increase in the volatility of cost, that leaves the average level of cost unchanged, can trigger a large decline in price stickiness.

Key finding

The surprising implication of this investigation is that a small increase in the volatility of cost, that leaves the average level of cost unchanged, can trigger a large decline in price stickiness.

The next section of the paper presents an empirical analysis demonstrating a large increase in cost volatility around the time of a burst of inflation during and after the pandemic, followed by a reversal.

.

Robustness

Wide variations in the parameters, δ and κ, of the model, preserve the basic property that the price is constant over time if the volatility of the cost shock is below the critical level.

Robustness

Wide variations in the parameters, δ and κ, of the model, preserve the basic property that the price is constant over time if the volatility of the cost shock is below the critical level.

And that the incidence of unimpeded pricing explodes if the volatility is just above the critical level.

.

Second proposition: The volatility of cost shocks rises in crises, such as the financial crisis and the pandemic

.

The study of cross-industry standard deviations

documents a large increase during the pandemic and other crises in the volatility of two variables directly involved in price formation: input cost, and total factor productivity.

.

The pricing equation with three driving forces

With variations in total factor productivity (TFP), denoted A, and the markup ratio denoted μ, the pricing equation becomes

$$p = \mu \frac{c}{A}$$

The pricing equation with three driving forces

With variations in total factor productivity (TFP), denoted A, and the markup ratio denoted μ, the pricing equation becomes

$$p = \mu \frac{c}{A}$$

This equation implies that volatility in cost, productivity, and market power breeds volatility in product prices.

The pricing equation with three driving forces

With variations in total factor productivity (TFP), denoted A, and the markup ratio denoted μ, the pricing equation becomes

$$p = \mu \frac{c}{A}$$

This equation implies that volatility in cost, productivity, and market power breeds volatility in product prices.

The paper focuses on cost and productivity because measurement of the volatility of market power is still a quite unsettled area of research.

The pricing equation with three driving forces

With variations in total factor productivity (TFP), denoted A, and the markup ratio denoted μ, the pricing equation becomes

$$p = \mu \frac{c}{A}$$

This equation implies that volatility in cost, productivity, and market power breeds volatility in product prices.

The paper focuses on cost and productivity because measurement of the volatility of market power is still a quite unsettled area of research.

Note the product demand does not influence price, a standard property of the Spence-Dixit-Stiglitz specification

.

Data on input cost by industry

The Bureau of Economic Analysis (BEA) publishes indexes of intermediate-input prices for 71 industries at quarterly frequency, starting in 2005, through the third quarter of 2022.

Data on input cost by industry

The Bureau of Economic Analysis (BEA) publishes indexes of intermediate-input prices for 71 industries at quarterly frequency, starting in 2005, through the third quarter of 2022.

Examine quarterly input-price growth ratios for each industry.

Data on input cost by industry

The Bureau of Economic Analysis (BEA) publishes indexes of intermediate-input prices for 71 industries at quarterly frequency, starting in 2005, through the third quarter of 2022.

Examine quarterly input-price growth ratios for each industry.

A compact but informative statistic of volatility each quarter is the standard deviation of the growth ratio across the 71 industries

Data on input cost by industry

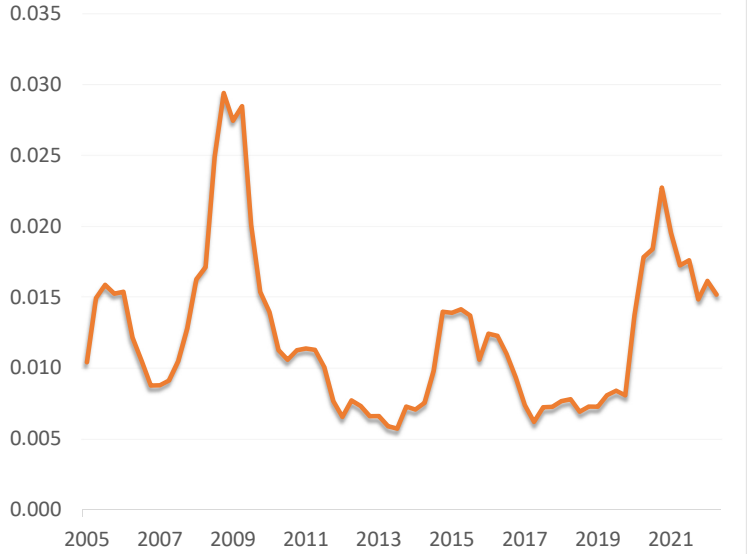
The Bureau of Economic Analysis (BEA) publishes indexes of intermediate-input prices for 71 industries at quarterly frequency, starting in 2005, through the third quarter of 2022.

