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BALANCING ECONOMIC RECOVERY AND INFLATIONARY CONCERNS OPTIMAL MONETARY POLICY RESPONSE TO THE INFLATION GAP

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Abstract

This paper provides an updated decomposition of headline PCE inflation in the United States. A one asset HANK model is calibrated to match the US and perfectly fit output and inflation data for the period 2020-2022. The most interesting finding shows that the optimal monetary response to the inflation gap uses a sensitivity parameter of 2.7 in contrast to the 1.25 common in literature, suggesting a tighter monetary policy stance should improve overall welfare. Relative welfare gains should be around 0.034%

Keywords: Optimal Monetary Response, HANK, Sign restrictions, VAR, Inflation decomposition

1 Introduction

As of 2021, inflation forced its way back to the center of public debate. Headline PCE inflation in the US peaked in June 2022 at 6.9%, which led to an interest rate hike that has set the Federal Funds Rate in a target range of 5.25% - 5.5%.

The surge in inflation coincided with two major events. The Covid pandemic and post-pandemic recovery and Russia's invasion of Ukraine, which provoked a turmoil in global energy markets. There was no consensus regarding the drivers of inflation, specifically on whether it was predominantly driven by supply or demand. The answer to this question raises a second question about the impacts on the effectiveness of monetary policy and on central banks' ability to deliver a so-called soft landing. When inflation is mainly demand driven it is easier to argue for a tightening in monetary conditions, however supply side shocks often involve difficult trade-offs (Boehm and House 2014).

Recently, researchers have delved into the drivers of inflation and used different approaches to provide a decomposition. (Shapiro 2022) uses a reduced form VAR and sign restrictions that rely on standard theory of the slopes of aggregate demand and supply curves, making his approach very intuitive. (Eickmeier and Hofmann 2023) chose a structural factor model using measures of inflation and real activity for the US and the Eurozone. They found that the share of supply shocks for Europe was higher compared to the US, mainly because of the greater exposure to energy prices. This can be pointed as one of the reasons why the European Central Bank has been accused of late intervention. (Cerrato and Gitti 2022) estimated the slope of the Phillips curve before, during, and after Covid. The conclusions are similar for all, both demand and supply have contributed to inflation, with the share of supply shocks being slightly higher than that of demand shocks. In this work, (Shapiro 2022) approach will be updated until September 2023.

These estimates will feed a heterogenous agents New Keynesian model calibrated to match the US economy. The model will solve for the series of discount factors and total factor productivity (TFP) that allow a perfect fit to the data.

The goal here is to tackle the second question. What is the optimal monetary policy response to the inflation gap and is it compatible with traditional literature. (Boehm and House 2014) argue the best policy choice will depend crucially on the underlying parameters of the model.

The work is organized as follows: section 2 provides an updated decomposition of headline PCE inflation, section 3 presents the one asset HANK, section 4 explains the calibration for the US, section 5 analyzes the optimal monetary policy response to the inflation gap, and section 6 concludes. The appendix shows model properties, estimation results and calibration details.

2 Supply and demand driven inflation

This section provides an update of (Shapiro 2022) approach for the US. The framework generates two new data series, the supply-driven contribution, and the demand-driven contribution to PCE inflation. The series quantify the degree to which supply or demand are driving inflation, each month.

Data on PCE price index (Table 2.4.4U.), PCE quantity index (Table 2.4.3U.) and weights for each PCE category (Table 2.4.5U.) are available in the Bureau of Economic Analysis – Interactive Data – Personal Income – Underlying Detail Tables – Section 2. At the fourth level of disaggregation, there are 132 categories for headline inflation[1].

[1] (Shapiro 2022) used 136 categories for headline inflation. The difference should not impact the results significantly.

Quantity and price regressions are run using twelve lags of quantity and prices for each category each month. This work follows (Shapiro 2022) in using logarithms of prices and quantities to control for technological, demographic, and cost-of-living adjustments that may impact existing trends.

