Sticky Expectations and Consumption Dynamics

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Consumption Dynamics

Macro

- Theory: Uninsurable Risk Is Unimportant
- Evidence: Consumption Is Too Smooth
- Conclusion: Habits ≈ 0.75

Micro

- Theory: Uninsurable Risk Is Essential
- Evidence: Habits $=0.75$ Rejectable With Confidence $= \infty$
- $\text{var}(\Delta \log \mathbf{c}) \approx 100\ \text{var}(\Delta \log \mathbf{C})$

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Proposal: Macro (Not Micro) Inattention

- Income Has Idiosyncratic And Aggregate Components
- Idiosyncratic Component Is Perfectly Observed
- Aggregate Component Is Stochastically Observed

Not *ad hoc*

- Identical: Mankiw and Reis (2002), Carroll (2003)
- Similar: Sims (2003), Woodford (2001), Reis (2003)

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Why This Is Plausible

Idiosyncratic Variability Is $\sim 100\times$ Bigger

- If Same Equation Estimated on Micro vs Macro Data
- Pervasive Lesson Of All Micro Data

Utility Cost Of Inattention

- Micro: Critical (and Easy) To Notice You're Unemployed
- Unlike Pischke (1995)
- Macro: Not Critical To Instantly Notice If U $\uparrow$

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- Smoothness: Campbell and Deaton (1989), Pischke (1995), Rotemberg and Woodford (1997)
- Inattention: Pischke (1995); Mankiw and Reis (2002); Reis (2003); Sims (2003)
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Quadratic Utility Benchmark

Total Wealth:

$$\mathbf{z}_{t+1} = (\mathbf{z}_t - \mathbf{c}_t)\mathsf{R} + \zeta_{t+1}, \tag{1}$$

Euler Equation:

$$\mathbf{u}'(\mathbf{c}_t) = \mathsf{R}\beta\mathbf{E}_t[\mathbf{u}'(\mathbf{c}_{t+1})], \tag{2}$$

Random Walk:

$$\Delta\mathbf{c}_{t+1} = \epsilon_{t+1}. \tag{3}$$

Expected wealth:

$$\mathbf{z}_t = \mathbf{E}_t[\mathbf{z}_{t+1}] = \mathbf{E}_t[\mathbf{z}_{t+2}]... \tag{4}$$

Sticky Expectations

- Consumer Who Happens To Update At t and $t+n$

$$
\begin{aligned}
\mathbf{c}_t &= (\mathsf{r}/\mathsf{R})\mathbf{z}_t \\
\mathbf{c}_{t+1} &= (\mathsf{r}/\mathsf{R})\bar{\mathbf{z}}_{t+1} = (\mathsf{r}/\mathsf{R})\mathbf{z}_t = \mathbf{c}_t \\
\vdots &\quad \vdots \\
\mathbf{c}_{t+n-1} &= \mathbf{c}_t .
\end{aligned}
$$

- Implies that $\Delta^n \mathbf{z}_{t+n} \equiv \mathbf{z}_{t+n} - \mathbf{z}_t$ is white noise
- So individual $\mathbf{c}$ is RW across updating periods:

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\mathbf{c}_{t+n} - \mathbf{c}_t = (\mathsf{r}/\mathsf{R}) \underbrace{(\mathbf{z}_{t+n} - \mathbf{z}_t)}_{\Delta^n \mathbf{z}_{t+n}} \qquad (5)
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Sticky Expectations

- Pop normed to one, uniformly dist on $[0, 1]$

$$\mathbf{C}_t = \int_0^1 \mathbf{c}_{t,i}\, di.$$

- Calvo (1983) Type Updating Of Expectations:
  - Probability $\Pi = 0.25$
- Economy Composed Of Many Sticky Conumers:

$$\Delta \mathbf{C}_{t+1} \approx \underbrace{(1-\Pi)}_{=0.75} \Delta \mathbf{C}_t + \epsilon_{t+1} \qquad (6)$$

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One More Ingredient ...

