Habit Formation in State-Dependent Pricing Models: Implications for the Dynamics of Output and Prices

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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.
JEL classification: E20; E31; E37; E52.

Key words: sticky prices, state dependent pricing, habit formation, monetary policy transmission mechanism.

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.

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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).

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 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 household are now less willing 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:

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

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:

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

$\theta_{j,t+1}$ is the weight of $c_{j,t}$, which will be discussed in the following section; ϵ is the elasticity of substitution between the differentiated goods; N denotes labor supply; ϕ^{-1} is the Frisch labor supply elasticity; χ is a disutility parameter of working; σ 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 κ represents the importance of habit formation. If κ 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:

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

subject to the following budget constraint:

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

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

2.2. Intermediate-goods producers

As in Dotsey et al. (1999), an intermediate-goods 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:

$$\max\ \{\upsilon_{0,t} - w_t\xi_t; \upsilon_{j,t}\} \tag{5}$$

subject to:

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

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

$$z_{j,t} = \left(\frac{P^*_{j,t}}{P_t} - w_t n_{jt} - R^k_t k_{jt}\right) y_{j,t}, \tag{8}$$

$$y_{jt} = k_{jt}^{1-\gamma} n_{jt}^{\gamma}, \tag{9}$$

$$c_{j,t} \leq y_{j,t}, \tag{10}$$

where z and υ denote real profit and firm value; subscript 0 represents the situation where the firm adjusts its price; ξ is an adjustment cost in terms of labor; α_j and η_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 β and the marginal utility of consumption in period t and $t+1$; γ 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 equation (9). It has to produce enough to satisfy all the demands as in equation (10) given its quoted price. Second, the adjustment cost ξ is identically and independently distributed across firms and time from a fixed distribution.

2.3. Evolution of the distribution of intermediate goods firms

Let $(\theta_{1,t}, ..., \theta_{J,t})$ 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 $\eta_{j,t} = (1 - \alpha_{j,t})$. Therefore, the law of motion for the distribution of firms will be:

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

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

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

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 equation states that the vintage-j firms, who do not adjust their prices today, will be in vintage $j+1$ in the next period. Note that all the firms in vintage-J will adjust their prices with the probability $\alpha_J = 1$. The distribution of firms is endogenously determined and is used to construct aggregate variables.

2.4. Money demand and supply

The money demand $M_t^d = P_t c_t$ is a slightly modified version of the quantity theory. The money supply is exogenously controlled by the central bank through different specifications:

$$\Delta \ln M_t^s = (1-\rho)\mu + \rho \Delta \ln M_{t-1}^s + \varepsilon_t \tag{14}$$

and

$$\begin{aligned} M_t^s &= (1+\mu)^t M_0^s + u_t \\ u_t &= \rho u_{t-1} + \varepsilon_t \end{aligned} \tag{15}$$

where μ is the money growth rate. In the first specification, ε is the shock to the growth rate of money supply while in the second specification, ε is the shock to the level of money supply. In both cases, the persistence of the shock is ρ.

2.5. General equilibrium

Definition 1. *An equilibrium is a set of prices* $\left\{R_t, R_t^k, w_t, \left\{P_{t-j}^*\right\}_{j=0}^{J-1}, P_t\right\}_{t=0}^{\infty}$*, allocation* $\left\{N_t, c_t, \left\{c_{j,t}\right\}_{j=1}^{J}, y_{jt}, \left\{n_{jt}\right\}_{j=1}^{J}, \left\{k_{jt}\right\}_{j=1}^{J}, M_t^d, M_t^s, B_t\right\}_{t=0}^{\infty}$*, probability of price adjustments* $\left\{\left\{\alpha_{jt}\right\}_{j=1}^{J}\right\}_{t=0}^{\infty}$*, and distribution of firms* $\left\{\left\{\theta_{jt}\right\}_{j=1}^{J}\right\}_{t=0}^{\infty}$ *that (i) solve the representative household's problem and firms' problems; (ii) satisfy the law of motion for the distribution of firms and for the money supply; and (iii) clear all the markets for labor, capital, differentiated goods and money.*

There is only one representative household in the economy. Therefore, the aggregate bond, B_t, is zero for all periods.

3. Dynamics of output and prices

3.1. Calibration

The complete set of model parameters, except the habit formation coefficient κ, is taken directly from DKW. Some of these parameters are nontrivial and discussed in details in DKW. Table 1 lists some important parameters. The distribution of the adjustment cost is the same in DKW. Although it is interesting to study different specifications of adjustment cost distribution, it is not the focus of the paper, so I leave this open for future research.