Reduced form VAR:

$$q_{i,t} = \sum_{j=1}^{12} \gamma_j^{qp} p_{i,t-j} + \sum_{j=1}^{12} \gamma_j^{qq} q_{i,t-j} + v_{i,t}^{q} \tag{1}$$

$$p_{i,t} = \sum_{j=1}^{12} \gamma_j^{pp} p_{i,t-j} + \sum_{j=1}^{12} \gamma_j^{pq} q_{i,t-j} + v_{i,t}^{p} \tag{2}$$

Here, p and q are the logarithms of prices and quantities of category i at month t.

The key to this exercise is labeling each category each month as mainly net-supply or net-demand driven, by collecting the reduced form residuals $v_{i,t}^{q}$ and $v_{i,t}^{p}$. Note that, even if one category is labeled as demand driven, it might be affected by a supply shock. We are only considering net effects.

The identification strategy is theoretically intuitive, making use of standard theory on the slopes of demand and supply curves. Assuming an upward sloping supply curve and a downward sloping demand curve for each category i we are left with, respectively:

$$q_i = \sigma^i p_i + \alpha^i \tag{3}$$

$$p_i = -\delta^i q_i + \beta^i \tag{4}$$

It follows that a shock to the curves is given by:

$$\varepsilon_i^{supply} = \left(q_{i,t} - \sigma^i p_{i,t}\right) - \left(q_{i,t-1} - \sigma^i p_{i,t-1}\right) \tag{5}$$

$$\varepsilon_i^{demand} = \left(\delta^i q_{i,t} + p_{i,t}\right) - \left(\delta^i q_{i,t-1} + p_{i,t-1}\right) \tag{6}$$

So, the structural VAR representation comes as:

$$q_{i,t} - \sigma^i p_{i,t} = \sum_{j=1}^{N} q_{i,t-j} - \sigma^i p_{i,t-j} + \varepsilon_{i,t}^{supply} \tag{7}$$

$$\delta^i q_{i,t} + p_{i,t} = \sum_{j=1}^{N} \delta^i q_{i,t-j} + p_{i,t-j} + \varepsilon_{i,t}^{demand} \tag{8}$$

The structural shocks can be recovered via transformation of the reduced form residuals:

$$\varepsilon_{i,t} = A^i v_{i,t} \tag{9}$$

where $\varepsilon_{i,t} = \begin{bmatrix} \varepsilon_{i,t}^{supply} \\ \varepsilon_{i,t}^{demand} \end{bmatrix}$, $A^i = \begin{bmatrix} 1 & -\sigma^i \\ \delta^i & 1 \end{bmatrix}$ and $v_{i,t} = \begin{bmatrix} v_{i,t}^q \\ v_{i,t}^p \end{bmatrix}$.

The restrictions on the slopes of the curves imply restrictions on the signs of the structural shocks $\varepsilon_{i,t}$ and therefore restrictions on the signs of the reduced form residuals $v_{i,t}$, as shown in (Jump e Kohler 2022).

The signs of the reduced form residuals give information about the signs of the structural shocks. A shock to aggregate demand shifts the demand curve along the upward sloping supply curve. This means that both quantity and prices move in the same direction (increase in the case of a positive demand shock or decrease in the case of a negative demand shock). A shock to aggregate supply shifts the supply curve along the downward sloping demand curve, meaning that quantities and prices will move in opposite directions (prices decrease and quantities increase in the case of a positive supply shock and prices increase and quantities decrease in the case of a negative supply shock).

