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# Habit formation in state-dependent pricing models: Implications for the dynamics of output and prices

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## HIGHLIGHTS

- We examine habit formation in a standard state-dependent pricing model.
- With habit formation, output responses are more realistic under monetary shocks.
- Incorporating habit formation makes pricing behaviors change dramatically.

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## ABSTRACT

This paper examines the role of habit formation in a standard state-dependent pricing (SDP) model. Incorporating habit formation helps the SDP model to generate hump-shaped and more persistent output responses under a monetary shock. More importantly, incorporating habit formation causes dramatic changes in firm-level pricing behaviors and, as a result, the aggregate price index.

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## 1. Introduction

Since the work by Dotsey et al. (1999), a large body of research in modeling money disturbances with SDP has been conducted. However, output responses to monetary shocks produced by the existing SDP models do not match the empirical findings that output responses are hump-shaped and persistent.[1] In this paper, I introduce habit formation in a standard SDP model of Dotsey et al. (1999), hereafter called the DKW model. The aim of introducing habit formation is to generate output responses under a monetary shock that can better match the empirical findings. In addition, it would be interesting to see how habit formation causes firms' pricing behaviors and the price index to change.

Habit formation has been studied extensively in the literature on asset pricing, economic growth, and monetary economics. However, none of the existing SDP literature has examined this interesting preference. Intuitively, habit formation causes households to care more about consumption smoothing, leading to more persistent responses in consumption and output to a monetary shock. In addition, with habit formation, households relate *changes in consumption growth* to interest rates. A positive monetary shock causes lower interest rates that are associated with a declining consumption growth profile. The consumption growth rate is positive initially and consumption increases. Consumption then declines and returns to the steady state. Hence, consumption and, as a result, output responses are hump-shaped.

With a moderate level of habit formation, the SDP model in the paper is able to produce hump-shaped and persistent output

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[1] The output responses from the SDP models can be seen in Dotsey et al. (1999), Dotsey and King (2005), Gertler and Leahy (2005), Burstein (2006), Midrigan (2006), and Golosov and Lucas (2007). The empirical findings can be found in Christiano et al. (2005), Bouakez et al. (2005).

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responses. These results are robust to various specifications of the money supply conducted by the central bank. More interestingly, the price index, while more persistent, is also more responsive to a permanent monetary shock in the model with habit formation than in the original DKW model. This is because habit formation induces more firms to adjust their prices in view of the fact that households are now less willing to change their consumption drastically under monetary shocks.

While in this paper the issue of habit formation is not explicitly investigated in a time-dependent pricing (TDP) model, its capacity to generate the hump-shaped and persistent output responses should extend to a TDP model under the same logic. However, a TDP model is not able to produce the interesting results associated with firm-level pricing behaviors and the price index. It is because firms in the TDP framework face a fixed probability of adjusting their prices.

## 2. Model

The model in the paper is the same as the standard DKW model except that I introduce habit formation in the preference of representative households. Specifically, the instantaneous utility function is as follows:

$$U(C_t, N_t, h_t) = \frac{(c_t - h_t)^{1-\sigma} - 1}{1-\sigma} - \frac{\chi}{1+\phi} N_t^{1+\phi} \quad (1)$$

where $c_t$ is the composite consumption good that is aggregated from differentiated goods, $c_{j,t}$, with $j \in [1, J]$, using a constant elasticity of substitution (CES) technology:

$$c_t = \left[ \sum_{j=1}^{J} \theta_{j,t+1} c_{jt}^{(\epsilon-1)/\varepsilon} dj \right]^{\epsilon/(\epsilon-1)}; \quad (2)$$

$\theta_{j,t+1}$ is the weight of $c_{j,t}$, which will be discussed in the following section; $\epsilon$ is the elasticity of substitution between the differentiated goods; $N$ denotes labor supply; $\phi^{-1}$ is the Frisch labor supply elasticity; $\chi$ is a disutility parameter of working; $\sigma$ denotes the risk aversion; and $h$ denotes habit stock.

The utility function with habit formation follows Constantinides (1990) and has been used extensively in the literature of asset prices and development. Incorporating the habit formation helps to reduce "front-loading" behavior of consumers, generating smaller changes in consumption and, as a result, output under shocks to the economy.

To be consistent with the empirical literature of habit formation, in this paper, the habit stock depends only on the last period's consumption, or $h_t = \kappa c_{t-1}$. Parameter $\kappa$ represents the importance of habit formation. If $\kappa$ is zero, the utility function will collapse into the traditional time separable one as in the existing SDP literature.

