Supply Side Inflation Persistence*

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Abstract

We explore the role of the cost channel in accounting for inflation persistence in the New Keynesian model with Calvo pricing. Hump-shaped responses of inflation to monetary shocks are obtained under purely nominal rigidities.

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1 Introduction

In this paper, we explore the implications of the cost channel of monetary policy for inflation persistence. We do this using the purely forward looking version of a Calvo-style model of price stickiness. It is well known that the degree of inflation persistence generated by the baseline version of this model is lower than that observed in aggregate data: Inflation has no intrinsic persistence beyond what is inherited from its real driving process (typically some measure of real marginal costs). Moreover, and importantly, inflation responds monotonically to a monetary shock, peaking on impact. This is at odds with VAR empirical evidence, in which inflation follows a characteristic hump-shaped response (see Figure 1). A substantial literature has shown that more realistic degrees of persistence along these lines require either ad-hoc deviations from the forward-looking version of the Calvo model, or more radically different approaches, such as departures from full rationality.[1]

The cost channel introduces a direct dependence of firms' marginal costs of production on some measure of interest rates, as firms have to borrow to finance their working capital in advance. We show that adding this simple credit mechanism to the Calvo model can generate "hump-shaped" responses of inflation in line with empirical evidence, for standard parameterizations and with nominal rigidities only. The cost channel

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[1] As an early example of the first group, Gali and Gertler (1999) add backward-looking pricing to produce a hybrid version of the model. Dotsey and King (2005) introduce several other "supply side" features. Carvalho (2006) incorporates heterogeneous stickiness to increase strategic complementarity in pricing. As an example of the latter group, Mankiw and Reis (2002) study a model of sticky information.

augments the transmission mechanism of monetary policy with a supply-side effect that interacts with the traditional demand-side channel: following, say, a contractionary monetary policy shock, this allows for a response of marginal costs that is initially positive, which is a key ingredient to a non-monotone response of inflation.

Barth and Ramey (2001) carefully argue for the empirical relevance of a cost channel of monetary policy. Related to our analysis, Christiano and Eichenbaum (1992) and Christiano et al. (2005) incorporate working capital considerations in a New Keynesian framework. Recent literature uses modeling frameworks similar to ours: Ravenna and Walsh (2006), for example, study optimal monetary policy with a cost channel. Rabanal (2007), Castelnuovo (2011), and Henzel et al. (2009) add the cost channel to a model with real rigidities to explore conditions for a model-consistent price puzzle, but don't explicitly analyze its implications for inflation persistence.

2   Model

Our framework is a relatively standard New Keynesian general equilibrium model, where both prices and wages are characterized by Calvo (1983)-style stickiness. In addition, we introduce financial intermediaries that have some monopoly power in allocating funds to firms, and thus in setting the interest rate on their loans (see Henzel et al.). Firms are assumed to pay their wage bill in advance, as is common in the cost channel literature. The model is log-linearized around a symmetric, zero-inflation steady state. We assume complete financial markets.

There are three main equations of interest. Price and wage inflation ($\pi_t = p_t - p_{t-1}$ and $\pi_t^w = w_t - w_{t-1}$) are described by the following two "Phillips curve" equations:

$$\pi_t = \beta\mathbb{E}_t\pi_{t+1} + \kappa_\pi mc_t \tag{1}$$

$$\pi_t^w = \beta\mathbb{E}_t\pi_{t+1}^w + \kappa_w\left(\sigma c_{t+k} + \eta n_{t+k} - (w_t - p_t)\right) \tag{2}$$

where c_t, mc_t, and n_t denote consumption, real marginal costs, and labor supply, respectively. The parameters $\beta \in (0,1)$, $\sigma > 0$, and $\eta > 0$ are the discount factor, the CRRA parameter, and the elasticity of marginal disutility of labor; κ_π and κ_w are the slopes of these Phillips curves, and depend on the degree of nominal price and wage stickiness (see, for example, Woodford, 2003 and Gali, 2008).

The third core equation describes the dynamics of the loan rate, $r_{L,t}$. We assume banks offer differentiated loans (which can be explained, for instance, by long-term lending relationships) and, again, we model the choice of the optimal loan rate as a Calvo-style staggered contract decision. Denoting the probability of

adjusting with $1 - \theta_L$, we obtain:

$$r_{L,t} = \beta\kappa_L\mathbb{E}_t r_{L,t+1} + \kappa_L r_{L,t-1} + \kappa_D r_{D,t} \tag{3}$$

where $r_{D,t}$ is the policy rate (set by the central bank), $\kappa_D = (1 - \theta_L)(1 - \beta\theta_L)/(1 + \theta_L^2\beta)$ and $\kappa_L = \theta_L/(1 + \theta_L^2\beta)$.