Binary labeling of the shocks:

$$Positive\ Supply\ Shock_{(i,t)} = \begin{cases} 1, & if\ v_{i,t}^{p} < 0 \cap v_{i,t}^{q} > 0 \\ 0, & otherwise \end{cases} \tag{10}$$

$$Negative\ Supply\ Shock_{(i,t)} = \begin{cases} 1, & if\ v_{i,t}^{p} > 0 \cap v_{i,t}^{q} < 0 \\ 0, & otherwise \end{cases} \tag{11}$$

$$Positive\ Demand\ Shock_{(i,t)} = \begin{cases} 1, & if\ v_{i,t}^{p} > 0 \cap v_{i,t}^{q} > 0 \\ 0, & otherwise \end{cases} \tag{12}$$

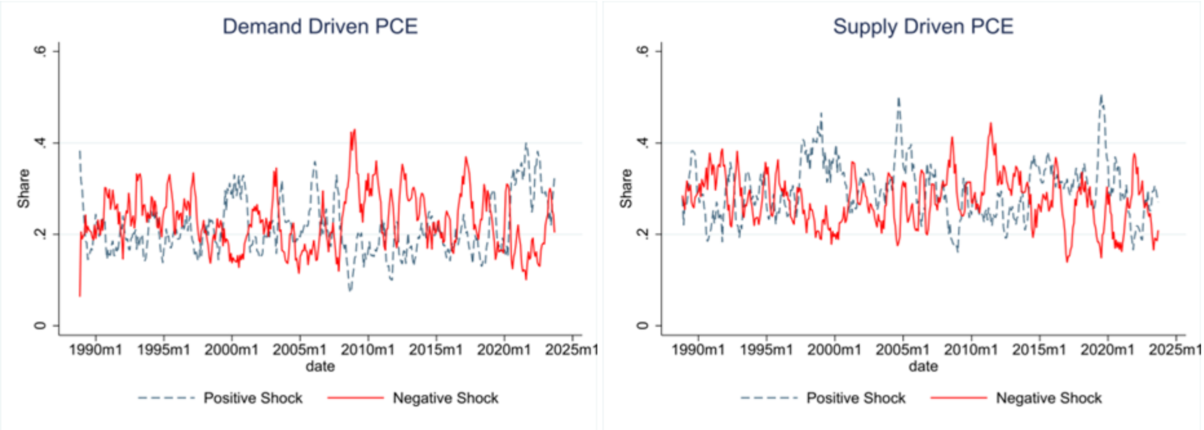
$$Negative\ Demand\ Shock_{(i,t)} = \begin{cases} 1, & if\ v_{i,t}^{p} < 0 \cap v_{i,t}^{q} < 0 \\ 0, & otherwise \end{cases} \tag{13}$$

The share of PCE by shock type in month t will be given by:

$$Share = \sum_{i} \omega_{i,t} Shock_{i,t} \tag{14}$$

where $Shock_{i,t}$ refers to one of the labeling above and $\omega_{i,t}$ is the weight of category i at month t in the PCE consumption basket.

Figure 1. Decomposition of the shocks to PCE



The share[2] of supply shocks is slightly higher than the share of demand shocks when looking at the entire sample period (January 1989 to September 2023). Note that, immediately after the beginning of 2020 it is possible to spot a hike in the share of positive demand shocks and in the share of negative supply shocks which is not surprising, since these are the ones that contribute to an increase in prices.

Even more interestingly, this decomposition makes the procyclical nature of demand driven inflation clear. Prices are rising simultaneously with output, justifying a tighter monetary policy.

The countercyclical nature of supply driven inflation also surfaces, as prices are rising while output is decreasing, hence the difficult policy trade-offs that arise. Central banks are faced with the decision of loosening their control over the inflation gap in favor of a smaller variation of output.

