Inflation Persistence and a new Phillips Curve*

Chek Choi Marcus Hagedorn Juan Llavador Kurt Mitman

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Abstract

Inflation exhibits substantial persistence in the data, yet the standard New Keynesian Phillips Curve (NKPC) fails to generate this persistence without resorting to ad-hoc assumptions like inflation indexation. This paper demonstrates that menu-cost models with state-dependent pricing naturally produce inflation persistence consistent with empirical evidence. The key insight is that menu-cost models feature both intensive and extensive margins of price adjustment. In response to shocks to the growth rate of nominal demand, the intensive margin generates the standard marginal cost channel as in the NKPC, whereas the extensive margin generates history dependence that is captured by the lagged inflation rate. Using a calibrated menu-cost model with idiosyncratic productivity and stochastic adjustment costs, we show that when nominal demand growth is autocorrelated (as in the data), firms optimally delay price adjustments, generating history-dependent inflation dynamics. In Phillips Curve regressions, lagged inflation exhibits a coefficient of 0.50 when controlling for expected marginal costs alone—consistent with empirical estimates. However, this coefficient drops to 0.05 when we include lagged nominal demand growth, revealing that the persistence primarily stems from the extensive margin channel. Our findings suggest that inflation persistence emerges endogenously from firms' optimal price-setting behavior under menu costs, without invoking the Lucas critique concerns associated with mechanical indexation assumptions.

Keywords: Phillips Curve, Menu cost, State Dependent Pricing, Monetary Economics

*Choi: Institute for International Economic Studies, Stockholm University. Email:chek-yin.choi@iies.su.se. Hagedorn: University of Oslo, Department of Economics. Llavador: Institute for International Economic Studies, Stockholm University. Email: juan.llavadorperalt@iies.su.se. Mitman: IIES, CEMFI, CEPR, IZA. Email: kurt.mitman@iies.su.se.

1 Introduction

The dynamics of inflation lie at the heart of monetary economics and policy design. Central banks worldwide base their decisions on models of how inflation responds to economic conditions, making the accurate characterization of inflation persistence crucial for policy effectiveness. The recent post-COVID inflation surge and subsequent debate between "team transitory" and "team permanent" has underscored how different views about inflation persistence can lead to dramatically different policy prescriptions. Yet despite decades of research, a fundamental puzzle remains: while inflation exhibits substantial persistence in the data, our workhorse model—the New Keynesian Phillips Curve—cannot generate this persistence from its microfoundations.

The New Keynesian Phillips Curve, derived from Calvo (1983) pricing frictions, posits that current inflation depends on current and expected future real marginal costs. This elegant relationship, while theoretically appealing, suffers from a critical empirical failure: it is purely forward-looking. Past inflation rates and past economic conditions have no direct effect on current inflation once we control for current and future marginal costs. As a result, inflation in the NKPC inherits its persistence solely from the persistence of real marginal costs. Given that empirical estimates consistently find inflation persistence well beyond what marginal cost persistence can explain (Fuhrer, 2010), and that recent evidence suggests an increasingly flat Phillips Curve with inflation largely decoupled from real activity (Hazell et al., 2022), the model's ability to match inflation dynamics appears fundamentally limited.

The literature has responded to this shortcoming primarily through ad-hoc fixes. The most common approach, pioneered by Christiano et al. (2005), assumes that firms mechanically index their prices to past inflation when unable to optimize. While this generates the desired persistence, it does so at significant cost: the indexation assumption lacks microeconomic foundation, makes welfare analysis problematic, and falls prey to the Lucas critique. As inflation dynamics are precisely what monetary policy seeks to influence, assuming a mechanical backward-looking component undermines the model's usefulness for policy analysis.

This paper demonstrates that menu-cost models naturally generate inflation persistence without resorting to ad-hoc assumptions. The crucial difference from Calvo pricing is that menu-cost models feature state-dependent rather than time-dependent price adjustment. This creates both an intensive margin (how much firms adjust prices) and an extensive margin (whether and when firms adjust prices). We show that the extensive margin, which captures firms' endogenous timing decisions, fundamentally alters the Phillips Curve relationship. It captures both the change in the overall probability of price adjustment and the changes in the probability to increase or decrease the price, respectively (Caballero and Engel, 2007).[1]

[1]This definition differs from the definition in Klenow and Kryvtsov (2008); Midrigan (2011) who restrict the extensive margin to changes in the overall price adjustment probability.

Importantly, when nominal demand growth is autocorrelated—as it is in the data (Nakamura and Steinsson, 2010)—this generates endogenous inflation persistence. Following a demand shock, forward-looking firms recognize that current demand changes signal future changes in the same direction. In a menu-cost model, firms can optimally delay adjustment since they retain the option to adjust at any future date by paying the fixed cost. This "wait-and-see" behavior, first emphasized by Midrigan (2006), breaks the extreme front-loading of inflation responses that characterizes the NKPC. An initial demand decrease leads to a small inflation decline, followed by larger declines as more firms find it optimal to adjust—creating the autocorrelation in inflation that we observe in the data.

We formalize this intuition using a quantitative menu-cost model calibrated to match micro-price facts. The model features heterogeneous firms facing idiosyncratic productivity shocks and stochastic price adjustment costs, following Midrigan (2011). We first establish that our calibration successfully replicates key moments of the price change distribution and the behavior of both intensive and extensive margins documented by Alvarez et al. (2019). Our main results come from estimating Phillips Curve regressions on model-simulated data. When we estimate the standard NKPC specification—regressing inflation on expected discounted marginal costs and lagged inflation—we find a coefficient of 0.50 on lagged inflation, squarely within the range of empirical estimates. This demonstrates that menu-cost models can generate substantial inflation persistence even when controlling for the marginal cost channel. However, when we add lagged nominal demand growth to this regression, the coefficient on lagged inflation drops to 0.05, while nominal demand growth exhibits a large and significant coefficient. This reveals that the apparent inflation persistence in the NKPC specification actually reflects omitted variable bias: lagged inflation proxies for the history-dependence created by the extensive margin, but this information is better captured by nominal demand growth itself.