The model is then closed by the Euler equation

$$c_t = \mathbb{E}_t c_{t+1} - \frac{1}{\sigma}(r_{D,t} - \mathbb{E}_t\pi_{t+1}) + u_t, \tag{4}$$

the expression for real marginal costs

$$mc_t = \gamma r_{L,t} + (w_t - p_t) - a_t, \tag{5}$$

and a Taylor (1993)-type policy rule

$$r_{D,t} = \rho_D r_{D,t-1} + \phi_\pi\pi_t + \phi_y y_t + v_t, \tag{6}$$

along with the market clearing conditions in the goods and loans markets. The parameter $\gamma \in [0,1]$ in (5) represents the fraction of the wage bill firms have to pay in advance. In (6), $\rho_D \in (0,1)$, $\phi_\pi > 0$, and $\phi_y > 0$ indicate the degree of interest rate smoothing and the responsiveness of the policy rate to inflation and output, y_t. Finally, we assume AR(1) processes for the exogenous innovations (technology, a_t, demand, u_t, and monetary policy, v_t).
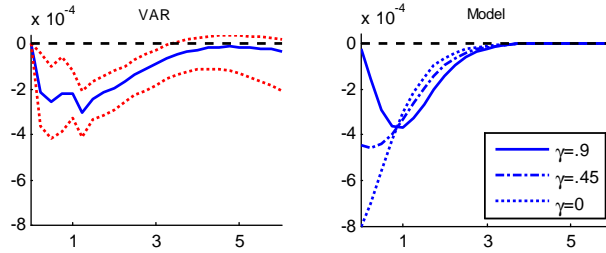

Figure 1: Inflation responses to a monetary shock. Years from the shock.

3 Results

Figure 1 compares the empirical and theoretical inflation responses to a one s.d. (contractionary) monetary shock, obtained from a VAR on US data for the post-Volcker era and a baseline calibration of our model, respectively. The VAR includes output, GDP deflator, commodity price, federal funds rate and bank reserves in this order, and a recursive identification is employed accordingly. The estimation uses four lags and Minnesota priors. We calibrate most parameters using relatively non-controversial values in the literature. Specifically, we set $\beta = .99$, $\sigma = \eta = 2$, $\rho_D = .7$, $\phi_\pi = 1.5$, and $\phi_y = 0.2$. The slopes in (1)-(3) are determined by the stickiness parameters, which we set as $\theta_p = 0.75$, $\theta_w = 0.6$, and $\theta_L = 0.4$, and the elasticity of substitution across differentiated labor types, which we assume is $\phi_w = 6$. Finally, we calibrate γ as 0.9 and all the first-order autocorrelation coefficients of the exogenous shocks as 0.4.[2]

This is, for the most part, a standard calibration, and it generates a hump-shaped response of inflation to a monetary shock that is both qualitatively and quantitatively in line with the empirical response. The parameter γ governs the direct effect of the cost channel: the hump progressively disappears (and inflation persistence decreases) as γ decreases. When $\gamma = 0$, the cost channel is shut down and the response is monotonically increasing as in the standard Calvo model.

For a better understanding of the determinants of the inflation response, and the role of the other parameters, we combine (1) and (5) to obtain a closed form of inflation, as the sum of the expected future marginal costs:

$$\pi_t = \kappa_\pi \sum_{i=0}^{\infty} \beta^i \mathbb{E}_t (\gamma r_{L,t+i} + w_{t+i} - p_{t+i} - a_{t+i}) \tag{7}$$

In a similar vein to the real exchange rate analysis in Steinsson (2008), inflation is a forward looking variable whose only source of persistence is inherited from its driving variable mc. A hump-shaped response to a contractionary monetary shock requires that the first few terms in the summation in (7) be *positive*, followed by negative terms. Crucially, this way, the response of inflation doesn't peak on impact. While the demand channel of monetary policy affects real wages, the cost channel generates a supply-side effect, which introduces a direct dependence of mc on the loan rate r_L. These channels have opposite effects, and we look for calibrations such that, on impact and for a few periods, $|r_{L,t}| > |w_t - p_t|$.[3] The main parameters can thus be analyzed in terms of their impact on these two components of the mc. Figure 2 depicts the response of key variables under baseline (blue line) and alternative (red line) calibrations. The latter are obtained by changing the value of one parameter at a time, as indicated by the column headers. In each plot, the dashed lines represent the responses corresponding to the other columns, for ease of comparison. We summarize the

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[2] More extensive discussion and robustness analysis are provided with an online supplementary manuscript.