Now, extending the decomposition to inflation is easy. It is enough to redefine the four binary variables into two – one for demand shocks (positive and negative) and one for supply

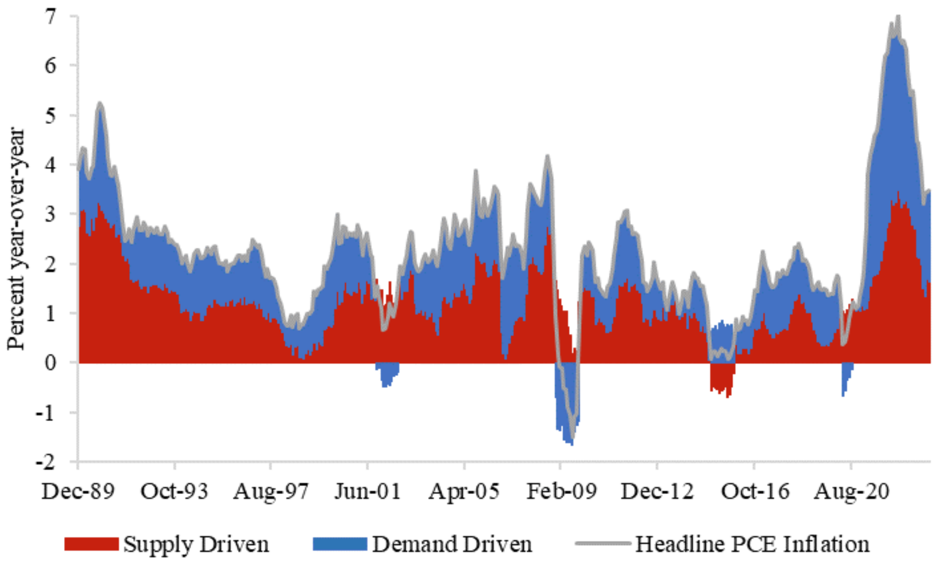
[2] The shock series have been smoothed using a 5-month centered moving average smoother.

shocks (positive and negative). The first difference of the price index is going to be the sum of supply driven contributions and demand driven contributions.

$$\pi_{t,t-1} = \sum_i Shock_{i,t}^{supply} \omega_{i,t} \pi_{i,t,t-1} + \sum_i Shock_{i,t}^{demand} \omega_{i,t} \pi_{i,t,t-1} \tag{15}$$

where $\pi_{t,t-1}$ is the monthly percent change in the PCE price index, $Shock_{i,t}^{supply}$ and $Shock_{i,t}^{demand}$ are the two new binary variables and $\pi_{i,t,t-1}$ is the monthly percent change in the PCE price index of category i. Weights were already defined. Year-over-year inflation will be the sum of current month inflation and inflation in the past eleven months.

Figure 2. Headline PCE Inflation Decomposition



It is straightforward that both supply and demand factors contribute to inflation. For the entire sample period (December 1989 to September 2023), the average supply driven contribution to PCE inflation is 45% and the average demand driven contribution is 55%. The results are consistent with those of (Shapiro 2022) and (Eickmeier and Hofmann 2023). If the sample is cut from 2020 onwards the averages change in favor of a higher contribution of supply driven inflation, because the period is highly influenced by the lockdowns, during which the demand contribution to inflation was negative.

This concludes the empirical section of the work. It was established that inflation is supply and demand driven and that the shares of supply shocks (both positive and negative) have been slightly higher than those of demand shocks when looking at the entire sample period.

3 One asset HANK

A one asset HANK is calibrated to match the US economy. The model closely follows the one presented in (Brinca, et al. 2023) and (Auclert, et al. 2021). Nominal rigidities are introduced by monopolistically competitive producers and the source of heterogeneity is in the different discount factors.

Preferences

Household's utility depends positively on consumption and negatively on the number of hours worked:

$$U(c,n) = \frac{c^{1-\sigma}}{1-\sigma} - \chi \frac{n^{1+\eta}}{1+\eta} \tag{16}$$