- Distinguish idiosyncratic and aggregate shocks
  - Frictionless observation of idiosyncratic shocks
  - True RW with respect to these
  - Sticky observation of aggregate shocks
- Result:
  - Idiosyncratic $\Delta \mathbf{c}$ dominated by frictionless RW part
  - Aggregate $\Delta \mathbf{C}$ highly serially correlated
  - Law of large numbers: idiosyncratic part vanishes

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Muth–Pischke/Lucas/Kalman

Muth (1960)-Pischke (1995)/Lucas (1973) - Kalman filter

- All you can see is Y
  - Lucas: Can't distinguish agg. from idio.
  - Muth-Pischke: Can't distinguish tran from perm
- Here: Can see own circumstances perfectly
- Only the (tiny) aggregate part is hard to see
- But *can't* permit signal extraction wrt aggregate
  - Signal extraction wrt agg implies agg random walk
- Will return to this below

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Serious Model

Partial Equilibrium/Small Open Economy

- CRRA Utility
- Idiosyncratic Shocks Calibrated From Micro Data
- Aggregate Shocks Calibrated From Macro Data
- No Liquidity Constraints
- Mildly Impatient Consumers

DSGE Model

- Same!

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Income Process

- Individual's labor productivity is

$$\boldsymbol{\ell}_{t+1} = \overbrace{\theta_{t+1}\Theta_{t+1}}^{\equiv\boldsymbol{\theta}_{t+1}} \underbrace{p_{t+1}P_{t+1}}_{\equiv\mathbf{p}_{t+1}} \quad (7)$$

- Idiosyncratic and aggregate p evolve according to

$$p_{t+1} = p_t\psi_{t+1} \quad (8)$$

$$P_{t+1} = P_t\Psi_{t+1} \quad (9)$$

- $\mathbf{E}_t[\theta_{t+n}] = \mathbf{E}_t[\Theta_{t+n}] = \mathbf{E}_t[\psi_{t+n}] = \mathbf{E}_t[\Psi_{t+n}] = 1 \ \forall \ n > 0$

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- Idiosyncratic and aggregate p evolve according to

$$p_{t+1} = p_t\psi_{t+1} \quad (8)$$

$$P_{t+1} = P_t\Psi_{t+1} \quad (9)$$

- $\mathbb{E}_t[\theta_{t+n}] = \mathbb{E}_t[\Theta_{t+n}] = \mathbb{E}_t[\psi_{t+n}] = \mathbb{E}_t[\Psi_{t+n}] = 1 \; \forall \; n > 0$

Income Process

- Individual's labor productivity is

$$\boldsymbol{\ell}_{t+1} = \overbrace{\theta_{t+1}\Theta_{t+1}}^{\equiv \boldsymbol{\theta}_{t+1}} \underbrace{p_{t+1}P_{t+1}}_{\equiv \mathbf{p}_{t+1}} \tag{7}$$

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Resources

- Market resources:

$$\mathbf{m}_{t+1} = \underbrace{\mathcal{W}_{t+1}\boldsymbol{\ell}_{t+1}}_{\equiv \mathbf{y}_{t+1}} + \underbrace{\mathsf{R}_{t+1}}_{1+\mathsf{r}_{t+1}} \mathbf{k}_{t+1} \tag{10}$$

- 'Assets': Unspent resources

$$\mathbf{a}_t = \mathbf{m}_t - \mathbf{c}_t \tag{11}$$

- Capital transition depends on prob of survival Ω:

$$\mathbf{k}_{t+1} = \mathbf{a}_t/\Omega \tag{12}$$

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Frictionless Solution

- Assume constant $\mathcal{R}, \mathcal{W}$
- Normalize everything by $p_t P_t$ e.g. $m_t = \mathbf{m}_t / p_t P_t$
- $c(m_t)$ is the function that solves

$$v(m_t) = \max_{c} \{ u(c) + \beta \mathbf{E}_t [\psi_{t+1}^{1-\rho} v(m_{t+1})] \}$$

- Level of consumption given by

$$\mathbf{c}_t = c(m_t) \mathbf{p}_t .$$

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Blanchard (1985) Mortality

- Agent survives from t to $t+1$ with probability Ω

$$p_{t+1,i} = \begin{cases} 1 & \text{for newborns} \\ p_{t,i}\psi_{t+1,i} & \text{for survivors,} \end{cases}$$

- Implies steady-state distribution of p with variance:

$$\text{var}(p) = \left(\frac{1-\Omega}{1-\Omega E[\psi^2]} - 1 \right)$$

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Blanchard (1985) Insurance

$$\mathbf{k}_{t+1,i} = \begin{cases} 0 & \text{if agent at } i \text{ dies, is replaced by a newborn} \\ \mathbf{a}_{t,i}\daleth/\Omega & \text{if agent at } i \text{ survives} \end{cases}$$