The most important parameter of interest is the habit formation coefficient κ. This coefficient is estimated to be around 0.8 in Constantinides (1990) and Jermann (1998). Durham and Dale (1991) estimate that the habit formation coefficient is around 0.85 using aggregate time series data and about 0.25 using the U.S. household

Table 1: Benchmark parameters

Name	Parameter	Value	Annualized
Real interest rate	r	0.0123	0.05
Discount factor	β	0.9879	0.9524
Faction of time endowment used for working	N	0.2	
Economy-wide productivity factor	A	1	
Demand elasticity (using markup of 33%)	ε	4.33	
Share of labor in production	γ	2/3	
Labor supply elasticity	ϕ^{-1}	∞	
Inter-temporal elasticity of substitution	σ	1	
Steady state inflation	μ	0.0123	0.05
Habit formation coefficient	κ	0.6	

data. Dynan (2000) shows no habit formation using the households' annual food consumption. In this paper, to reconcile the empirical studies, I choose a moderate habit formation of 0.60.[2]

3.2. Results

Figure 1 shows the dynamics of the selected variables under a 1% permanent increase in the money supply. The results from the habit formation model and the DKW model are presented by the solid blue lines and dashed red lines, respectively. In the new steady state, the value of real variables is unchanged, but the value of nominal variables, such as the price index, is 1% higher than the initial one. Note that the steady state number of vintages J is 8 and the same in both models.[3]

Apparently, in the DKW model, output increases on impact by about 0.45% and returns to the steady state after about 4 quarters. No hump-shaped response of output is found. In contrast, in the habit formation model, the output response is hump-shaped and more persistent.

[2]Due to its complexity, the model cannot be solved if the habit formation coefficient is larger than 0.65, given the set of parameters from DKW.

[3]For tractibility, I assume that the number of vintages is kept at the steady state value when we compute the dynamic results. The jumps in all variables at the 8th quarter after the shock reflect the evolution of the distribution of firms.

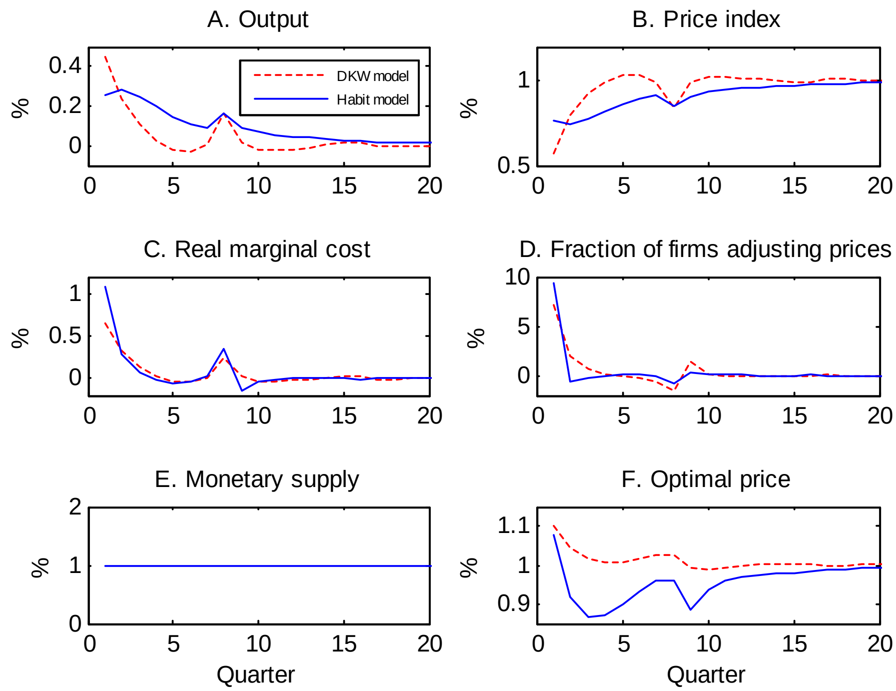

Figure 1: Impulse responses under a 1% increase in the money supply and the shock to the money supply is permanent.

Specifically, in the habit model, the impact response of output is only 0.3% compared to 0.45% in the DKW model. The response of output peaks after 1 quarter and then dies out gradually after 12 quarters. Although incorporating moderate habit formation in the model cannot bring the response of output to match perfectly with the empirical findings, it obviously improves the dynamic results from the conventional DKW model, making them closer to reality.

More interestingly, the response of the optimal price and the price index in the habit formation model are strikingly different from those in the DKW model. The deviation of the price index from the steady state is quite persistent. It returns to the new steady state after approximately 15 quarters compared to 5 quarters in the DKW model.