Examine quarterly input-price growth ratios for each industry.

A compact but informative statistic of volatility each quarter is the standard deviation of the growth ratio across the 71 industries

To deal with higher-frequency noise, the data are smoothed by calculating 4-quarter moving averages.

.



Cross-Industry Standard Deviation of Intermediate Cost, Quarterly

Starting in the second quarter of 2020, cost volatility tripled.

It remained high until the present, at more than double the level of the calm period from 2017 until the beginning of 2020.

Starting in the second quarter of 2020, cost volatility tripled.

It remained high until the present, at more than double the level of the calm period from 2017 until the beginning of 2020.

Volatility also rose moderately around 2006 and 2016.

Starting in the second quarter of 2020, cost volatility tripled.

It remained high until the present, at more than double the level of the calm period from 2017 until the beginning of 2020.

Volatility also rose moderately around 2006 and 2016.

The biggest bulge, greater than the one associated with the pandemic, occurred during the financial-crisis recession, peaking in 2009.

.

Productivity

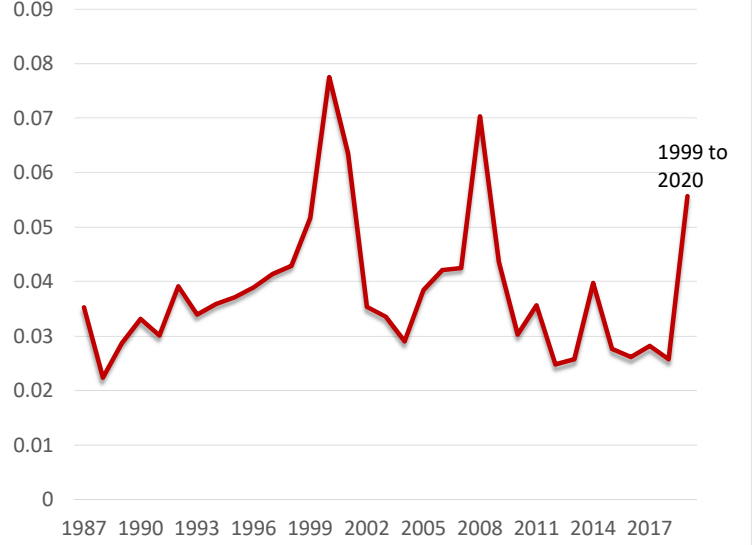
The Bureau of Labor Statistics, in cooperation with the BEA, publishes annual data on TFP, starting in 1987, for essentially the same industries as for cost.

Productivity

The Bureau of Labor Statistics, in cooperation with the BEA, publishes annual data on TFP, starting in 1987, for essentially the same industries as for cost.

As of March 2023, the most recent year available is 2020; data for 2021 should be available in May 2023.

.



Cross-Industry Standard Deviation of Total Factor Productivity, by Year

Productivity findings

The time paths of two determinants of price volatility, input cost and productivity, tell a common story.

Productivity findings

The time paths of two determinants of price volatility, input cost and productivity, tell a common story.

Burst of volatility during the tech recession, in 2001

Productivity findings

The time paths of two determinants of price volatility, input cost and productivity, tell a common story.

Burst of volatility during the tech recession, in 2001

Another burst during the financial crisis in 2009

Productivity findings

The time paths of two determinants of price volatility, input cost and productivity, tell a common story.

Burst of volatility during the tech recession, in 2001

Another burst during the financial crisis in 2009

Incomplete coverage of the pandemic burst—data coming out next month

.

Relation of volatility to inflation

Volatility of the driving forces is not itself a driving force for inflation.

Relation of volatility to inflation

Volatility of the driving forces is not itself a driving force for inflation.

In particular, in the financial crisis of 2008 and 2009, a large increase in volatility of both cost and productivity occurred, but inflation remained near normal levels.

