Deep versus Superficial Habit: It’s All in the Persistence

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The assumption that agents form habit in consumption has become a **standard feature** of dynamic stochastic general equilibrium (DSGE) models.

Such a feature was introduced on empirical grounds to enable these models to match the **hump-shaped response of consumption** obtained in empirical exercises employing vector-autoregressions (VARs).

There exist **several forms of habit**, which in turn affect the model’s equilibrium conditions in different ways.

While **internal** habit captures inertia in household’s consumption decisions, **external** habit captures preference interdependence across households (i.e. keeping up with the Joneses).

However, as shown by [Dennis, 2009], up to a first-order approximation of the model, **whether habit is internal or external has empirically little effect on its business cycle characteristics.**
Motivation

- [Ravn et al., 2006] introduce in the DSGE literature the idea that agents may form habit not on the overall consumption level, but separately over a continuum of varieties of goods.

- Whether agents form habit on a composite good – i.e. they exhibit superficial habit (SH) – or on categories of goods – known as deep habit (DH) – has potentially important consequences for the propagation mechanism of macroeconomic shocks.

- In fact, whereas in the symmetric equilibrium both habit specifications affect the demand side of the model in the same indistinguishable way, DH also alters the supply side of the model.

- This occurs because firms incorporate in their decisions that the demand they will face tomorrow is partly a function of the current firm-specific demand they are able to attract today.

- Regardless of the presence of price stickiness, this in turn implies that the price mark-up exhibits a counter-cyclical behavior, although [Jacob, 2014] shows that this mechanism is more muted for high levels of price stickiness.
In this paper, we use Bayesian estimation techniques to determine the extent to which assuming DH as opposed to SH enhance an otherwise standard DSGE model’s ability to fit US data.

Assessing these features requires particular care as DSGE models incorporating DH typically assume, on one hand, that this is present also in government consumption and, on the other hand, that there is an additional persistence in the stock of habit.

Thus, in order to evaluate the individual and joint contribution of each of these issues, and for the sake of robustness, we estimate:

- a battery of four different permutations of a DSGE model
- with two alternative datasets,
- and two alternative data transformations,
- for a total of sixteen estimation rounds.

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Model features

- NK DSGE model
- Real frictions
  - Habit formation (superficial or deep) only in private or also in government consumption
  - Convex investment adjustment costs
  - Variable capital utilization
- Nominal frictions
  - Price stickiness
  - Nominal wage stickiness
Households $j \in [0, 1]$ have preferences over differentiated consumption varieties $i \in [0, 1]$ and derive utility from $(X^c_t)^j$, i.e. a habit-adjusted composite of differentiated consumption goods.

\[
(X^c_t)^j = \begin{cases} 
\left[ \int_0^1 (C^j_{it} - \tilde{\theta}^c S^c_{it-1}) \frac{1}{e^{P^\eta t}} di \right]^{\frac{1}{1 - \frac{1}{e^{P^\eta t}}}} & \text{under deep habit,} \\
\left[ \int_0^1 (C^j_{it}) \frac{1}{e^{P^\eta t}} di \right]^{\frac{1}{1 - \frac{1}{e^{P^\eta t}}}} - \hat{\theta}^c S^c_{t-1} & \text{under superficial habit.}
\end{cases}
\]  

The stocks of habit evolve over time according to

\[
\begin{align*}
S^c_{it} &= \bar{\theta}^c S^c_{it-1} + (1 - \bar{\theta}^c) C_{it} & \text{under deep habit,} \\
S^c_t &= \hat{\theta}^c S^c_{t-1} + (1 - \hat{\theta}^c) C_t & \text{under superficial habit.}
\end{align*}
\]

The optimal level of demand for each variety, $C^j_{it}$, is

\[
C^j_{it} = \begin{cases} 
\left( \frac{P^c_{it}}{P_t} \right)^{-e^{P^\eta t}} (X^c_t)^j + \hat{\theta}^c S^c_{it-1} & \text{under deep habit,} \\
\left( \frac{P^c_{it}}{P_t} \right)^{-e^{P^\eta t}} (X^c_t)^j & \text{under superficial habit.}
\end{cases}
\]
Habit in Government Consumption

- Habit can be present also in government consumption. From a technical point of view this is entirely analogous to how these are introduced in private consumption.

- Therefore, DH in government consumption affect dynamics also with a standard utility function not featuring government consumption, such as the one employed in this paper, or if government consumption enters linearly.

- On the contrary, SH in government consumption would only affect dynamics only if the habit-adjusted government consumption composite, $X_t^g$, entered the utility function multiplicatively.