### 2.1. Households

There is a mass 1 of representative households who maximize the expected present discounted lifetime utility:

$$\underset{\{c_t, N_t\}}{Max}\, E_0 \sum_{t=1}^{\infty} \beta^t \left[ \frac{(c_t - h_t)^{1-\sigma}}{1-\sigma} - \frac{\chi}{1+\phi} N_t^{1+\phi} \right] \quad (3)$$

subject to the following budget constraint:

$$P_t c_t + B_t = P_t w_t N_t + P_t R_t^k k + P_t \left( \sum_{j=1}^{J} z_{jt} dj \right) + (1 + R_t) B_{t-1}, \quad (4)$$

where $B$ denotes nominal bonds; $z_j$ denotes the real profit received from the firm that produces intermediate good $j$; $w$ and $R^k$ denote the real wage and the capital rental rate, respectively; $R$ and $P$ denote the nominal interest rate and the price index, which is the price of the composite consumption goods, respectively. As in the original DKW model, the capital stock is assumed to be constant.

### 2.2. Intermediate-good producers

As in Dotsey et al. (1999), an intermediate-good firm is characterized by its vintage $j \in [1, J]$, where the number of vintages $J$ is determined endogenously. A firm in vintage $j \in [1, J]$ adjusted its price *j periods ago* and it enters period $t$ with the price $P_{j,t}^*$. At time $t$, a vintage-$j$ firm must choose between keeping or adjusting its price. If the firm adjusts the price, then it has to pay an adjustment cost that is exogenously realized in the beginning of the period. Therefore, the vintage-$j$ firm faces the following problem:

$$\max\{\upsilon_{0,t} - w_t \xi_t;\, \upsilon_{j,t}\} \quad (5)$$

subject to:

$$\upsilon_{j,t} = \max_{\{n_{jt}, k_{jt}\}} z_{j,t} + E_t Q_{t,t+1} \left( \eta_{j+1,t+1} \upsilon_{j+1,t+1} + \alpha_{j+1,t+1} \left( \upsilon_{0,t+1} - w_{t+1} \xi_{t+1} \right) \right), \quad (6)$$

$$\upsilon_{0,t} = \max_{\{P_t^*, n_{0t}, k_{0t}\}} \left\{ z_{0,t} + E_t Q_{t,t+1} \left( \eta_{1,t+1} \upsilon_{1,t+1} + \alpha_{1,t+1} \left( \upsilon_{0,t+1} - w_{t+1} \xi_{t+1} \right) \right) \right\}, \quad (7)$$

$$z_{j,t} = \left( \frac{P_{j,t}^*}{P_t} - w_t n_{jt} - R_t^k k_{jt} \right) y_{j,t}, \quad (8)$$

$$y_{jt} = k_{jt}^{1-\gamma} n_{jt}^{\gamma}, \quad (9)$$

$$c_{j,t} \le y_{j,t}, \quad (10)$$

where $z$ and $\upsilon$ denote the real profit and the firm value, respectively; subscript 0 represents the situation where the firm adjusts its price; $\xi$ is an adjustment cost in terms of labor; $\alpha_j$ and $\eta_j$ are the probabilities that a vintage-$j$ firm will adjust and keep its price respectively; the probabilities are determined endogenously; $Q_{t,t+1}$ is the stochastic discount factor that depends on the subjective time discount $\beta$ and the marginal utility of consumption in period $t$ and $t + 1$; $\gamma$ is the labor share in the production function.

First note that a vintage-$j$ firm produces its differentiated output using a Cobb–Douglas production function as in Eq. (9). It has to produce enough to satisfy all the demands as in Eq. (10) given its quoted price. Second, the adjustment cost $\xi$ is identically and independently distributed across firms and time from a fixed distribution.

### 2.3. Evolution of the distribution of intermediate goods firms

Let $\left(\theta_{1,t}, \ldots, \theta_{J,t}\right)$ be the beginning-period distribution of intermediate-good producers. The probability that a vintage-$j$ firm adjusts its price is $\alpha_{j,t}$, and the probability it keeps its price unchanged is $\eta_{j,t} = \left(1 - \alpha_{j,t}\right)$. Therefore, the law of motion for the distribution of firms will be:

$$\theta_{1,t+1} = \sum_{j=1}^{J} \alpha_{j,t} \theta_{j,t}, \quad (11)$$

$$\theta_{j+1,t+1} = \eta_{j,t} \theta_{j,t}, \quad \text{for } j \in [1, J-1], \quad (12)$$

$$\sum_{j=1}^{J} \theta_{j,t} = 1 \quad \text{for all } t. \quad (13)$$

The first equation says that in the next period, $t+1$, the fraction of firms whose prices are one-quarter old is the total fraction of firms who adjust their prices in the current period, $t$. The second

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