Households

Heterogeneity is present through the different discount factors $\beta_i \epsilon \{\beta_1, \beta_2, \beta_3\}$. Agents choose how much to consume, c, work, n, and save, b', in order to maximize the utility function, subject to the budget constraint. Since monopolistically competitive firms make positive profits at the stationary equilibrium, it is assumed that they are equally distributed across households in a lump-sum manner, d. The problem of the household can be written as:

$$V(b,\beta,u) \; = \; \max_{c,n,b'} \left\{ \frac{c^{(1-\sigma)}}{1-\sigma} - \chi \frac{n^{(1+\eta)}}{1+\eta} + \beta E_{u'} V(b',\beta,u) \right\} \tag{17}$$

$$c + b' \; = \; (1+r)b \; + \; (1-\tau_l)wnu + g + d \tag{18}$$

$$b' \geq b \tag{19}$$

where u is the idiosyncratic productivity shock which follows an AR (1) process such that:

$$u' = \rho u + \epsilon_t \qquad\qquad \epsilon_t \sim N(0, \sigma_u^2) \tag{20}$$

Firms

A competitive final goods firm aggregates a continuum of intermediate goods indexed by j with a constant elasticity of substitution $\frac{\mu}{(\mu-1)} > 1$. Intermediate goods are produced by monopolistically competitive firms with a linear production function (physical capital is excluded for computational purposes):

$$y_i = F(n_j) \equiv n_j \tag{21}$$

Each firm sets the price of its product ${p'}_j$ subject to quadratic adjustment costs, with κ moderating the extent of price rigidity. As $\kappa \to \infty$, we approach flexible prices:

$$\psi(p',p) = \frac{\mu}{\mu-1}\frac{1}{2\kappa}[log\,(p'/p)]^2\gamma \tag{22}$$

The firm's value function is given by:

$$V(p) = \max_{p'} \left\{ \frac{p'}{p} y - wy - \frac{\mu}{\mu-1}\frac{1}{2\kappa}[log(p'/p)]^2\gamma + E\left[\frac{V(p')}{1+r'}\right] \right\} \tag{23}$$

subject to

$$y = \left(\frac{p'}{p}\right)^{-\frac{\mu}{\mu-1}} \gamma \tag{24}$$

The FOC of the firm's problem plus the assumption that firms adopt symmetric pricing strategies give rise to a New Keynesian Phillips Curve that relates aggregate output to price inflation:

$$log(1+\pi) + \kappa\left(\frac{1}{\mu} - w\right) = E\left[\frac{1}{1+r'}\frac{\gamma'}{\gamma}log(1+\pi')\right] \tag{25}$$

Households receive dividends from the ownership of firms, and these equal output net of labor and price adjustment costs: $d = \gamma - wN - \psi$

Fiscal and monetary policies

Government debt is denominated in real terms. The government budget constraint is given by:

$$\tau_l wN + B = (1+r)B_{-1} + G + g \tag{26}$$

In balanced budget experiments, lump-sum transfers adjust to keep the real stock of debt constant.

The monetary authority sets the nominal interest rate following a standard Taylor Rule:

$$i = r^* + \phi_\pi \pi \tag{27}$$

where r^* is the real interest rate target, π is the inflation rate, and ϕ_π is the inflation Taylor Rule coefficient. For simplicity, the central bank's inflation target is zero (meaning inflation in the SS is zero and so the nominal and real rate targets coincide).

Equilibrium

1) Taking a sequence of factor prices and initial conditions as given, households maximize the value function $V(b,\beta,u)$ with respective policy functions being given by $c(b,\beta,u)$, $n(b,\beta,u)$, and $b'(b,\beta,u)$.
2) Firms optimally choose sequences of prices, production, and employment.
3) Fiscal and monetary authorities follow fiscal and interest rate rules.
4) Markets clear:

$$B = \int bd\Phi \tag{28}$$

$$N = \int n(b,\beta,u)\, ud\Phi \tag{29}$$

$$\gamma = \int c(b,\beta,u)d\Phi + G + \psi \tag{30}$$

4 Calibration

The model is calibrated to match the US economy. Some parameters are calibrated using a Simulated Method of Moments (SMM). The SMM is set to minimize the following loss function:

$$L(\beta_1,\beta_2,\beta_3,\underline{b},\chi,\sigma_u) = \|M_{model} - M_{data}\| \tag{31}$$

These six parameters are calibrated to match the three quartiles of the wealth distribution, the level of government debt, the aggregate fraction of hours worked, and the annual variance of log wages.