Relation of volatility to inflation

Volatility of the driving forces is not itself a driving force for inflation.

In particular, in the financial crisis of 2008 and 2009, a large increase in volatility of both cost and productivity occurred, but inflation remained near normal levels.

Rather, the volatility of the determinants of inflation influences the *slope* of the response of inflation to monetary policy.

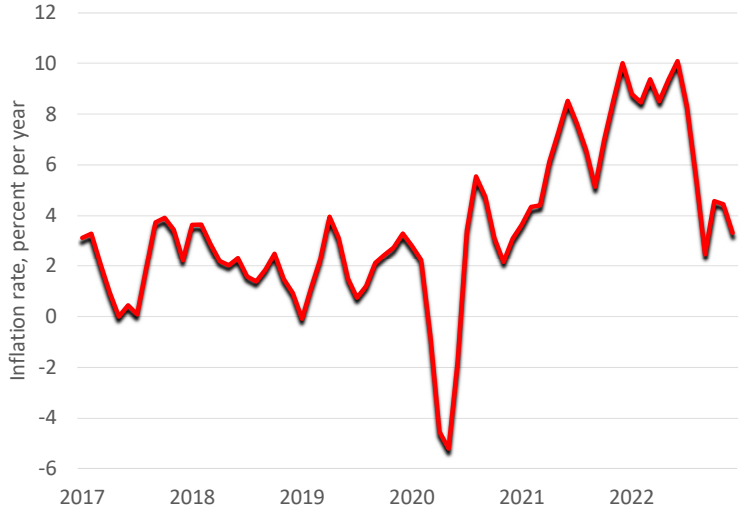
.

Third proposition: Episodes of runaway inflation or deflation may occur in crises if real interest rates are flexible, along with inflation.

.

Key variables, 2018 through 2022

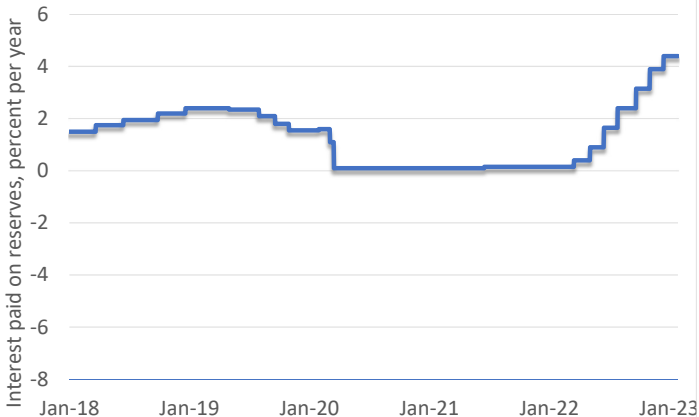
Inflation
Interest rate
Monetary policy rate
Fiscal policy