It is also interesting that, at the time of shock, the price index in the habit model is more responsive than in the DKW model. Intuitively, firms know that households

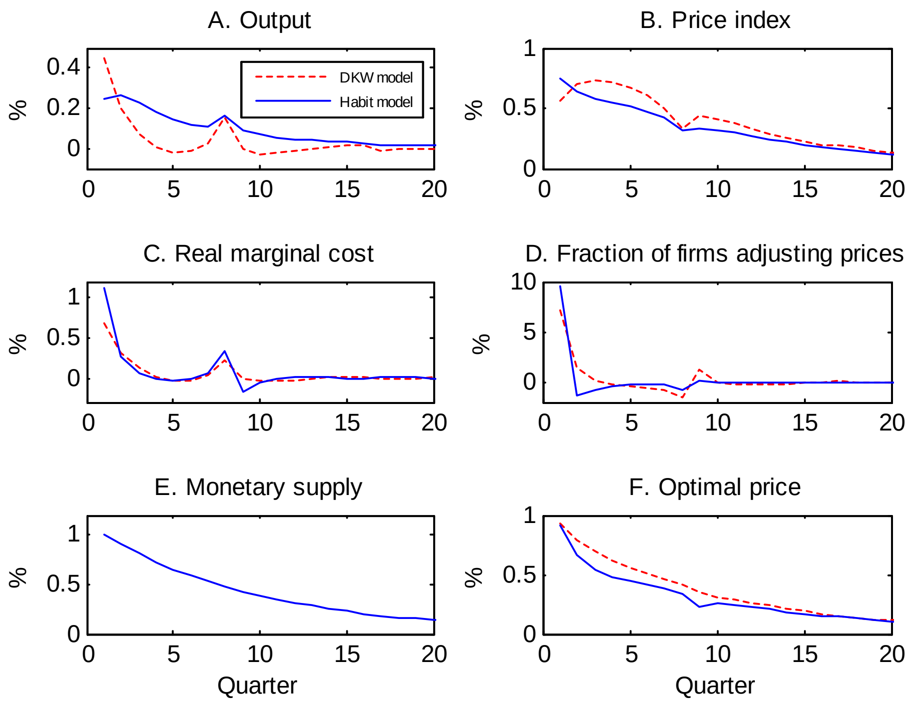

Figure 2: Impulse responses under a 1% increase in the money supply and the shock to the money supply is persistent.

have more money due to an increase in the money supply but are afraid of a sudden increase in consumption due to habit formation. Hence, the firms can increase their prices without losing customers.

Therefore, there are more firms adjusting their prices because the opportunity cost of keeping the past prices unchanged is now higher due to a higher inflation rate and higher optimal price. In Panel D, Figure 1, on impact, 9.5% more firms charge new prices in the habit model compared with about 7.0% in the DKW model.

Panel F of Figure 1 shows that, conditional on adjusting prices, firms raise their optimal prices by more than 1% on impact in both models, which is approximately 10% over the long run optimal price. Surprisingly, the optimal price in the habit model is smaller than the long run value in the second period; it then returns to the long run value from below. In contrast, the optimal price in the DKW model returns to the long run value from above.

The above-mentioned responses of output are robust to different specifications of money supply process, while the pricing behaviors, at both firm and the aggregate levels, are not. Figure 2 shows the results of both models under a 1% persistent shock to the money supply. In this case, the persistence parameter ρ is 0.9. From Panel E in Figure 2, the money supply deviates from the balanced growth path for about 20 quarters. The output response in the habit formation model is persistent, hump-shaped, and is at a peak of around 0.3% in the second quarter.

In this case, the fraction of firms adjusting their prices behaves similarly as in the first case. However, the responses of the optimal price and the price index are altered. As seen in Panels B and F of Figure 2, the price index returns to the initial steady state after about 20 quarters in both models instead of diverging to a new steady state. In the two models, the optimal price increases less than 1% on impact; it then returns to the initial steady state from above.