Table 1. Internally calibrated parameters, HANK model

Parameter	Value	Description
$\beta_1, \beta_2, \beta_3$	0.969, 0.9747, 0.9758	Discount factors
$\underline{b}$	-0.147	Borrowing limit
σ_u	0.437	Cross-sectional std of log earnings
χ	12.697	Disutility of labor

Table 2. Model fit, HANK model

Data moment	Description	Source	Data	Model
$\mathrm{Var}(\ln w)$	Yearly variance of log wages	LIS	0.509	0.509
$\bar{n}$	Fraction of hours worked	OECD	0.248	0.248
Q_{25}, Q_{50}, Q_{75}	Wealth quartiles	LWS	-0.014, 0.003, 0.130	-0.014, 0.004, 0.246
B/Y	Government debt	(Brinca, et al. 2023)	1.74	1.74

Preferences

The Frisch elasticity of labor supply is set to 1, a standard value in the literature, as in (Trabandt and Uhlig 2011). The coefficient of risk aversion is set to 1.2, also consistent with literature.

New Keynesian parameters

The degree of price rigidity is set to 0.1 and the elasticity of substitution between varieties is set to target a steady state markup of 20%, μ = 1.2. The central bank's sensitivity to deviations of inflation from its target is set to ϕ_π= 1.25. These parameters are similar to those in (Auclert, et al. 2021).

Government spending

Government spending is set to be 15% of GDP following (Hagedorn, Manovskii and Mitman 2019). Lump-sum transfers adjust to keep the real stock of debt constant.

5 Optimal monetary policy response to the inflation gap

Resorting to the decomposition of headline PCE inflation from section 2, the experiment feeds the model with two data series: quarterly indexes of output and quarterly changes to the price index for the period between 2020 and 2022. This yields 11 data points for prices and 11 data points for output.

The model solves for the series of discount factors and TFP that set the difference between model estimates and data equal to zero. The choice of discount factors and TFP is intended to mimic demand and supply shocks, respectively.

A decrease in the discount factors makes consumers more impatient and drives prices and output up. A decrease in TFP should work as a negative supply shock, restricting output and increasing prices.

The impulse response functions (IRF) of output and inflation show that both increase following the MIT shock in the first quarter of 2020.