We verify the robustness of these findings across multiple specifications. Following the instrumental variables approach of Hazell et al. (2022), we continue to find that nominal demand growth drives out the significance of lagged inflation. Similarly, when estimating hybrid Phillips Curves à la Gali and Gertler (1999), the same pattern emerges. The consistency across specifications reinforces our main message: menu-cost models generate inflation persistence through the extensive margin channel, not through mechanical backward-looking behavior.

Our findings relate to but differ from recent work by Auclert et al. (2024) (henceforth, ARRS), who show that menu-cost models can be approximated by a single-equation Phillips Curve under certain conditions. While they focus on permanent level shocks to nominal demand, we emphasize that autocorrelated growth shocks—the empirically relevant case—fundamentally change the inflation dynamics. The persistence of demand growth gives firms stronger incentives to delay price adjustment, breaking the front-loading that would otherwise make menu-cost models observationally similar to the NKPC.

The rest of the paper is structured as follows. Section 2 presents our menu-cost model with idiosyncratic productivity and idiosyncratic fixed adjustment costs. Section 3 presents the calibration and computational strategy. The computational method is laid out in Section 3.2 and builds on the sequence-space method developed by Boppart et al. (2018) and extended in Auclert et al. (2021). Section 3.1 follows the calibration strategy in Midrigan (2011) and establishes the good model fits including key moments of the price distribution and the observed behavior of the intensive and the extensive margin (Alvarez et al., 2019). Our results are presented in Section 4. Finally, section 5 concludes.

2 Model

We describe a state-dependent pricing model with idiosyncratic productivity shocks and stochastic price adjustment costs. Our main focus is on the firm side to understand how exogenous aggregate nominal demand translates into inflation. The firm model is therefore quite detailed whereas the household model is kept quite simple. The main purpose of including the household sector is to endogenously derive flexible wages which equal marginal costs and to obtain the demand schedule which firms take as given. We first describe the household sector before describing the firm side.

2.1 Households

We assume a representative household with preferences over consumption $\{c_t\}_{t=0}^{\infty}$ and hours $\{h_t\}_{t=0}^{\infty}$,

$$\sum_{t=0}^{\infty} \beta^t u(C_t, h_t) \tag{1}$$

Households consume differentiated goods $c_t(i)$ at a price $p_t(i)$ indexed by $i \in [0,1]$. The composite consumption C_t is assumed to be a Dixit-Stiglitz aggregator of differentiated goods $c_t(i)$,

$$C_t = \Big[\int_0^1 c_t(i)^{\frac{\epsilon-1}{\epsilon}} \Big]^{\frac{\epsilon}{\epsilon-1}}. \tag{2}$$

Each period the household chooses $c_t(i)$ at a price $p_t(i)$ to maximize utility (1) subject to the budget constraint

$$\int_0^1 p_t(i)c_t(i)di \leq W_t l_t + \Pi_t, \tag{3}$$

where Π_t is distributed profits and W_t is the nominal wage.

This requires that household demand for each good i is

$$c_t(i) = \Big(\frac{p_t(i)}{P_t}\Big)^{-\epsilon}\frac{D_t}{P_t},$$

where

$$P_t = \Big[\int_0^1 p_t(i)^{1-\epsilon}\Big]^{\frac{1}{1-\epsilon}} \tag{4}$$

is the price index and total nominal expenditures satisfies

$$P_tC_t = \int_0^1 p_t(i)c_t(i)di, \tag{5}$$

Households' hours choice h_t satisfies

$$\frac{W_t}{P_t} = \frac{u_h(c_t,h_t)}{u_c(c_t,h_t)}.$$

2.2 Firms

There is a measure one of firms indexed by $i \in [0,1]$ producing differentiated goods. Firm i hires labor $n_t(i,z)$ to produce output with idiosyncratic productivity z_{it} and aggregate productivity Z_t,

$$y_t(i,z) = z_{it}Z_tn_t(i,z).$$

A firm $i \in [0,1]$ with price $p_t(i)$ faces demand

$$y(p_t(i),P_t,D_t) := \Big(\frac{p_t(i)}{P_t}\Big)^{-\epsilon}\frac{D_t}{P_t},$$

taking aggregate nominal demand D_t and the price level P_t as given. The nominal cost of producing $y_t(i)$ units of real output is

$$P_tmc(\frac{D_t}{P_t})\frac{y_t(i)}{z_{it}},$$

where $mc_t = MC(\frac{D_t}{P_t})$ is real marginal costs, which depends on real aggregate demand D_t/P_t and are thus common to all firms. Since labor is the only input into production, real marginal cost equals the real wage,

$$MC(\frac{D_t}{P_t},Z_t) = \frac{W_t}{P_t}\frac{1}{Z_t} = \frac{-u_h(C_t,h_t)}{u_c(C_t,h_t)}\frac{1}{Z_t} = \frac{-u_h(\frac{D_t}{P_t},\frac{D_t}{P_t}\frac{1}{Z_t})}{u_c(\frac{D_t}{P_t},\frac{D_t}{P_t}\frac{1}{Z_t})}\frac{1}{Z_t},$$

where $\frac{W_t}{P_t}$ is the hourly wage to produce Z_t units of output and taking into account that in equilibrium $C_t = \frac{D_t}{P_t}$ and $h_t = \frac{D_t}{P_t}\frac{1}{Z_t}$. In quantitative analysis we assume that

$$u(c_t, h_t) = \frac{c_t^{1-\sigma}}{1-\sigma} - \frac{h_t^{1+\varphi}}{1+\varphi},$$

and thus obtain for marginal costs,

$$MC(\frac{D_t}{P_t}, Z_t) = \frac{(\frac{D_t}{P_t}\frac{1}{Z_t})^{\varphi}}{\frac{D_t}{P_t}^{-\sigma}}\frac{1}{Z_t} = (\frac{D_t}{P_t})^{\varphi+\sigma}(\frac{1}{Z_t})^{1+\varphi}$$

Disutility of labor depends on own output

$$MC(y_{ti}, \frac{D_t}{P_t}, Z_t) = \frac{((\frac{p_t(i)}{P_t})^{-\epsilon}\frac{D_t}{P_t}\frac{1}{z_{ti}Z_t})^{\varphi}}{\frac{D_t}{P_t}^{-\sigma}}\frac{1}{z_{ti}Z_t} = (\frac{D_t}{P_t})^{\varphi+\sigma}(\frac{1}{z_{ti}Z_t})^{1+\varphi}(\frac{p_t(i)}{P_t})^{-\epsilon\varphi}$$

We set out to rewrite real profits as a function of real variables. A firm's state is its (nominal) price p, its productivity z, aggregate nominal demand D, and the aggregate price level P. Lower-case variables denote firm-specific variables, upper-case denote aggregate variables.