Implies

$$\begin{aligned} \mathbf{K}_{t+1} &= \int_0^1 \omega_{t+1,i}\daleth\mathbf{a}_{t,i}/\Omega di \\ &= \daleth\mathbf{A}_t \\ K_{t+1} &= \daleth A_t/\Psi_{t+1} \end{aligned}$$

Sticky Aggregate Expectations

$$\bar{\Theta}_{t,i} = \begin{cases} \Theta_t & \text{for updaters} \\ 1 & \text{for nonupdaters} \end{cases}$$

$$\bar{P}_{t+1,i} = \pi_{t+1,i} P_{t+1} + (1 - \pi_{t+1,i}) \bar{P}_{t,i} \tag{13}$$

Sequence within period:

1. Shocks are Realized
2. Each Individual Updates (Or Not)
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Behavior

Consumers behave according to frictionless consumption function:

$$\begin{aligned} \bar{c}_{t,i} &= c(\bar{m}_{t,i}) \\ \mathbf{c}_{t,i} &= \bar{c}_{t,i}\bar{P}_{t,i}p_{t,i} \end{aligned}$$

- Correctly perceive level of spending

$$\bar{\mathbf{a}}_{t,i} = \bar{\mathbf{m}}_{t,i} - \mathbf{c}_{t,i} \tag{14}$$

$$\bar{\mathbf{k}}_{t+1,i} = \omega_{t+1,i}\urcorner\left(\mathbf{a}_{t,i}\pi_{t+1,i} + \bar{\mathbf{a}}_{t,i}(1-\pi_{t+1,i})\right)/\Omega + (1-\omega_{t+1,i})0 \tag{15}$$

Cost Of Stickiness

Newborns' value can be approximated by

$$\bar{v}(\mathcal{W}) \approx \overleftarrow{v}(\mathcal{W}) - (\kappa/\Pi)\sigma_{\Psi}^{2}. \tag{16}$$

If Newborns Pick Optimal Π, they solve

$$\max_{\Pi} \overleftarrow{v}(\mathcal{W}) - (\kappa/\Pi)\sigma_{\Psi}^{2} - \iota\Pi. \tag{17}$$

Solution:

$$\Pi = (\kappa/\iota)^{0.5}\sigma_{\Psi} \tag{18}$$

Muth–Pischke Perception Dynamics

$$\bar{P}_{t+1} = \Pi P_{t+1} + (1 - \Pi)\bar{P}_t \tag{19}$$

- Observe $\mathbf{Y}$
- Define signal-to-noise ratio $\varphi = \sigma_\psi^2 / \sigma_\theta^2$

Optimal Estimate of P obtained from

$$\bar{P}_{t+1} = \Pi \mathbf{Y}_{t+1} + (1 - \Pi)\bar{P}_t \tag{20}$$

where

$$\Pi = \left(\frac{1}{1 + 2/(\varphi + \sqrt{\varphi^2 + 4\varphi})} \right), \tag{21}$$

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Pischke (1995): This is why **C** is too smooth

- If we calibrate using observed micro data
  - $\Rightarrow \Delta \log \mathbf{C}_{t+1} \approx 0.967 \, \Delta \log \mathbf{C}_t$
  - Goes too far!
- It's because people can't tell agg from ind shocks
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DSGE Model

Frictionless:

- No Idiosyncratic Shocks
- Aggregate Shocks Same as PE/SOE
- Cobb-Douglas production: $M_t = K_t + K_t^{\varepsilon}\Theta_t^{1-\varepsilon}$

$$
\begin{aligned}
V(M_t) &= \max_{C_t} \left\{ \mathbf{u}(c_t) + \beta \mathbf{E}_t[\Psi_{t+1}^{1-\rho} V(M_{t+1})] \right\} \qquad (23) \\
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Sticky Expectations DSGE

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Benchmark: Random Walk

$$* \quad \Delta \log \mathbf{C}_{t+1} \approx \varsigma + \vartheta \mathbf{E}_t[r_{t+1}] + \mu X_{t-1} + \epsilon_{t+1}, \qquad (24)$$

and random walk means $\mu = 0$.
In GE, r depends on A so $*$ is equivalent to:

$$\Delta \log \mathbf{C}_{t+1} \approx \varsigma + \alpha A_t + \mu X_{t-1} + \epsilon_{t+1} \qquad (25)$$

In either case, lots of X_{t-1} were found for which $\mu \neq 0$.