- In fact, if government consumption does not enter the utility function – or if it enters linearly – households’ first-order conditions will not depend on $X_t^g$ as well as those of the firms.
Taking the model to the data

- The model is **estimated** with US data over the Great Moderation (1984:Q1-2008:Q3).
- Parameters that cannot be identified in the dataset and/or are related to steady state values of the variables are **calibrated**.
- Parameters related to the shock processes and real/nominal frictions are estimated with **Bayesian techniques**.
- Seven observables correspond to the seven structural shocks present in the model: real investment, real private consumption, real government consumption, GDP deflator inflation, real wage, hours worked and the fed funds rate.
- In addition to the “**standard**” (STD) dataset à la [Smets and Wouters, 2007], we construct an “**alternative**” (ALT) dataset in which data for private investment include both gross private domestic investment and private consumption expenditure in durable goods, while private consumption only features consumption expenditure in non-durables and services ([Galí et al., 2007], [Zubairy, 2014]).
- **Two different filters**: FD and HP(1600).
The aims of our estimation exercise can be summarized in two questions:

1. Conditional on the presence of the additional persistence in the stock of habit, does DH in private consumption fit the data better than SH?
2. Does DH in government consumption improve the fit of the model?

In order to provide an answer to these questions we set-up and estimate a battery of modifications of the model in order to compare log-likelihoods and their predictions.
Model battery

<table>
<thead>
<tr>
<th>Model</th>
<th>SH in C</th>
<th>DH in C</th>
<th>DH in G</th>
<th>No $\hat{\rho}_c$ in SH</th>
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<tr>
<td>D</td>
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</table>

**Table**: Models specifications

4 models × 2 datasets × 2 data transformations = 16 estimation rounds
# Deep vs superficial habit

<table>
<thead>
<tr>
<th>Model</th>
<th>SH in C</th>
<th>DH in C</th>
<th>DH in G</th>
<th>No $\hat{\rho}_c$ in SH</th>
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<tr>
<td>B</td>
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<tr>
<td>D</td>
<td>✓</td>
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</table>

<table>
<thead>
<tr>
<th>Models</th>
</tr>
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<tbody>
<tr>
<td>STD</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>ALT</td>
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## Habit in government spending?

<table>
<thead>
<tr>
<th>Model</th>
<th>SH in C</th>
<th>DH in C</th>
<th>DH in G</th>
<th>No $\hat{\rho}^c$ in SH</th>
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<tbody>
<tr>
<td>A</td>
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<td></td>
<td></td>
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<tr>
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<tr>
<td>C</td>
<td></td>
<td>✓</td>
<td>✓</td>
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### Models

<table>
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<th>STD</th>
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Impulse response functions (Technology)

Impulse responses to a shock to technology
- Real output
- Priv. consumption
- Investment
- Nom. int. rate
- Infl. rate
- Price mark-up

Model A: SH in C
Model B: DH in C
Model C: DH in C and G
Model D: SH in C, $\rho_c = 0$

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Impulse response functions (Government)

Impulse responses to a shock to government spending

- **Real output**
- **Priv. consumption**
- **Investment**
- **Nom. int. rate**
- **Infl. rate**
- **Price mark-up**

**Models:**
- Model A: SH in C
- Model B: DH in C
- Model C: DH in C and G
- Model D: SH in C, $\rho_c = 0$

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The fact that, once the persistence in the stock of habit is accounted for, the marginal likelihood of a model with DH does not significantly differ from that of a model with SH is the consequence of the fact that model dynamics are very similar across the two habit specifications for the vast majority of shocks, namely all but the government spending shock.

Hence we look at the variance decomposition of shocks to check the role of the government spending shock in explaining the variance of observables in our model.

We present the variance decomposition of Model C (results for all other models are very similar.)
### Variance Decomposition Model C