The period t nominal profit of the firm is given by

$$\Pi(p_t, z_t, P_t, D_t, Z_t) = \left(\frac{p_t}{P_t}\right)^{1-\epsilon} D_t - MC\left(\frac{D_t}{P_t Z_t}\right)\left(\frac{p_t}{P_t}\right)^{-\epsilon}\frac{D_t}{z_t Z_t}.$$

and real profits are given by

$$\frac{\Pi(p_t, P_t, D_t, Z_t)}{P_t} = \left(\frac{p_t}{P_t} - MC\left(\frac{D_t}{P_t Z_t}\right)\frac{1}{z_t Z_t}\right)\left(\frac{p_t}{P_t}\right)^{-\epsilon}\frac{D_t}{P_t}.$$

Define the firm-specific markup by $\mu_t = \frac{p_t/P_t}{MC(D_t/(P_t Z_t))/(z_t Z_t)}$. We can the rewrite real profits as

$$\frac{\Pi(\mu_t, z_t, D_t/P_t, Z_t)}{P_t} = \underbrace{(\mu_t - 1)\,\mu_t^{-\epsilon} z_t^{\epsilon-1}}_{\text{idiosyncratic}} \times \underbrace{\left(MC\left(\frac{D_t}{P_t Z_t}\right)\right)^{1-\epsilon}\frac{D_t}{P_t}Z_t^{\epsilon-1}}_{\text{aggregate}}.$$

We postulate that the firm can change its price (prior to production) if paying a fixed cost $z_t^{\epsilon-1}\varepsilon_t$ where ε_t is an idiosyncratic shock drawn each period. We write the firm problem recursively. Productivity is evolving according to a random walk in logs, $z_{t+1} = \eta_{t+1} z_t$.

The recursive formulation of the risk-neutral profit-maximizing firm's problem, under a perfect-foresight path for aggregate variables, is described by

$$
\begin{aligned}
V_t^{noadj}(\mu, z) &= (\mu - 1)\mu^{-\epsilon} z^{\epsilon-1} \times (MC_t)^{1-\epsilon} \frac{D_t}{P_t} Z_t^{\epsilon-1} + \beta \mathbb{E} V_{t+1}(\mu', z') \\
&\quad \text{s.t. } z' = \eta' z \\
&\qquad\quad \mu' = \eta' \frac{P_t}{P_{t+1}} \frac{MC_t}{MC_{t+1}} \frac{Z_{t+1}}{Z_t} \mu \\
V_t^{adj}(\mu, z|\varepsilon) &= \max_{\mu^*} (\mu^* - 1)(\mu^*)^{-\epsilon} z^{\epsilon-1} \times (MC_t)^{1-\epsilon} \frac{D_t}{P_t} Z_t^{\epsilon-1} - z^{\epsilon-1}\varepsilon + \beta \mathbb{E} V_{t+1}(\mu', z') \\
&\quad \text{s.t. } z' = \eta' z \\
&\qquad\quad \mu' = \eta' \frac{P_t}{P_{t+1}} \frac{MC_t}{MC_{t+1}} \frac{Z_{t+1}}{Z_t} \mu^* \\
V_t(\mu, z|\varepsilon) &= \max\{V_t^{noadj}(\mu, z), V_t^{adj}(\mu, z|\varepsilon)\} \\
V_t(\mu, z) &= \mathbb{E}_\varepsilon \left[V_t(\mu, z|\varepsilon)\right]
\end{aligned}
$$

Since the problem is homothetic in z, we can eliminate z as a state variable. We guess and verify that all value functions satisfy $V(\mu, z) = v(\mu) z^{\epsilon-1}$:

$$
\begin{aligned}
v_t^{noadj}(\mu) &= (\mu - 1)\mu^{-\epsilon} \times (MC_t)^{1-\epsilon} \frac{D_t}{P_t} Z_t^{\epsilon-1} + \\
&\qquad \beta \mathbb{E} \left[(\eta')^{\epsilon-1} v_{t+1} \left(\eta' \frac{P_t}{P_{t+1}} \frac{MC_t}{MC_{t+1}} \frac{Z_{t+1}}{Z_t} \mu \right) \right] \\
v_t^{adj}(\mu|\varepsilon) &= \max_{\mu^*} (\mu^* - 1)(\mu^*)^{-\epsilon} \times (MC_t)^{1-\epsilon} \frac{D_t}{P_t} Z_t^{\epsilon-1} - \varepsilon \\
&\qquad + \beta \mathbb{E} \left[(\eta')^{\epsilon-1} v_{t+1} \left(\eta' \frac{P_t}{P_{t+1}} \frac{MC_t}{MC_{t+1}} \frac{Z_{t+1}}{Z_t} \mu^* \right) \right] \\
v_t(\mu|\varepsilon) &= \max\{v_t^{noadj}(\mu), v_t^{adj}(\mu|\varepsilon)\} \\
v_t(\mu) &= \mathbb{E}_\varepsilon \left[v_t(\mu|\varepsilon)\right]
\end{aligned}
$$

2.3 Equilibrium

As in Midrigan (2011) we assume that nominal spending equals exogenous nominal demand D_t,

$$
D_t = P_t C_t = \int_0^1 p_t(i) c_t(i) di
$$

The aggregate price level, through the Dixit-Stiglitz aggregator, is given by

$$
\begin{aligned}
P_t = \left(\int p_{it}^{1-\epsilon} di \right)^{1/(1-\epsilon)} &= \left(\int \left(\mu_{it} P_t MC_t / (z_t Z_t)\right)^{1-\epsilon} di \right)^{1/(1-\epsilon)} = \\
&\qquad \left(\int \mu_{it}^{1-\epsilon} z_{it}^{\epsilon-1} \right)^{1/(1-\epsilon)} \frac{P_t MC_t}{Z_t}
\end{aligned}
$$

so we get the equilibrium condition that real marginal cost times the economy-wide markup equals one,

$$1 = \left(\int \mu_{it}^{1-\epsilon} z_{it}^{\epsilon-1} di \right)^{1/(1-\epsilon)} \frac{MC_t}{Z_t}. \tag{6}$$