Campbell and Mankiw (1989)

$$\Delta \log \mathbf{C}_{t+1} \quad \approx \quad \varsigma + \alpha A_t + \eta \mathbf{E}[\Delta \log \mathbf{Y}_{t+1}] + \epsilon_{t+1} \qquad (26)$$

Claims:

- η estimates fraction of 'rule-of-thumb' $C = Y$ consumers
- $\eta \approx 0.5$ robustly for U.S. and other countries
- No further predictability in $\Delta \log \mathbf{C}_{t+1}$

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Macro Habits

Campbell and Deaton (1989); Rotemberg and Woodford (1997); Fuhrer (2000); Sommer (2001)
Dynan (2000)/Sommer specification:

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Micro Evidence

$$\Delta \log \mathbf{c}_{t+1} \approx \varsigma + \alpha a_t + \eta \mathbf{E}[\Delta \log \mathbf{y}_{t+1}] + \chi \mathbf{E}[\Delta \log \mathbf{c}_t] + \epsilon_{t+1}$$

Separable Theory:

- $\alpha < 0$
- $0 < \eta < 1$
- $\chi \approx 0$

Micro Evidence on Habits:

- No: Meghir and Weber (1996); Dynan (2000); Flavin and Nakagawa (2005)
- Maybe a little: Carrasco, Labeaga, and Lòpez-Salido (2005)

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Micro Vs Macro

$$\Delta \log \mathbf{C}_{t+1} \approx \varsigma + \chi \Delta \log \mathbf{C}_t + \eta \mathbf{E}_t[\Delta \log \mathbf{Y}_{t+1}] + \alpha A_t + \epsilon_{t+1}$$

	χ	η	α
Micro (Separable)			
Theory	≈ 0	$0 < \eta < 1$	< 0
Data	≈ 0	$0 < \eta < 1$	< 0
Macro			
Theory:Separable	≈ 0	≈ 0	< 0
Theory:CampMan	≈ 0	≈ 0.5	< 0
Theory:Habits	≈ 0.75	≈ 0	< 0

Calibration—DSGE

DSGE Model		
Calibrated Parameters		
ρ	2.	Coefficient of Relative Risk Aversion
$\daleth$	$0.94^{1/4}$	Quarterly Depreciation Factor
K/K^{ε}	12	Perf Foresight SS Capital/Output Ratio
σ_{Θ}^{2}	0.00001	Variance Qtrly Tran Agg Pty Shocks
σ_{Ψ}^{2}	0.00004	Variance Qtrly Perm Agg Pty Shocks
Steady State Solution of Model With $\sigma_{\Psi} = \sigma_{\Theta} = 0$		
$K = 12^{1/(1-\varepsilon)}$	≈ 48.55	Steady State Quarterly **K**/**P** Ratio
$M = K + K^{\varepsilon}$	≈ 52.6	Steady State Quarterly **M**/**P** Ratio
$\mathcal{W} = (1-\varepsilon)K^{\epsilon}$	≈ 2.59	Quarterly Wage Rate
$\mathcal{R} = 1 + \varepsilon K^{\varepsilon-1}$	$= 1.03$	Quarterly Gross Capital Income Factor
$\mathbf{R} = \mathcal{R}\daleth$	≈ 1.014	Quarterly Between-Period Interest Factor
$\beta = \mathbf{R}^{-1}$	≈ 0.986	Quarterly Time Preference Factor

Calibration—PE/SOE

Partial Equilibrium/Small Open Economy (PE/SOE) Model Parameters		
Calibrated Parameters		
$\sigma^2_{\vec{\psi}}$	0.016	Variance Annual Perm Idiosyncratic Shocks (I
$\sigma^2_{\vec{\theta}}$	0.03	Variance Annual Tran Idiosyncratic Shocks (F
$\wp$	0.05	Quarterly Probability of Unemployment Spell
Π	0.25	Quarterly Probability of Updating Expectatio
$(1-\Omega)$	0.005	Quarterly Probability of Mortality
Calculated Parameters		
$\beta = 0.99\Omega/E[(\psi)^{-\rho}]\mathbf{R}$	0.965	Satisfies Impatience Condition: $\beta < \Omega/E[(\Psi\psi$
σ^2_{ψ}	0.004	Variance Qtrly Perm Idiosyncratic Shocks $(=$
σ^2_{θ}	0.12	Variance Qtrly Tran Idiosyncratic Shocks $(=4$