Figure 3. IRF of output for 15 periods

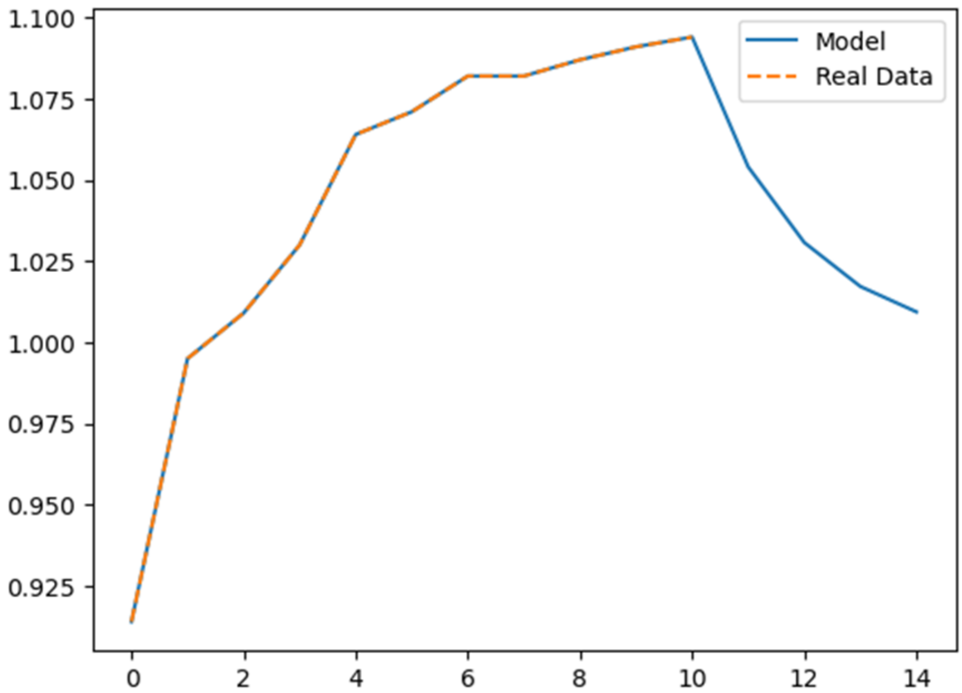
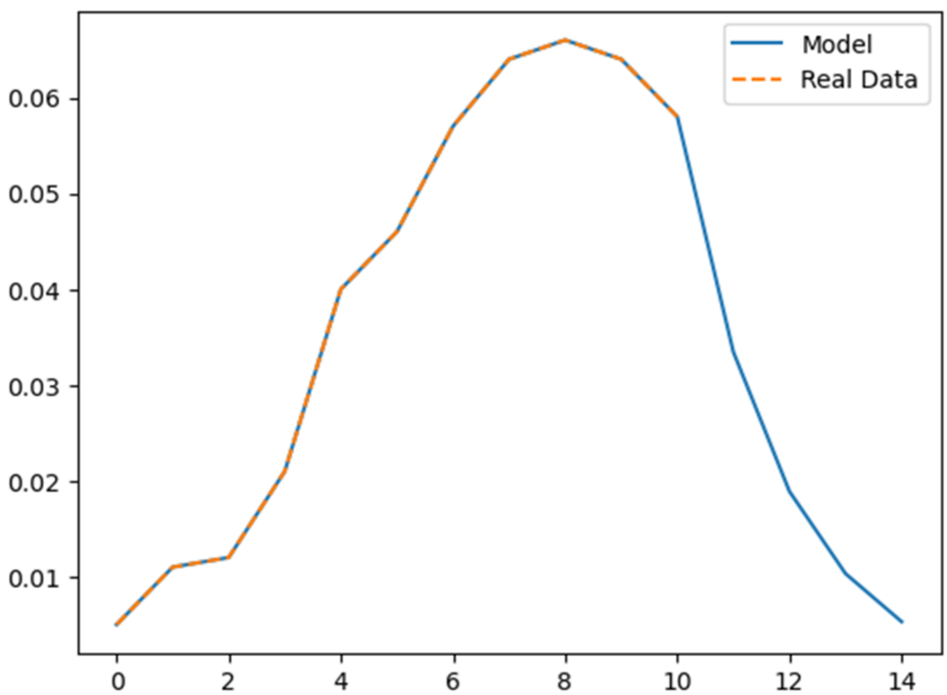