Equivalently, aggregation of quantities yields the equilibrium condition

$$\left(\int p_t(i)^{1-\epsilon} di \right)^{1/(\epsilon-1)} = P_t$$

since it is equivalent to the equilibrium conditions that supply, Y_t, equals demand, D_t/P_t,

$$D_t/P_t = Y_t = \left(\int y_t(i)^{(\epsilon-1)/\epsilon} di \right)^{\epsilon/(\epsilon-1)} = \left(\int \left(p_t(i)^{-\epsilon} P_t^{\epsilon-1} D_t \right)^{(\epsilon-1)/\epsilon} di \right)^{\epsilon/(\epsilon-1)} =$$
$$= \left(\int p_t(i)^{1-\epsilon} di \right)^{\epsilon/(\epsilon-1)} P_t^{\epsilon-1} D_t.$$

3 Computation and Calibration

3.1 Calibration

The calibration strategy follows Midrigan (2011). The model period is a week. We choose the idiosyncratic firm productivity shock and stochastic (exponential) adjustment cost parameters to match key steady state targets: the frequency of (regular) weekly price changes, 2.9%, and the distribution of the size of (regular) price changes. We use the same targets as in Midrigan (2011): the mean size of regular price changes is 11%, 10% of prices changes are less than 3 percent, 25% of prices changes are less than 5 percent, 50% of price changes are less than 9 percent, 75% of price changes are less than 13 percent and 90% of prices changes are less than 21 percent. Figure 1 shows these 5 data moments (blue dots) and the distribution of prices changes in our calibrated model, confirming that we are able to match all five data targets. Figure 1 also shows that the distribution of prices has no mass points. We choose $\sigma = 1$ to be balanced-growth path consistent so that we can also consider permanent aggregate technology shocks. We set $\varphi = 1$ consistent with a Frisch elasticity of 0.5.

Following Alvarez et al. (2019) inflation satisfies the accounting identity

$$1 + \pi = \lambda^+ \Delta^+ - \lambda^- \Delta^-,$$

where λ^+ is the frequency of price increases, λ^- is the frequency of price decreases, Δ^+ is the average size of price increases and Δ^- is the average size of price decreases. Total differentiation inflation with respect to demand D_t delivers a decomposition into an extensive and an intensive

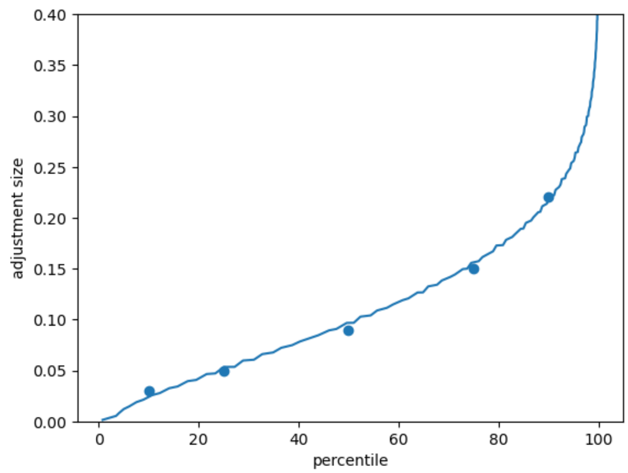

Figure 1: Distribution of prices changes in the model (line) and in the data (5 dots)

margin,

$$\frac{\partial \Delta 1+\pi_t}{\partial \Delta D_t} = \underbrace{\frac{\partial \lambda^+}{\partial \Delta D_t}\Delta^+ - \frac{\partial \lambda^-}{\partial \Delta D_t}\Delta^-}_{\text{Extensive Margin}} + \underbrace{\lambda^+\frac{\partial \Delta^+}{\partial \Delta D_t} - \lambda^-\frac{\partial \Delta^-}{\partial \Delta D_t}\Delta^-}_{\text{Intensive Margin}}.$$

The extensive margin is positive since $\frac{\partial \lambda^+}{\partial \Delta D_t} > 0$, $\frac{\partial \lambda^-}{\partial \Delta D_t} < 0$, $\Delta^+ > 0$ and $\Delta^- < 0$. Defining λ as the overall frequency of price changes, the extensive margin can be further decomposed into the selection effect and changes in the total frequency of price changes,

$$\frac{\partial \lambda^+}{\partial \Delta D_t}\Delta^+ - \frac{\partial \lambda^-}{\partial \Delta D_t}\Delta^- = \underbrace{\frac{\partial (\lambda^+-\lambda)}{\partial \Delta D_t}\Delta^+ - \frac{\partial (\lambda^- - \lambda)}{\partial \Delta D_t}\Delta^-}_{\text{Selection}} + \underbrace{\frac{\partial \lambda}{\partial \Delta D_t}(\Delta^+ - \Delta^-)}_{\text{Total Frequency}}$$

By the same arguments as above, the selection effect is positive. In response to an increase in nominal demand growth, the probability to increase the price, λ^+ increases where the probability to decrease the price, λ^- increases. The selection effect is thus positive even if the overall frequency of price changes is constant, $\frac{\partial \lambda}{\partial \Delta D_t} = 0$.