Inflation, π

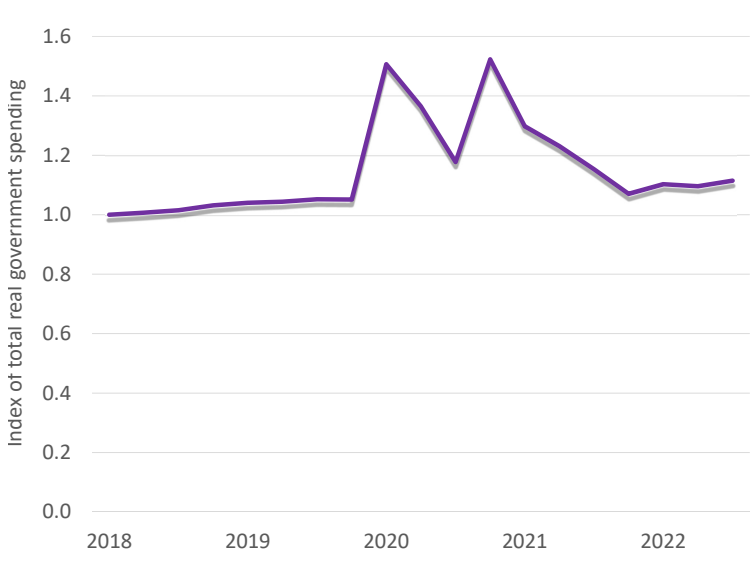
BLS CPI

Short-term, Real, Safe Interest Rate, r,
Cleveland Fed



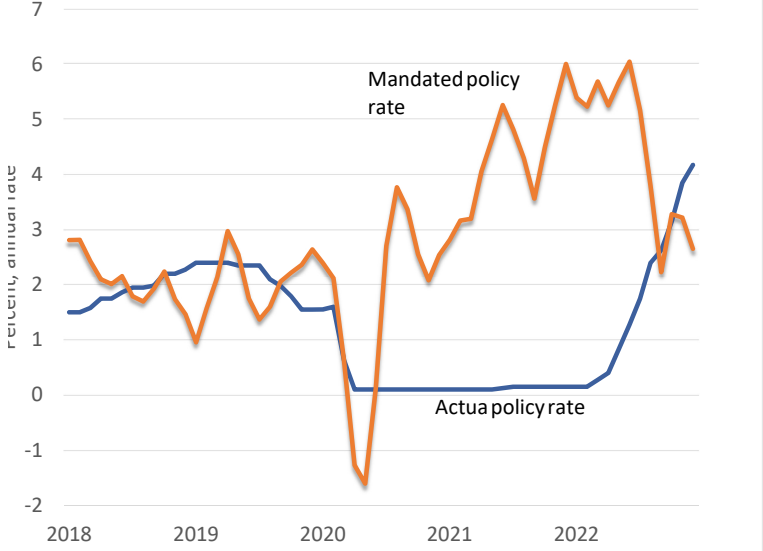
Fed's Policy Interest Rate, b

Federal Reserve Board, IOER and IORB



Index of Real Government Spending, g

NIPAs, purchases plus transfers divided by CPI



Standard critical view of the recent runaway invlation

Informal Analysis with Shifting Phillips Curve

Vavra(2014) observes that monetary policy has attenuated effects when the dispersion rises of the shocks to the determinants of price changes.

Informal Analysis with Shifting Phillips Curve

Vavra(2014) observes that monetary policy has attenuated effects when the dispersion rises of the shocks to the determinants of price changes.

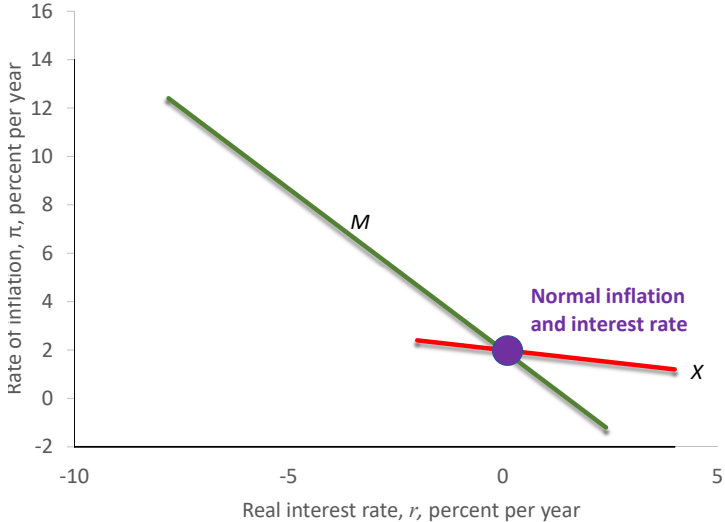
I study the conditions underlying weakly anchored inflation in a diagram with inflation π on the vertical axis and the real interest rate r on the horizontal axis

Informal Analysis with Shifting Phillips Curve

Vavra(2014) observes that monetary policy has attenuated effects when the dispersion rises of the shocks to the determinants of price changes.

I study the conditions underlying weakly anchored inflation in a diagram with inflation π on the vertical axis and the real interest rate r on the horizontal axis

.



Equilibrium in normal times: $r = 0$ and $\pi = 2\%$

Passive monetary policy with reserve saturation

The economy's Fisher equation implies a line with slope -1, labeled M.

Passive monetary policy with reserve saturation

The economy's Fisher equation implies a line with slope -1, labeled M.

The central bank determines the position of M by choosing its nominal policy rate, b.

