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# Flattening of the Phillips curve under low trend inflation

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## HIGHLIGHTS

- Major economies face the flattening of the Phillips curve under low inflation.
- However, standard sticky-price models cannot explain this empirical fact.
- This paper explains why the Phillips curve is flattened under low trend inflation.
- We find that the key is the curvature of the demand curve.

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## ABSTRACT

This study indicates why the Phillips curve is flattened in an environment of low trend inflation. The key is the curvature of the demand curve.



## 1. Introduction

It is a conventional view that the output–inflation correlation, i.e., the Phillips curve, is flatter under low trend inflation. Ball et al. (1988) (hereafter BMR) suggest that the slope of the Phillips curve becomes *flatter* when the average rate of inflation is low. Recently, Benati (2007) has statistically verified BMR's argument using data from OECD countries.

However, standard sticky price models, which occupy the predominant position in recent monetary policy analyses,[1] fail to account for this empirical phenomenon. Notably, Bakhshi et al. (2007) demonstrate that the slope of the new Keynesian Phillips curve (NKPC) becomes *steeper* under lower trend inflation.[2] This theoretical implication of trend inflation is not consistent with the data.

This study demonstrates how to resolve this discrepancy between empirical facts and the implications derived from standard models. Here, what we consider important is the curvature of the demand curve.

Suppose that price-setting firms can reset prices only infrequently and face a constant elasticity of substitution (CES) demand curve, which is most commonly used in standard sticky price models. In this situation, demand becomes more price sensitive as the relative price declines. Then, infrequent pricing firms are more forward-looking under higher trend inflation. Hence, reset prices are less sensitive to current economic conditions and the slope of the Phillips curve becomes flatter.

In contrast, if firms face a kinked demand curve, which was first formulated by Sweezy (1939) and revived by Kimball (1995) in the context of modern dynamic stochastic equilibrium models, demand becomes less price sensitive as the relative price declines. Then, firms are less forward-looking under higher trend inflation and the slope of the Phillips curve becomes steeper as trend inflation increases.

Concerning the flatter slope of the Phillips curve under lower inflation, past literature has emphasized the role of time-varying

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[1] Sticky price models with the Calvo (1983) type infrequent price adjustments and monopolistic competition are widely used in this literature (*e.g.*, Woodford, 2003).

[2] Ascari (2004) derives the New Keynesian Phillips curve under non-zero trend inflation. Recent developments in this field are summarized in Ascari and Sbordone (2014).

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price rigidities. BMR and Romer (1990) claim that the frequency of price adjustments is lower in an environment of low inflation. Bakhshi et al. (2007) apply Romer (1990)'s concept to the typical sticky price model and derive the flatter slope of the Phillips curve under lower inflation. As an alternative argument, Tobin (1972) and Akerlof et al. (1996) claim that the unemployment rate is apt to increase during a low-inflation period because nominal prices and nominal wages tend to be more rigid downwards than upwards. Consequently, the Phillips curve flattens when the inflation rate is near zero.

Our approach complements these lines of research, however, differs from them in that we focus on demand behavior instead of price-setting friction or wage-setting behavior.

For the ease of explanation, we first consider the pricing decision of firms in a partial equilibrium setting and indicate that the curvature of demand curve has important implications for firms' pricing behavior. Further, we extend the analysis to the general equilibrium setting and perform stochastic simulations. By doing so, we demonstrate that the Phillips curve is flatter under lower trend inflation if the demand curve is kinked; however, it is steeper if the demand curve is CES.

## 2. A two-period sticky price model with positive inflation: the partial equilibrium approach

Consider a two-period version of a staggered price setting where a fraction of monopolistic competitive firms $z$ on a unit interval fix prices $P(z)$ for two periods.[3]

Let an increasing concave function $D(\cdot)$ be a demand aggregator. Households solve an expenditure minimization problem: $\min_{C(z)} \int_0^1 P(z)C(z)dz$ subject to $\int_0^1 D(C(z)/C)dz = 1$, where $C$ is the total consumption implicitly defined by the demand aggregator $D$. The aggregate price level, $P$, is implicitly defined by $\int_0^1 (\frac{P_z}{P})(\frac{C(z)}{C}) = 1$. The expenditure minimization problem can be solved to obtain the following demand curve: $\frac{C(z)}{C} = d(\frac{P(z)}{\lambda})$, where $\lambda$ is a Lagrange multiplier on the constraint. Dotsey and King (2005) give a specific function form of $d(\cdot)$ as

$$\frac{C_t(z)}{C_t} = \frac{1}{1+\psi}\left[\left(\frac{P_t(z)}{\lambda_t}\right)^{-\epsilon(1+\psi)} + \psi\right], \tag{1}$$

where $\epsilon$ is the parameter of demand elasticity and assumed to be greater than one; $\psi$ is the parameter of curvature of demand curve. When $\psi = 0$, a demand curve exhibits constant elasticity, as the CES formulation. When $\psi < 0$, each firm faces a quasi-kinked demand curve, à la Kimball (1995).