In general both components of the extensive margin are positive, although certain assumption imply $\frac{\partial \lambda}{\partial \Delta D_t} = 0$ for small changes in demand (Alvarez et al., 2019). In particular, both components are positive in response to large shocks as non-linear effects kick in.

$$\begin{aligned}
\frac{\partial \Delta 1+\pi_t}{\partial \Delta D_t} &= \frac{\partial (\lambda^+-\lambda)}{\partial \Delta D_t}\Delta^+ - \frac{\partial (\lambda^- - \lambda)}{\partial \Delta D_t}\Delta^- + \frac{\partial \lambda}{\partial \Delta D_t}(\Delta^+ - \Delta^-) + \lambda^+\frac{\partial \Delta^+}{\partial \Delta D_t} - \lambda^-\frac{\partial \Delta^-}{\partial \Delta D_t}\Delta^- && \textbf{Linear} \\
&+ \frac{\partial^2 (\lambda^+-\lambda)}{\partial^2 \Delta D_t}\Delta^+ + \frac{\partial^2 \lambda}{\partial^2 \Delta D_t}\Delta^+ + 2\frac{\partial^2 \lambda^+}{\partial^2 \Delta D_t}\frac{\partial \Delta^+}{\partial \Delta D_t} + \lambda^+\frac{\partial^2 \Delta^+}{\partial^2 \Delta D_t} && \textbf{Second Order (+)} \\
&- \frac{\partial^2 (\lambda^- -\lambda)}{\partial^2 \Delta D_t}\Delta^- - \frac{\partial^2 \lambda}{\partial^2 \Delta D_t}\Delta^- - 2\frac{\partial^2 \lambda^-}{\partial^2 \Delta D_t}\frac{\partial \Delta^-}{\partial \Delta D_t} + \lambda^-\frac{\partial^2 \Delta^-}{\partial^2 \Delta D_t} && \textbf{Second Order (-)} \\
&+ \dots && \textbf{ThirdOrder},
\end{aligned}$$

where the second derivative of the total frequency of price changes, $\frac{\partial^2 \lambda}{\partial^2 \Delta D_t}$, is positive.

Comparing the steady-state properties of the intensive and extensive margins to empirical results in Alvarez et al. (2019) shows that our calibrated model captures both margins well. Concretely, we conduct this experiment: Increase steady-state growth rate of nominal demand to increase the steady-state inflation rate while keeping all other parameters unchanged. Figures 2 shows the size of price increases Δ^+ and size of price decreases Δ^- as a function of the annual inflation rate in the data and in the model. Figures 3 shows the monthly frequency of prices increases λ^+, prices decreases λ^- and of all price changes, $\lambda^+ + \lambda^-$ as a function of the annual inflation rate in the data and in the model. Figures 3 shows the extensive margin, the selection effect $\lambda^+ - \lambda^-$ and the total frequency, $\lambda^+ + \lambda^-$. The Figures lead to the conclusion that the model replicates the data well.

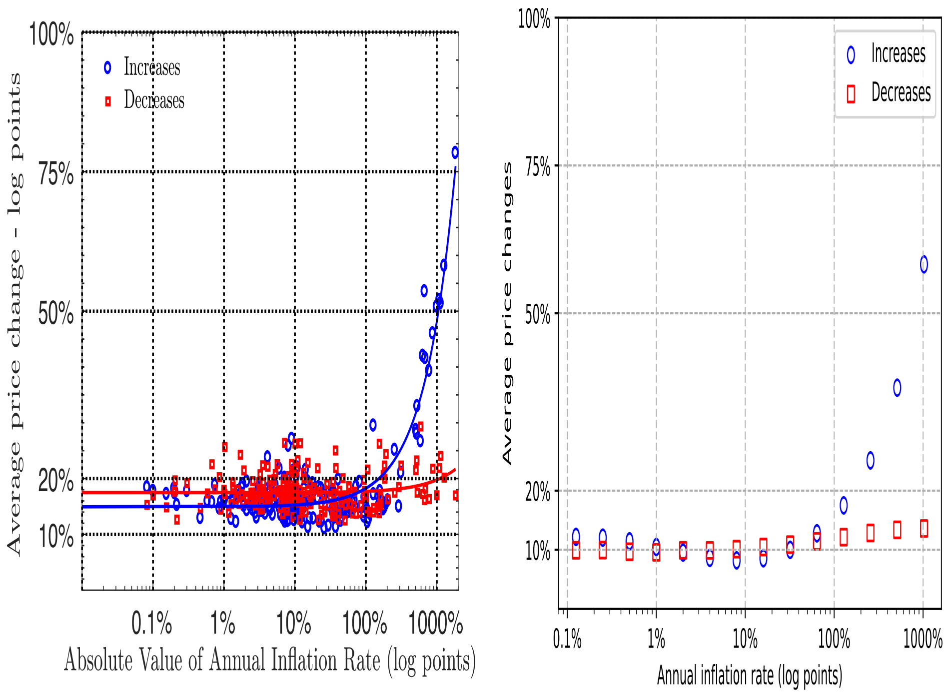

Figure 2: Intensive margin in the data and the model: Size of price increases Δ^+ and size of price decreases Δ^-. Left panel: data. Right panel: model

3.2 Computation Method

We solve the model using standard methods. We solve for the firm price setting problem using dynamic programming. In order to solve for the steady state, we discretize the state space and simulation the idiosyncratic shocks via non-stochastic simulation following Young (2010). To deal with the random walk shocks for productivity, we divide through by idiosyncratic productivity and express the cross-sectional distributions in terms of mark-up gaps (current markup relative to desired markup). To compute aggregate statistics, we then integrate this