[3] a_t is not considered here because it doesn't respond to monetary shocks.

analysis with four main observations.

1. Without *some* degree of wage rigidity, the cost channel is not sufficient to counteract the demand-channel effect. On the other hand, wage rigidities *alone* cannot generate the desired result within the Calvo model: in this instance, all terms in (7) would be negative and the inflation response would be monotonic. Importantly, moderate degrees of wage rigidity are enough to produce a hump-shaped response of inflation. Ceteris paribus, the model switches to non-monotonic inflation responses for $\theta_w > .45$, as the first scenario in Figure 2 illustrates.

2. The more flexible the loan rate, the stronger the effects of the cost channel. Excessive stickiness prevents r_L from moving enough to compensate wages (second scenario in Figure 2); on the other hand, excessive flexibility generates a "model-consistent" price puzzle. Our goal, however, is to explore a mechanism that can generate more realistic inflation persistence, rather than finding theoretical justifications for the price puzzle. Indeed, Rabanal (2007) argues that the cost channel is an empirically implausible explanation of this puzzle.

3. Mechanisms introducing strategic complementarity in pricing have been extensively used in the literature to dampen price adjustment beyond the effects of nominal stickiness. In the context of the New Keynesian model, the elasticity of marginal costs to output determines whether price setting is characterized by strategic complementarity or substitutability.[4] With our baseline calibration, this elasticity is $\eta + \sigma > 1$, which in fact implies strategic *substitutability*. Therefore, our results do not rely on a high degree of strategic complementarity.

4. Changing the other parameters does have an impact on the sluggishness of the inflation response, but doesn't overturn the baseline results. For instance, price stickiness affects the inertia of inflation, but the "sign switch" of marginal costs, and the resulting hump-shape property of inflation response, are always preserved. Furthermore, through its effect on κ_π, θ_p affects the depth of the trough of the response. The third scenario in Figure 2 emphasizes this effect. Finally, greater risk aversion (last scenario in the figure) only implies marginal differences for inflation persistence; it does however introduce, ceteris paribus, some degree of price puzzle.

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[4]This is the elasticity of the notional Short-Run Aggregate Supply (Woodford 2003).
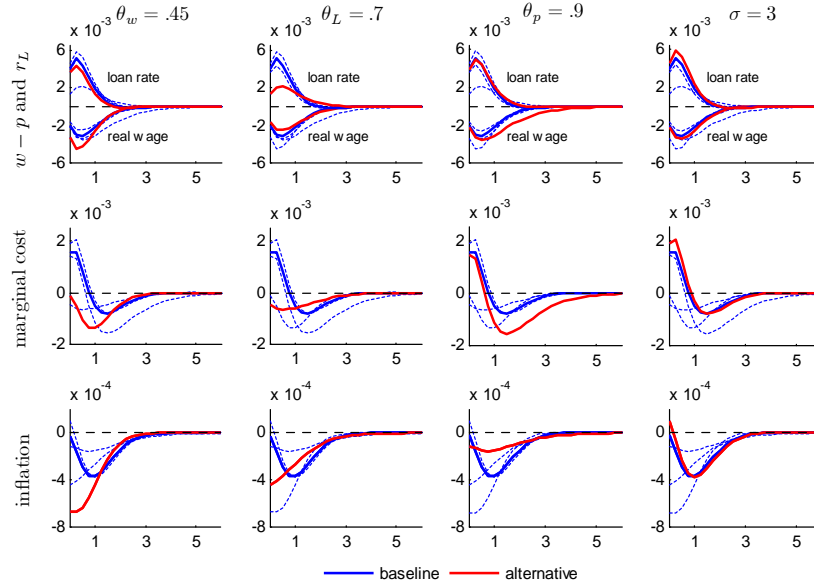
Figure 2: Calibration sensitivity analysis.

4   Conclusions

We explore the cost channel of the transmission of monetary policy and use it as a potential mechanism to explain the persistence of inflation responses to monetary shocks. We argue that this simple, but conceptually realistic, addition to the standard New Keynesian model can generate responses of inflation that are qualitatively in line with empirical evidence, a feature that models of this kind typically have trouble replicating. Importantly, we do so without altering the basic framework of Calvo-style pricing, and we thus view our analysis as a methodological contribution to the understanding of the sources of inflation persistence in this context.

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