<table>
<thead>
<tr>
<th>Observable</th>
<th>Technology</th>
<th>Gov. Spending</th>
<th>Mon. Policy</th>
<th>Price mark-up</th>
<th>Preference</th>
<th>Inv. specific</th>
<th>Wage mark-up</th>
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<td>Hours worked</td>
<td>2.19</td>
<td>1.3</td>
<td>0.78</td>
<td>34.87</td>
<td>0.53</td>
<td>5.03</td>
<td>55.31</td>
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<tr>
<td>Inflation</td>
<td>8.49</td>
<td>0.34</td>
<td>17.94</td>
<td>18.75</td>
<td>9.57</td>
<td>24.6</td>
<td>20.31</td>
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<tr>
<td>Interest rate</td>
<td>7</td>
<td>0.59</td>
<td>9.88</td>
<td>11.96</td>
<td>8.52</td>
<td>40.27</td>
<td>21.78</td>
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<tr>
<td>Consumption</td>
<td>10.57</td>
<td>0.51</td>
<td>7.35</td>
<td>10.94</td>
<td>25.14</td>
<td>2.9</td>
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<td>Gov. Spending</td>
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<td>0</td>
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<tr>
<td>Investment</td>
<td>7.31</td>
<td>0.03</td>
<td>1.32</td>
<td>24.3</td>
<td>5.85</td>
<td>37.8</td>
<td>23.39</td>
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<tr>
<td>Real wage</td>
<td>10.53</td>
<td>0.08</td>
<td>2.29</td>
<td>44.13</td>
<td>6.22</td>
<td>0.79</td>
<td>35.96</td>
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</table>
DH seem better than SH, but only due to the additional persistence in the stock of habit.

Introducing DH in public consumption does not improve (nor worsen) the fit of the model.

At the posterior mean, all model variants produce very similar responses to all demand and supply shocks with the exception of the government spending shock which has, however, a small role in the variance decomposition of the estimated model.
As regards habit in government consumption, we believe that future research should focus on its implications for fiscal shocks.

An earlier version of this paper provides a preliminary insight on this issue in conjunction with that on the complementarity between public and private consumption.

The latter, however, requires augmenting the model to account for a richer fiscal sector.

In fact, as shown by [Fève et al., 2013], in order to obtain an unbiased estimate of the elasticity of substitution between public and private goods, government spending needs to be endogenized, at least via the introduction of an automatic-stabilizer component in the spending rule.
As far as DH is concerned, in the microeconometric literature, [Verhelst and Van den Poel, 2013] find some evidence of DH formation by estimating a spatial panel model using scanner data from a large European retailer.

[Ravn et al., 2006] estimate the DH parameters via Generalized Method of Moments (GMM) methods.

[Zubairy, 2014] estimates the DH parameters within the Bayesian estimation of a medium-scale DSGE model.

[Kormilitsina and Zubairy, 2013] compare various mechanisms that may deliver the private consumption crowding-in result in response to a government spending shock. However, they compare, among other things, a model with DH jointly in private and public consumption (including the additional persistence in the stock of habit) with a canonical model with SH only in private consumption and no persistence in the stock of habit.
Habit in Government Consumption

In each period $t$, the government allocates spending $P_t G_t$ over differentiated goods sold by firms in a monopolistic market to maximize the quantity of a habit-adjusted composite good:

$$X_t^g = \left[ \int_0^1 \left(G_{it} - \tilde{\theta}^g S^g_{it-1} \right)^{1 - \frac{1}{e_t \eta}} \, di \right]^{\frac{1}{1 - \frac{1}{e_t \eta}}}$$

subject to the budget constraint $\int_0^1 P_{it} G_{it} \, di \leq P_t G_t$, where $\tilde{\theta}^g$ is the degree of deep habit formation in government spending and $S^g_{it-1}$ denotes the good-specific stock of habit for this expenditure, which evolve as

$$S^g_{it} = \tilde{\rho}^g S^g_{it-1} + (1 - \tilde{\rho}^g) G_{it},$$

and exhibits persistence $\tilde{\rho}^g$. At the optimum,

$$G_{it} = \left( \frac{P_{it}}{P_t} \right)^{-e_t \eta} X_t^g + \tilde{\theta}^g S^g_{it-1}.$$ 

Aggregate real government consumption, $G_t$, is an exogenous process and the government budget constraint equates government spending to lump-sum taxes, $G_t = \tau_t^L$. The standard case of no habit in government consumption is obtained by setting $\tilde{\theta}^g = \tilde{\rho}^g = 0$. 

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### Parameter Estimates

<table>
<thead>
<tr>
<th>Parameters</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_A$</td>
<td>0.9787</td>
<td>0.9787</td>
<td>0.9787</td>
<td>0.9531</td>
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<td>1.2598</td>
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**Table:** Estimated parameters across model variants. STD data and FD of real observables.
## Parameter Estimates

<table>
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<tr>
<th>Shocks</th>
<th>A</th>
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</table>

**Table**: Estimated structural shocks across model variants. STD data and FD of real observables.

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Model Details

Utility function and marginal utilities

\[ U_t = \frac{\left( X_t^c \right)^{(1-\varrho)} (1 - H_t) \varrho^{1 - \sigma_c}}{1 - \sigma_c} - 1 \]  