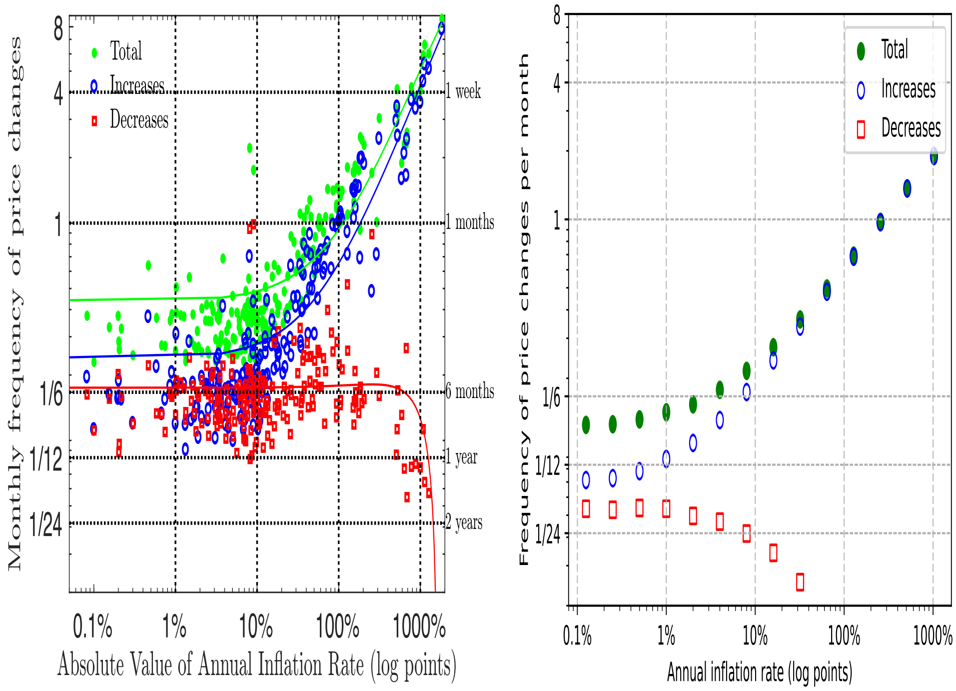

Figure 3: Monthly Frequency of prices changes: Increases λ^+, Decreases λ^- and total $\lambda^+ + \lambda^-$. Left panel: data. Right panel: model

distribution based on the permanent productivity neutral measure, following the method of Harmenberg (2023).

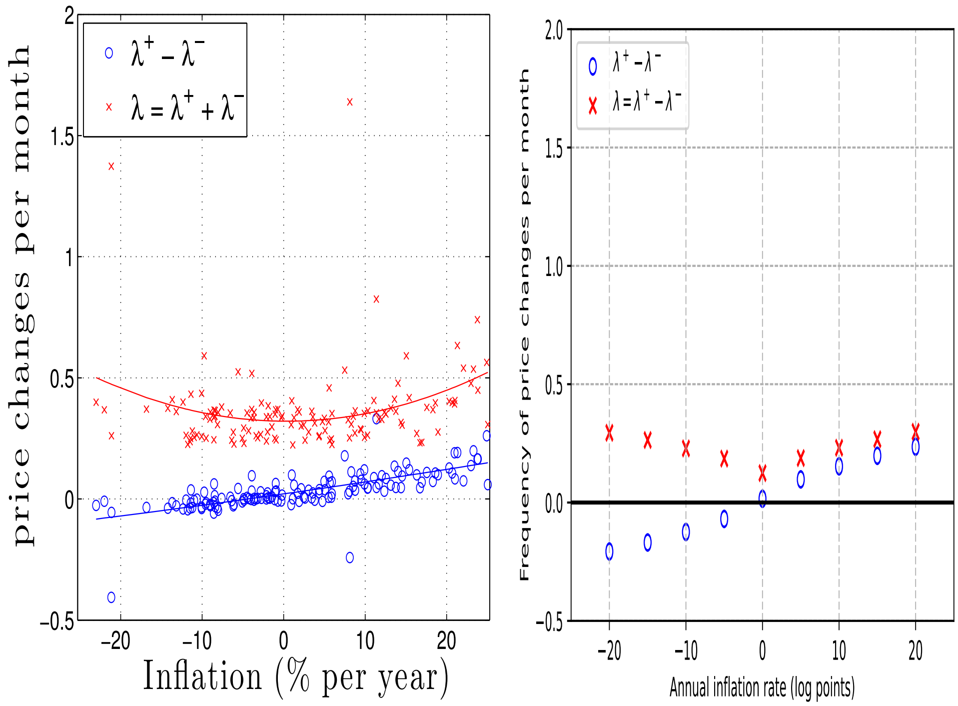

Figure 4: Extensive margin in the data and the model: Selection $\lambda^+ - \lambda^-$ and Total Frequency $\lambda^+ + \lambda^-$

4 Results

This Section presents our main results on the response of the calibrated model to shocks to nominal demand growth ΔD_t. We linearize model with small MIT-shocks in sequence space (Boppart et al., 2018; Auclert et al., 2021). We assume that the weekly process for nominal demand growth is autocorrelated,

$$\Delta D_t = \rho_D^w \Delta D_{t-1} + \epsilon_t^D,$$

where $\rho_D^w = 0.95$ matches the autocorrelation of nominal demand at the quarterly frequency of $\rho_D = 0.5$ (Nakamura and Steinsson, 2010; Midrigan, 2011) To explain our results and to relate to Auclert et al. (2024) we also consider permanent level shocks ($\rho_D^w = 0$). We simulate the economy to obtain weekly model generated data as in Midrigan (2011) and implement quarterly Phillips curve regressions consistent with frequency typically found in empirical studies. Before showing the Phillip curve regressions, we first present impulse responses of inflation and its driving forces so as to explain the model mechanisms.

4.1 Impulse Responses

We first show the weekly impulse responses to a negative demand shock $\epsilon_t < 0$ of inflation pi_t, marginal costs mc_t and the discounted sum of marginal costs, $\sum_{k=0}^{T} mc_{t+k}$ in Figure 5. The left panel shows the three variables when the first element is normalized to -1 and the right panel shows the best (affine-)linear fit of mc_t and $\sum_{k=0}^{T} mc_{t+k}$ to the inflation rate. It is evident that neither marginal costs nor the discounted sum of marginal costs can fully explain the inflation rate. This is equivalent to an R^2 lower than in the regressions underlying the right panel and assigns a role for the lagged inflation rate. Indeed the regression

$$\pi_t = c_0 + \kappa mc_t + \gamma \pi_{t-1} \tag{7}$$

delivers a coefficient $\alpha^\pi = 0.7828$ on lagged inflation. Likewise, the regression

$$\pi_t = c_0 + \kappa E_t \sum_{k=0}^{T} mc_{t+k} + \gamma \pi_{t-1} \tag{8}$$

yields a coefficient $\alpha^\pi = 0.2907$.[2]

The shape of the impulse responses are consistent with the regression results. The inflation rate response is U-shaped whereas the response of $\sum mc$ shows the front-loading properties known from New Keynesian Phillips Curves. The strongest response is observed on impact and then gradually dies out. Clearly, a front-loaded curve cannot perfectly fit a U-shaped curve.