Passive monetary policy with reserve saturation

The economy's Fisher equation implies a line with slope -1, labeled M.

The central bank determines the position of M by choosing its nominal policy rate, b.

I take b to be a constant, to express the idea that the central bank's initial response to threatened inflation is passive.

Passive monetary policy with reserve saturation

The economy's Fisher equation implies a line with slope -1, labeled M.

The central bank determines the position of M by choosing its nominal policy rate, b.

I take b to be a constant, to express the idea that the central bank's initial response to threatened inflation is passive.

Under reserve saturation, the real interest rate r tracks b closely, with r equal to b less the expected rate of inflation.

.

Where does the economy operate along the M line?

A curve, labeled X, shows the values of the real interest rate consistent with the economy's Phillips curve and IS curve.

Where does the economy operate along the M line?

A curve, labeled X, shows the values of the real interest rate consistent with the economy's Phillips curve and IS curve.

In a real-business-cycle model with monetary neutrality, the real interest rate is unaffected by monetary considerations. The X curve is vertical, with r equal to a constant, say $\bar{r}$. In that economy, the equilibrium is $r = \bar{r}$ and expected π is equal to $b - \bar{r}$.

Where does the economy operate along the M line?

A curve, labeled X, shows the values of the real interest rate consistent with the economy's Phillips curve and IS curve.

In a real-business-cycle model with monetary neutrality, the real interest rate is unaffected by monetary considerations. The X curve is vertical, with r equal to a constant, say $\bar{r}$. In that economy, the equilibrium is $r = \bar{r}$ and expected π is equal to $b - \bar{r}$.

.

With somewhat sticky prices,

The rate of inflation and the real interest rate lie along an upward-sloping line, labeled X.

With somewhat sticky prices,

The rate of inflation and the real interest rate lie along an upward-sloping line, labeled X.

X combines the roles of the IS curve and the Phillips curve in conventional New Keynesian models.

With somewhat sticky prices,

The rate of inflation and the real interest rate lie along an upward-sloping line, labeled X.

X combines the roles of the IS curve and the Phillips curve in conventional New Keynesian models.

The increase in the interest rate depresses output and thus slackens markets.

With somewhat sticky prices,

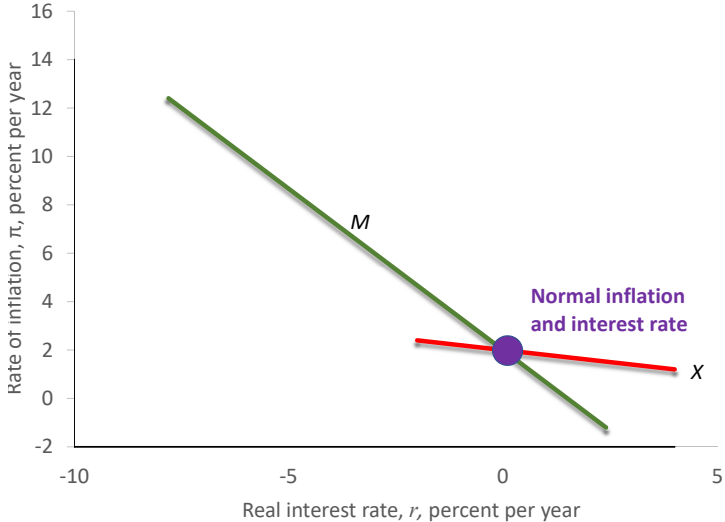
The rate of inflation and the real interest rate lie along an upward-sloping line, labeled X.

X combines the roles of the IS curve and the Phillips curve in conventional New Keynesian models.

The increase in the interest rate depresses output and thus slackens markets.

Then the Phillips curve indicates lower inflation.

.



Equilibrium in normal times—$r = 0$ and $\pi = 2\%$

Sticky-price equilibrium

Curves M and X intersect at a real interest rate of zero and a rate of inflation of 2 percent.

Sticky-price equilibrium

Curves M and X intersect at a real interest rate of zero and a rate of inflation of 2 percent.