(7)

\[ U_{X^c,t} = \nu_{X^c} \frac{1}{1 - \varrho} (X_t^c)^{(1-\varrho)(1-\sigma_c)-1} (1 - H_t) \varrho^{(1-\sigma_c)} \]  

(8)

\[ U_{H,t} = -\varrho (X_t^c)^{(1-\varrho)(1-\sigma_c)} (1 - H_t) \varrho^{(1-\sigma_c)-1} \]  

(9)

Euler equation

\[ 1 = E_t \left[ D_{t,t+1} \frac{R_t}{\bar{\pi}_{t+1}} \right] \]  

(10)

\[ D_{t,t+1} = \beta \frac{e_{t+1}^B X_{t+1}^c}{e_t^B X_{t}^c} \]  

(11)

Wage-setting equation

\[ \left( e_t^W \tilde{n} - 1 \right) w_t - e_t^W \tilde{\eta} \frac{w_t}{\hat{\mu}_t} + \xi^W \left( \bar{\pi}_t^W - \tilde{n} \right) w_t \bar{\pi}_t^W = E_t \left[ D_{t,t+1} \xi^W \left( \bar{\pi}_{t+1}^W - \tilde{n} \right) w_{t+1} \bar{\pi}_t^W \frac{H_{t+1}}{H_t} \right] \]  

(12)

\[ \hat{\mu}_t = \frac{w_t}{MRS_t} \]  

(13)

\[ MRS_t = -\frac{U_{H,t}}{U_{C,t}} \]  

(14)
Model Details

Capital accumulation and investment decisions

\[ K_{t+1} = (1 - \delta)K_t + e_t^l \left[ 1 - S \left( \frac{l_t}{l_{t-1}} \right) \right] \]  

(15)

\[ Q_t = E_t \left\{ D_{t,t+1} \left[ u_{t+1}R^K_{t+1} - a(u_{t+1}) + (1 - \delta)Q_{t+1} \right] \right\} \]  

(16)

\[ e_t^l Q_t \left( 1 - S \left( \frac{l_t}{l_{t-1}} \right) - S' \left( \frac{l_t}{l_{t-1}} \right) \frac{l_t}{l_{t-1}} \right) + E_t \left( D_{t,t+1}e_t^l Q_{t+1}S' \left( \frac{l_{t+1}}{l_t} \right) \left( \frac{l_{t+1}}{l_t} \right)^2 \right) = 1 \]  

(17)

\[ a'(u_t) = R^K_t \]  

(18)

\[ S \left( \frac{l_t}{l_{t-1}} \right) = \frac{\gamma}{2} \left( \frac{l_t}{l_{t-1}} - 1 \right)^2 \]  

(19)

\[ S' \left( \frac{l_t}{l_{t-1}} \right) = \gamma \left( \frac{l_t}{l_{t-1}} - 1 \right) \]  

(20)

\[ a(u_t) = \gamma_1 (u_t - 1) + \frac{\gamma_2}{2} (u_t - 1)^2 \]  

(21)

\[ a'(u_t) = \gamma_1 + \gamma_2 (u_t - 1) \]  

(22)
Model Details

Habit dynamics

\[ X^c_t = \begin{cases} C_t - \tilde{\theta}^c S^c_{t-1} & \text{under deep habit} \\ C_t - \tilde{\theta}^c S^c_{t-1} & \text{under superficial habit} \end{cases} \quad (23) \]

\[ S^c_t = \tilde{\theta}^c S^c_{t-1} + (1 - \tilde{\theta}^c) C_t \quad \text{under deep habit} \quad (24) \]

\[ S^c_t = \tilde{\theta}^c S^c_{t-1} + (1 - \tilde{\theta}^c) C_t \quad \text{under superficial habit} \]

\[ X^g_t = C_t - \tilde{\theta}^g S^g_{t-1} \quad (25) \]

\[ S^g_t = \tilde{\theta}^g S^g_{t-1} + (1 - \tilde{\theta}^g) G_t \quad (26) \]

Production function, marginal products and factor demands

\[ F(A_t, H_t, u_t, K_t) = (A_t H_t)^\alpha (u_t K_t)^{1-\alpha} \quad (27) \]

\[ Y_t = F(A_t, H_t, u_t, K_t) - FC \quad (28) \]

\[ F_{H,t} = \alpha \frac{F(A_t, H_t, u_t, K_t)}{H_t} \quad (29) \]

\[ F_{K,t} = (1 - \alpha) \frac{F(A_t, H_t, u_t, K_t)}{u_t K_t} \quad (30) \]

\[ R^K_t = MC_t F_{K,t} \quad (31) \]