[2]This regression uses the correct model expectations, rendering $E_t \sum_{k=0}^{T} mc_{t+k}$ a Period t variable which can be included in the regression.

The reason for the U-shape is the muted front-loading in menu-cost models as emphasized in Midrigan (2006). Firms can delay the price adjustment since they know that prices can always be adjusted at a fixed cost. The incentive to delay is strengthened if the growth rates of demand are autocorrelated. Firms are then less inclined to adjust their prices immediately at the time of the initial shock since they know that demand will further decrease in the future. It can then be profitable to wait and adjust the price later. In terms of inflation persistence, this means that an initial decrease in inflation is followed by a larger decrease in the next period, implying autocorrelation in inflation rates not captured by mc or $\sum mc$. Figure 6 replicates the same exercise but for $\rho_D = 0$, showing that this conclusion depends on the autocorrelation in nominal growth rates. The left panel again shows the three variables when the first element is normalized to -1 and the right panel shows the best (affine-)linear fit of mc_t and $\sum_{k=0}^{T} mc_{t+k}$ to the inflation rate. Now, the three curves, π, mc and $\sum mc$ are almost on top of each other. Correspondingly, the regression (7) for mc and regression (8) for $\sum mc$ deliver smaller coefficients on lagged inflation, $\alpha^\pi = 0.127$ for mc and $\alpha^\pi = 0.065$ for $\sum mc$. The permanent shock in contrast to the autocorrelated growth shock does not induce incentives to delay price adjustments so that the impulse response has the same front-loading shape as the NKPC. Auclert et al. (2024) reach the same conclusion for the same permanent level shock, establishing that the difference in results is due to our autocorrelated growth rate shocks which break the extreme front-loading in the NKPC.

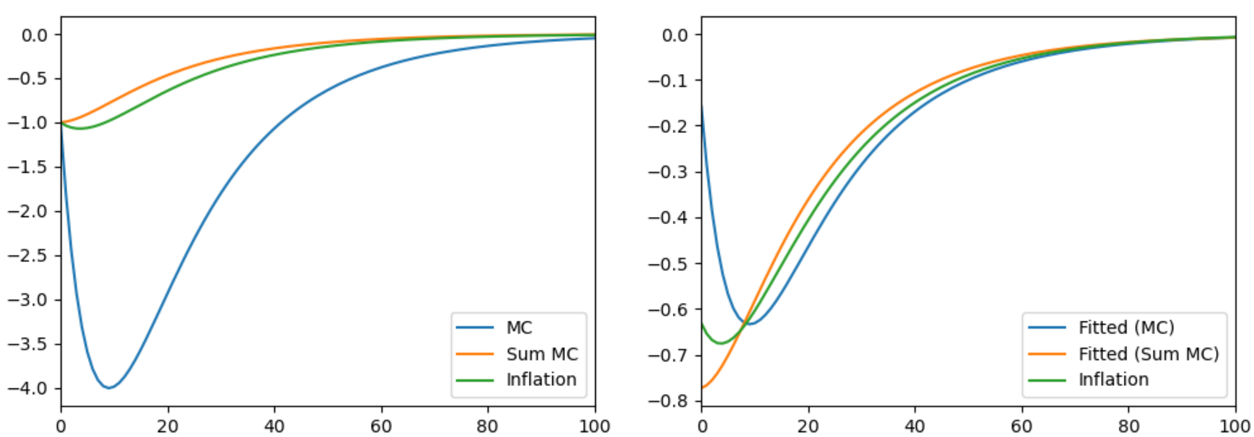

Figure 5: Weekly IRFs $\rho_D = 0.5$

Recall that λ^+ is the frequency of price increases, λ^- is the frequency of price decreases, Δ^+ is the average size of price increases and Δ^- is the average size of price decreases. Note that that both Δ^+ and Δ^- are positive numbers. A subscript ss means the steady-state value and a superscript t means time (since shocks in the IRF)

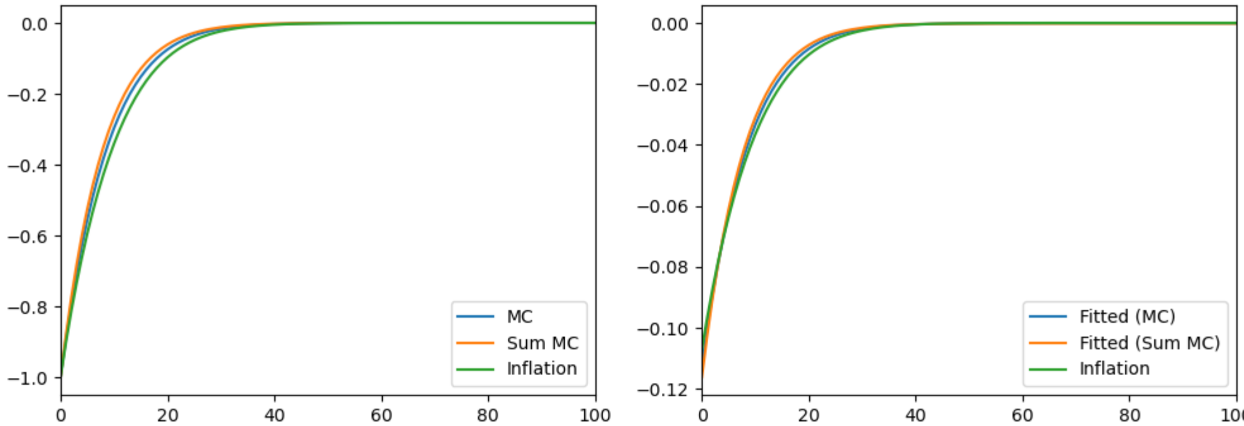

Figure 6: Weekly IRFs $\rho_D = 0$

Table I: Main Regression Results

	$\sum$ mc	π_{t-1}	ΔD_{t-1}
Calvo Specification	0.0027	0.4994	
	(0.0000)	(0.0069)	
Full Specification	0.0016	0.0529	7.0428
	(0.0000)	(0.0065)	(0.0797)

Standard errors in parentheses.