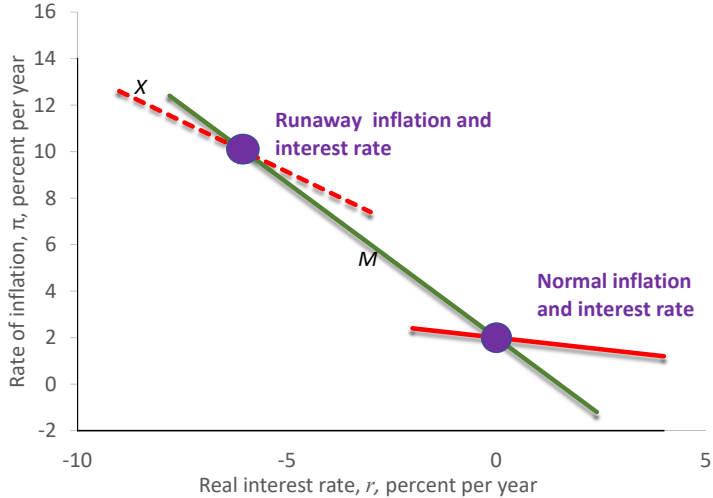
These values were typical of actual experience before the pandemic.

Sticky-price equilibrium

Curves M and X intersect at a real interest rate of zero and a rate of inflation of 2 percent.

These values were typical of actual experience before the pandemic.

.



Runaway Inflation: $r = -6\%$ and $\pi = 10\%$

Runaway inflation

The model is capable of generating a change comparable to what happened in the US economy between mid-2020 and mid-2022

Runaway inflation

The model is capable of generating a change comparable to what happened in the US economy between mid-2020 and mid-2022

The real interest rate fell into deeply negative territory while inflation exploded.

Runaway inflation

The model is capable of generating a change comparable to what happened in the US economy between mid-2020 and mid-2022

The real interest rate fell into deeply negative territory while inflation exploded.

.

Steepening Phillips curve

The M curve remains the same—there is no immediate response of monetary policy; the policy rate b is unchanged.

Steepening Phillips curve

The M curve remains the same—there is no immediate response of monetary policy; the policy rate b is unchanged.

The shifted X curve, shown as a dashed red curve, is steeper than normal—it intersects the M curve at values drawn from the data from mid-2022–the inflation rate is 10 percent per year and the real interest rate is minus 6 percent.

.

Halting runaway inflation

Runaway inflation occurs because of the delay in the central bank's response.

Halting runaway inflation

Runaway inflation occurs because of the delay in the central bank's response.

Once the bank fights inflation by raising its policy rate b, the M curve shifts toward the origin and the economy moves down the dashed X curve and inflation and the real interest rate both fall.

.

Recent developments

Starting in later 2022, the X curve has shifted back toward its normal position. Inflation has fallen and the real interest rate has risen as the economy returned toward normal.

.

The US has raised its policy rate

And there is reasonable evidence that US inflation is returning to target. Part of the decline in inflation has come from the tightening of policy and the rest from normalization of the Phillips curve.

.

Earlier research on variations in price flexibility

DeLong and Summers (1986) diagnosed one of the issue considered in this paper. They observed that increasing flexibility of prices could have perverse effects in an economy that retained some price stickiness.

.

Forces keeping the economy on its M curve

For any point on the M curve, the variables of the model satisfy the no-arbitrage condition mentioned earlier, which can be restated as the equality of the short-run nominal safe rate and the policy rate. Modern central banking ensures that the two rates are fairly close together by establishing a corridor where banks and other financial institutions can borrow from or lend to the central bank. Transactions in other safe instruments do not occur outside the corridor, because the central bank offers a better deal. Thus powerful forces of financial arbitrage keep the economy close to its M curve. See Castillo and Reis (2019) for an extensive discussion of how modern central banks steer their economies.

.

Stabilizing the Inflation Rate

To achieve stable inflation, it is both necessary and effective to change the policy rate quickly to head off inflation or deflation. Recent experience has shown that a sluggish response to inflation based on a philosophy of wait-and-see has adverse practical consequences.

.

The Taylor principle

The principle of boosting the policy rate by 1.5 points for every point of excess inflation embodies this idea. But Taylor rules generally impose gradual adjustment of the policy rate that can result in runaway inflation. A Taylor rule with a term that loads on the lagged policy rate invites unstable rates of change of the price level. Inflation can decline rapidly, so these lessons apply in reverse as well.

.