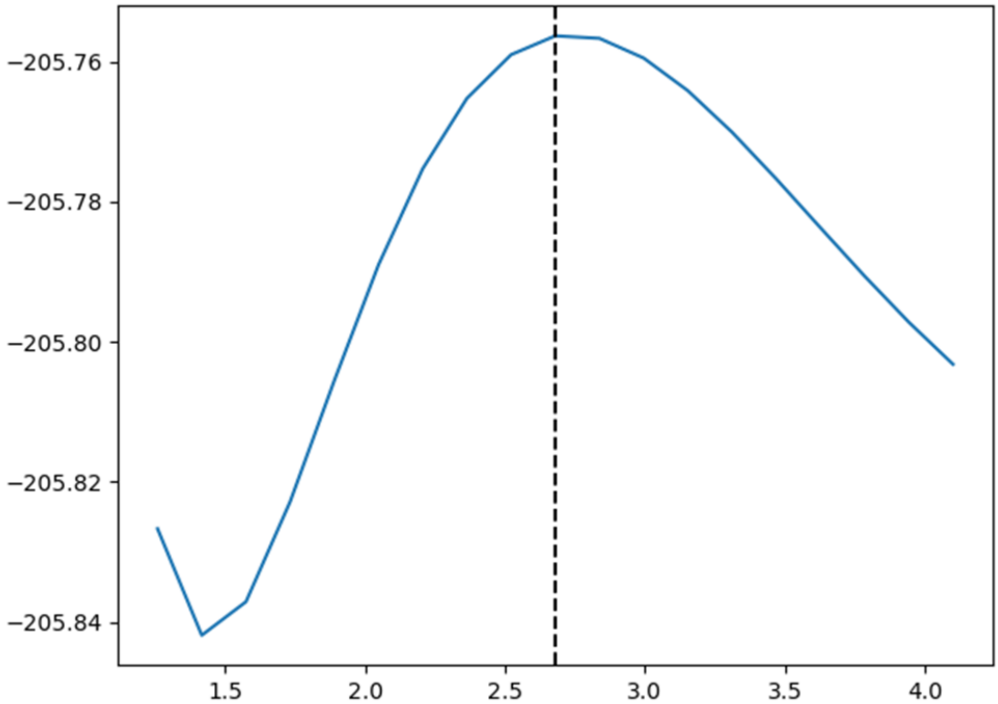
Figure 4. IRF of inflation for 15 periods



Now that we have IRFs that accurately capture the demand and supply dynamics uncovered in section 2 it is possible to find if the benchmark value of 1.25 for the inflation coefficient in the Taylor rule is welfare maximizing.

An optimal monetary policy response to the inflation gap is found using the Φ_π that maximizes the welfare function. Welfare is defined as the present value of utility using steady state discount factors. ϕ_π is restricted to be higher than 1 to guarantee a stable equilibrium, this is shown in (Bullard and Kaushik 2002) and (Blanchard and Khan 1980). The condition must be met for all the eigenvalues to fall within the unit circle. We therefore will exclude the value 1 from the analysis.

Figure 5. Optimal Monetary Policy response to the inflation gap



The coefficient for which the present value of aggregate utility is maximized is 2.7, calling for a tighter monetary policy compared to the steady state. We have found evidence in support of a tighter monetary policy response to the inflation gap by the Federal Reserve.

If you refer to the appendix, figure 6 shows the IRFs after the shock. The impact on TFP is initially negative. However, it does not take very long for it to shift and have an expansionary effect. Jointly with the growth in prices, the shock that hit US economy in the first quarter of 2021, was an example of a procyclical inflationary shock. It is, therefore expected that the response of monetary policy be very sensitive to changes in the inflation gap.

The results suggest that the relative gains in welfare from using the optimal response to inflation vs using the steady state rule are approximately 0.034%.

6 Conclusion

The period from December 1989 to September 2023 shows that both demand and supply contribute to headline PCE inflation, with a higher share of supply side shocks.

Feeding a one asset HANK model with price and output so that it solves for the sequences of discount factors and TFP that perfectly fit the data, uncovered an interesting finding. The steady state monetary policy coefficient, derived from the literature, is not welfare maximizing when applied in a scenario like the one for the US after 2020.

Since, a negative shock to TFP almost immediately shifts and there are gains in total factor productivity, the data for the US suggests a procyclical inflationary shock calling for a more aggressive response from the monetary authorities. This agrees with literature on optimal monetary responses to the inflation gap. ϕ_π should be as high as 2.7 and the relative gains in welfare from using the optimal monetary rule vs the steady state rule should amount up to 0.034%.

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Appendix

Table 3. Calibration one asset HANK

Parameter		Value
Households		
σ	Inverse IES	1.2
η	Inverse Frisch	1
ρ	Autocorrelation of earnings	0.966
Firms		
μ	Steady-state markup	1.2
k	Slope of Phillips curve	0.1
Policy		
G	Government spending	0.15
ϕ_π	Taylor rule coefficient on inflation	1.25

Figure 6. IRFs