4.2 Phillips Curve Results

We now first implement the Calvo specification of the Phillips Curve regression,

$$\pi_t = \kappa \sum \mathbb{E}[\beta^k mc_{t+k}] + \gamma \pi_{t-1} + \nu_t, \tag{9}$$

on our simulated data. The estimate coefficient γ is the parameter of interest as it describes the inflation persistence taking into account the NKPC determinant $\sum mc$. We run regression which assume that all variables are measured consistently with the model. In particular the expectation of future marginal costs use the model expectations and are thus a Period t variable which can therefore be included in the regressions. We consider specifications which resemble approaches used in empirical work in Section 4.3 below. The first row of Table I shows that our model delivers a large coefficient of lagged inflation rate, $\gamma = 0.4994$. The inflation is persistence in the model is in the range of empirical estimates although we control for $\sum mc$ in the regression. The autocorrelation of inflation is close to 0.8. The coefficient on $\sum mc$ is positive consistent with the theory model and small consistent with empirical evidence.

The inflation persistence captures the history dependence of price setting and is largely muted if we control for lagged nominal demand growth, a driving force in the model. Adding the lagged nominal demand growth rate to the previous regression,

$$\pi_t = \kappa \sum \mathbb{E}[\beta^k mc_{t+k}] + \gamma \pi_{t-1} + \delta \Delta D_{t-1} + \nu_t, \tag{10}$$

confirms this. The second raw of Table I shows that the coefficient of the lagged inflation rate is smaller by an order of magnitude and close to zero, $\gamma = 0.0529$. At the same time, we estimate a large and significant coefficient on lagged ΔD_{t-1}. Nominal demand growth as the driving force in the model largely captures the history dependence and as a result reduces the coefficient on lagged inflation, which does not provide substantial information about history not already captured by nominal demand growth. Since nominal demand growth and marginal costs are positively correlated, the coefficient on $\sum mc$ is lower in the second row than in the first row of Table I .

The key conclusions are

- The New Keynesian specification of the Phillips curve delivers a positive coefficient on $\sum mc$ and a sizeable coefficient on lagged inflation
- Adding nominal demand growth yields a positive coefficient and significantly reduces the coefficient on lagged inflation.

4.3 Other Specifications of Phillips Curve regressions

The regressions underlying our main results assume that we can observe all model variables without error. In this Section we consider specifications which resemble approaches used in empirical work. We first follow Hazell et al. (2022) (HHNS)and instrument the expected discounted sum of marginal cost since expectations are not included in their dataset. Our instrumental variable regression replicates their approach. We implement the regression:

$$\pi_t = \kappa \sum_{s=t}^{t+20} \beta^{s-t} mc_s + \gamma \pi_{t-1} + \nu_t \qquad \textstyle\sum_{s=t}^{t+20} \beta^{s-t} mc_s \text{ instrumented with } mc_t, \tag{11}$$

where we follow HHNS and truncate the sum after 20 quarters. The first row of Table II shows again that inflation is persistent with a coefficient $\gamma = 0.3663$. Using instruments instead of the correct model variables as in Table I leads to a larger coefficient on $\sum mc$ and a smaller but sizeable coefficient on lagged inflation, which is within the range of empirical estimates. As in the main results, adding lagged nominal growth as an additional regressor,

$$\pi_t = \kappa \sum_{s=t}^{t+20} \beta^{s-t} mc_s + \gamma \pi_{t-1} + \delta \Delta D_{t-1} + \nu_t, \qquad \textstyle\sum_{s=t}^{t+20} \beta^{s-t} mc_s \text{ instrumented with } mc_t, \tag{12}$$

Table II: New Keynesian Phillips Curve Results: Hazell et al. (2022) Approach

	$\sum$ mc	π_{t-1}	ΔD_{t-1}
Calvo Specification	0.0040	0.3663	
	(0.0077)	(0.0084)	
Full Specification	0.0025	0.0896	5.3829
	(0.0000)	(0.0076)	(0.0997)

Standard errors in parentheses.

Table III: New Keynesian Hybrid Phillips Regression Results

	mc_t	π_{t-1}	$E_t\pi_{t+1}$	ΔD_{t-1}
Calvo Specification	1.0786	0.3529	0.3042	
	(0.0243)	(0.0065)	(0.0051)	
Full Specification	0.4614	0.0533	0.2764	6.0622
	(0.0157)	((0.0054)	(0.0051)	(0.0751)

Standard errors in parentheses.

reduces the coefficient of lagged inflation, $\gamma = 0.0896$. Nominal demand growth again has a large and sizeable coefficient. Using the approach in HHNS delivers the same conclusion as the benchmark regression: A large coefficient on lagged inflation if only the instrumented marginal cost term is included and adding nominal demand growth reduces the coefficient close to zero.

We also estimate a hybrid Phillips curve as in Gali and Gertler (1999) which describes inflation as a function of three determinants: past inflation, current real marginal costs and expected future inflation.[3] Again, we confirm our main findings. Lagged inflation matters in the regression including only real marginal costs, $\gamma = 0.3529$ and becomes unimportant when nominal demand growth is included as a regressor, $\gamma = 0.0533$.

5 Conclusion

This paper finds that menu-cost models can generate inflation persistence in line with empirical evidence, in contrast to the standard New Keynesian model. The reason is that while the New

[3]The specification follows Auclert et al. (2024) and adds an i.i.d. term to marginal cost to avoid multi-collinearity issues.

$$\pi_t = \kappa mc_t + \gamma\pi_{t-1} + \zeta\mathbb{E}\pi_{t+1} + \epsilon_t,$$

Keynesian Phillips Curve (NKPC) posits a one-to-one relationship between marginal cost (gaps) and inflation, menu-cost models decouple inflation from real activity. Nominal and marginal cost (gaps) determine the inflation rate so that inflation can inherit its persistence from nominal demand in menu-cost models whereas real marginal costs is the only source of persistence in the NKPC.

Future work will explore whether the inflation persistence in menu-cost models deliver the same implications as the New Keynesian model, for example imply a "disinflationary boom" (Ball, 1994). A related important question is about the optimal policy in models with inflation persistence. Do they differ from the prescriptions of the New Keynesian model? How does an optimal disinflationary policy look like? It is conceivable that the optimal policy should address the source of the persistence, that it differs from conventional recommendations and that the answer depends on the source of the persistence.

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