Now, a firm $z$ solves the following two-period profit maximization problem:

$$\max_{P_t(z)} E_t\left[\left(\frac{P_t(z)}{P_t} - \frac{MC_t^n}{P_t}\right) d\left(\frac{P_t(z)}{P_t}Q_t\right) Y_t + \beta\Lambda_{t,t+1}\left(\frac{P_t(z)}{P_{t+1}} - \frac{MC_{t+1}^n}{P_{t+1}}\right) d\left(\frac{P_t(z)}{P_t}\frac{Q_{t+1}}{\pi_{t+1}}\right) Y_{t+1}\right], \tag{2}$$

where $Q_{t+n} \equiv P_{t+n}/\lambda_{t+n}$, $\pi_{t+1} \equiv P_{t+1}/P_t$, and $\beta$ is a subjective discount factor ($\beta < 1$). $MC_{t+n}^n$, $Y_{t+n}$, and $\Lambda_{t,t+n}$ are the nominal marginal cost, aggregated output, and stochastic discount factor at time $t+n$, respectively. $E_t[\cdot]$ is an expectation operator based on the information set at time $t$.

Assuming that the utility function is specified as $U_t = \log(C_t)$ and $C_t = Y_t$, the first-order condition of a firm $z$ can be summarized as follows:

$$\frac{P_t^*}{P_t} = \Theta_t \underbrace{(MC_t - \eta_t)}_{\text{variables at } t} + (1-\Theta_t)E_t \underbrace{[\pi_{t+1}(MC_{t+1} - \eta_{t+1})]}_{\text{variables at } t+1}, \tag{3}$$

where $P_t^*$ is the optimal price and $MC_t = MC_t^n/P_t$. $\eta_{t+n}$ is the inversed price sensitivity of demand: $\eta_{t+n} \equiv \frac{d_t}{d_t'}$ and $d_{t+n}' = \partial d(x_{t+n})/\partial(P_t(z)/P_t)$. The inter-temporal weight in (3) takes the following form: $\Theta_t \equiv d_t'/[d_t' + E_t(\frac{\beta}{\pi_{t+1}}d_{t+1}')]$.

(3) suggests that the optimal relative price is the weighted sum of the current and future variables. Furthermore, the concurrent relationship between the marginal cost and optimal price depends on the weight, $\Theta_t$. It is clearer when we log-linearize (3) around the steady state and derive the coefficient of the optimal price to changes in marginal costs: $\frac{d(\hat{P}_t^*/P_t)}{\bar{MC}\cdot d\hat{mc}_t} = \bar{\Theta}$, where $\hat{x}_t$ represents a log-deviation of $x$ from the steady state, $\bar{x}$.

Using the specific form of the demand curve in (1), we obtain

$$\bar{\Theta} = \frac{1}{1+\beta\bar{\pi}^{[\epsilon(1+\psi)-2]}}. \tag{4}$$

(4) means that the optimal price's responsiveness to marginal costs is determined by trend inflation, two parameters of the demand curve, and discount rate. Specific implications of (4) can be summarized as follows.

If the demand curve is CES ($\psi = 0$), then the optimal price is more responsive to changes in current marginal cost under lower trend inflation as long as the demand elasticity is $\epsilon > 2$; this condition is quite wide since the steady-state demand elasticity is calibrated as around 7 in many previous works. In contrast, if the demand curve is kinked ($\psi < 0$), the optimal price is less responsive to changes in current marginal costs under lower trend inflation as long as $\epsilon(\psi + 1) < 2$, which is also consistent with wide range of realistic parameter values.

Fig. 1 presents a graphical interpretation of the above results. The inter-temporal weight, $\Theta_t$, comprises the demand curve's current and future slope. If current demand is more price sensitive than inflation-adjusted future demand, the inter-temporal weight increases. As illustrated in the left-hand side of Fig. 1, when firms face a kinked demand curve, they expect less price sensitive demand in the future ($|d_{t+1}'/\pi_{t+1}| < |d_t'|$) under higher trend inflation. Hence, in case of the kinked demand, the reset price is less responsive to changes in current marginal costs under lower trend inflation.

Pricing behavior is different when firms face a CES demand curve. As illustrated in the right-hand side of Fig. 1, the higher trend inflation could result in more forward-looking pricing ($|d_{t+1}'/\pi_{t+1}| > |d_t'|$). In case of CES demand, the reset price is more responsive to changes in current marginal costs under lower trend inflation.

## 3. An infinite-period sticky price model with positive inflation: general equilibrium approach

This section studies the slope of the reduced-form Phillips curve under different trend inflation by simulation, using a standard New Keynesian type dynamic stochastic general equilibrium model. The brief description of the model is as follows.

[3] Ascari (2000) employs a similar two-period model and analyzes how sensitivities of new reset wages depend on trend inflation.