\[ \frac{W_t}{P_t} = MC_t F_{H,t} \quad (32) \]
Model Details

Price-setting under deep habit

\[ \nu^c_t = 1 - MC_t + (1 - \tilde{c}^c) \lambda^c_t \]  
\[ \lambda^c_t = E_t D_{t,t+1} (\tilde{c}^c \nu^c_{t+1} + \tilde{c}^c \lambda^c_{t+1}) \]  
\[ \nu^g_t = 1 - MC_t + (1 - \tilde{g}^g) \lambda^g_t \]  
\[ \lambda^g_t = E_t D_{t,t+1} (\tilde{g}^g \nu^g_{t+1} + \tilde{g}^g \lambda^g_{t+1}) \]

\[ C_{it} + G_{it} - e^P_t \eta (\nu^c_{t} X^c_{t} + \nu^g_{t} X^g_{t}) + (1 - e^P_t \eta) I_t + e^P_t \eta MC_t I_t \]  
\[ -\xi^P (\Pi_t - 1) \Pi_t Y_t + \xi^P E_t \{D_{t,t+1} [(\Pi_{t+1} - 1) \Pi_{t+1}] Y_{t+1} = 0\}. \]  

Price-setting under superficial habit

\[ 1 - e^P_t \eta + \frac{e^P_t \eta}{\mu_t} - \xi^P (\Pi_t - 1) \Pi_t + \xi^P E_t \left[D_{t,t+1} (\Pi_{t+1} - 1) \Pi_{t+1} \frac{Y_{t+1}}{Y_t}\right] = 0 \]
Taylor rule

\[
\log \left( \frac{R_t}{R} \right) = \rho_R \log \left( \frac{R_t}{R} \right) + (1 - \rho_R) \left[ \rho_{\Pi} \log \left( \frac{\Pi_t}{\Pi} \right) + \rho_Y \log \left( \frac{Y_t}{Y} \right) \right] + \epsilon^M_t
\]  

(39)

Resource constraint and autoregressive processes

\[
Y_t = C_t + I_t + G_t + \frac{\xi^P}{2} (\Pi_t - 1)^2 Y_t + \frac{\xi^W}{2} (\Pi_t^W - \bar{\Pi})^2 w_t H_t + a(\mu_t) K_t
\]  

(40)

\[
\log \left( \frac{G_t}{G} \right) = \rho_G \log \left( \frac{G_{t-1}}{G} \right) + \epsilon^G_t
\]  

(41)

\[
\log \left( \frac{A_t}{A} \right) = \rho_A \log \left( \frac{A_{t-1}}{A} \right) + \epsilon^A_t
\]  

(42)

\[
\log \left( \frac{e^P_t}{e^P} \right) = \rho_{eP} \log \left( \frac{e^P_{t-1}}{e^P} \right) + \epsilon^P_t
\]  

(43)

\[
\log \left( \frac{e^B_t}{e^B} \right) = \rho_{eB} \log \left( \frac{e^B_{t-1}}{e^B} \right) + \epsilon^B_t
\]  

(45)

\[
\log \left( \frac{e^W_t}{e^W} \right) = \rho_{eW} \log \left( \frac{e^W_{t-1}}{e^W} \right) + \epsilon^W_t
\]  

(46)
Impulse response functions (Preference)
Impulse response functions (Investment)

Impulse responses to a shock to investment

Real output
Priv. consumption
Investment
Nom. int. rate
Infl. rate
Price mark–up

Percentage deviations from steady state

Model A: SH in C
Model B: DH in C
Model C: DH in C and G
Model D: SH in C, $\rho_c = 0$
Impulse response functions (Monetary Policy)

Impulse responses to a shock to monetary policy

Real output

Priv. consumption

Investment

Nom. int. rate

Infl. rate

Price mark-up

Percentage deviations from steady state

Model A: SH in C
Model B: DH in C
Model C: DH in C and G
Model D: SH in C, \( \rho_c = 0 \)

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Deep versus Superficial Habit: It’s All in the Persistence
Impulse response functions (Wage Mark-up)

**Impulse responses to a shock to wage mark-up**

- Real output
- Priv. consumption
- Investment
- Nom. int. rate
- Infl. rate
- Price mark-up

**Model**
- Model A: SH in C
- Model B: DH in C
- Model C: DH in C and G
- Model D: SH in C, $\rho_c = 0$

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Impulse response functions (Price Mark-up)

- Real output
- Private consumption
- Investment
- Nominal interest rate
- Inflation rate
- Price mark-up

Model A: SH in C
Model B: DH in C
Model C: DH in C and G
Model D: SH in C, $\rho_c = 0$

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