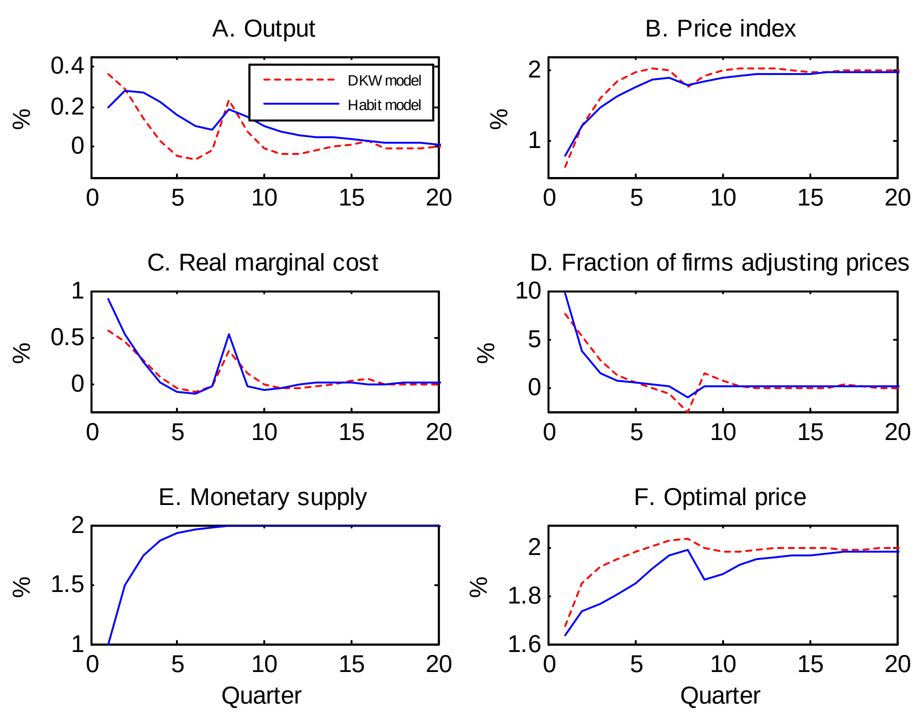

Figure 3: Impulse responses under a 1% increase in the growth rate of money supply and the shock to the growth rate is persistent.

The persistent and hump-shaped output response is also robust under a 1% persistent growth shock, as in Figure 3. The persistence of the growth shock is 0.5 and is considered to be empirically reasonable. The money supply increases by 2% in the long run as shown in Panel E of Figure 3, as does the price index in Panel B of Figure 3.

From Panel A, the output response is almost the same as in the other two cases. It is persistent and hump-shaped. The fraction of firms adjusting their prices is higher in the habit model. Remarkably, the fraction of adjusting firms is more persistent compared to the other two cases.

4. Conclusion

The paper investigates habit formation, which is popularly used in asset pricing, development, macro, and monetary economics, in the SDP framework. This real friction is shown to be able to bring the output response in the SDP model under a monetary shock closer to reality. More importantly, pricing behaviors of firms in the model with habit formation are remarkably different from those in the standard SDP model.

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6. References

References

Bouakez, H., Cardia, E., Ruge-Murcia, F. J., 2005. Habit formation and the persistence of monetary shocks. Journal of Monetary Economics 52 (6), 1073–1088.

Burstein, A. T., 2006. Inflation and output dynamics with state-dependent pricing decisions. Journal of Monetary Economics 53 (7), 1235–1257.

Burstein, A. T., Hellwig, C., 2006. Prices and market shares in a menu cost model. UCLA Working Paper.

Christiano, L. J., Eichenbaum, M., Evans, C. L., 2005. Nominal rigidities and the dynamics effects of a shock to monetary policy. Journal of Political Economy 113 (1), 1 – 45.

Constantinides, G. M., 1990. Habit formation: A resolution of the equity premium puzzle. Journal of Political Economy 98 (3), 510–543.

Dotsey, M., King, R. G., 2005. Implications of state-dependent pricing for dynamic macroeconomics models. Journal of Monetary Economics 52, 213–242.

Dotsey, M., King, R. G., Wolman, A., 2006. Inflation and real activity with firm level productivity shocks: a quantitative framework. Working Paper.

Dotsey, M., King, R. G., Wolman, A. L., 1999. State-dependent pricing and the general equilibrium dynamics of money and output. Quarterly Journal of Economics 114, 655–690.

Durham, C., Dale, H., 1991. A test of the habit formation hypothesis using household data. The Review of Economics and Statistics 73 (2), 189–199.

Dynan, K. E., 2000. Habit formation in consumer preferences: Evidence from panel data. American Economic Review 90 (3), 391–406.

Gertler, M., Leahy, J., 2005. A phillips curve with an ss foundation. Working Paper.

Golosov, M., Lucas, R. E. J., 2007. Menu cost and phillips curves. Journal of Political Economy 115 (2), 171–199.

Jermann, U. J., 1998. Asset pricing in production economies. Journal of Monetary Economics 41, 257–275.

Johnston, M. K., 2007. Real and nominal frictions within the firm: How lumpy investment matters for price adjustment. Boston University Working Paper.

Midrigan, V., 2006. Menu costs, multi-product firms, and aggregate fluctuation. Ohio State University Working Paper.