Equilibrium

	PE/SOE Economy		DSGE Economy	
	Frictionless	Sticky	Frictionless	Sticky
Means				
A	6.650	6.648	49.382	49.371
C	2.684	2.684	3.290	3.289
Standard Deviations				
Aggregate Time Series ('Macro')				
$\log \mathbf{A}$	0.089	0.091	0.085	0.085
$\Delta \log \mathbf{C}$	0.005	0.002	0.003	0.001
$\Delta \log \mathbf{Y}$	0.008	0.003	0.005	0.002
Individual Cross Sectional ('Micro')				
$\log \mathbf{a}$	1.273	1.273		
$\log \mathbf{c}$	1.207	1.207		
$\log \mathbf{p}$	1.221	1.221		
$\log \mathbf{y} \vert \mathbf{y} > 0$	0.846	0.846		
$\Delta \log \mathbf{c}$	0.151	0.149		
Cost Of Stickiness	0.31×10^{-4}		0.53×10^{-5}	

Micro Theory: Frictionless

$$\Delta \log \mathbf{c}_{t+1,i} \quad = \quad \varsigma + \chi \Delta \log \mathbf{c}_{t,i} + \eta \mathbf{E}_{t,i}[\Delta \log \mathbf{y}_{t+1,i}] + \alpha \underline{a}_{t,i}$$

Model of Expectations	χ	η	α	$\bar{R}^2$	nobs
Frictionless					
	0.083			0.007	76020
	(0.077)				
		0.003		-0.000	76020
		(0.004)			
			-0.111	0.000	76020
			(0.052)		
	0.083	0.009	-0.059	0.007	76020
	(0.004)	(0.004)	(0.024)		

Micro Theory: Sticky

$$\Delta \log \mathbf{c}_{t+1,i} \quad = \quad \varsigma + \chi \Delta \log \mathbf{c}_{t,i} + \eta \mathbf{E}_{t,i}[\Delta \log \mathbf{y}_{t+1,i}] + \alpha \underline{a}_{t,i}$$

Model of Expectations	χ	η	α	$\bar{R}^2$	nobs
Sticky					
	0.084			0.007	76020
	(0.077)				
		0.003		-0.000	76020
		(0.004)			
			−0.111	0.000	76020
			(0.051)		
	0.083	0.009	−0.059	0.007	76020
	(0.004)	(0.004)	(0.024)		

DSGE Macro: Frictionless

$$\Delta \log \mathbf{C}_{t+1} \quad = \quad \varsigma + \chi \Delta \mathbf{E}[\log \mathbf{C}_t] + \eta \mathbf{E}[\Delta \log \mathbf{Y}_{t+1}] + \alpha \mathbf{E}[A_t]$$

Expectations:Dep Var Independent Variables			OLS or IV	2nd Stage $\bar{R}^2$	IV F p-val IV OID
Frictionless: $\Delta \log \mathbf{C}_{t+1}$					
$\Delta \log \mathbf{C}_t$	$\Delta \log \mathbf{Y}_{t+1}$	A_t			
0.010 (0.032)			OLS	-0.001	
	0.184 (0.050)		IV	0.007	0.000 0.001
		-0.0002 (0.0001)	OLS	0.010	
-0.019 (0.027)	0.152 (0.052)	-0.0002 (0.0001)	IV	0.007	

DSGE Macro: Sticky

$$\Delta \log \mathbf{C}_{t+1} \quad = \quad \varsigma + \chi \Delta \mathbf{E}[\log \mathbf{C}_t] + \eta \mathbf{E}[\Delta \log \mathbf{Y}_{t+1}] + \alpha \mathbf{E}[A_t]$$

Expectations:Dep Var Independent Variables			OLS or IV	2nd Stage $\bar{R}^2$	IV F p-val IV OID
$\Delta \log \bar{\mathbf{C}}_t$	Sticky $\Delta \log \bar{\mathbf{Y}}_{t+1}$	$\bar{A}_t$			
0.823 (0.018)			OLS	0.677	
$\Delta \log \tilde{\bar{\mathbf{C}}}_t$					
0.387 (0.030)			OLS	0.141	
0.845 (0.042)			IV	0.422	0.000 0.210
	0.815 (0.025)		IV	0.395	0.000 0.000
		−0.0004 (0.0000)	OLS	0.115	
0.750 (0.148)	0.065 (0.146)	−0.0001 (0.0000)	IV	0.423	 0.126
Memo: For instruments $\mathbf{Z}_t$, $\Delta \log \mathbf{C}_{t+1} = \mathbf{Z}_t \zeta$, $\bar{R}^2 =$				0.425	

Small Open Economy: Frictionless

$$\Delta \log \mathbf{C}_{t+1} = \varsigma + \chi \Delta \mathbf{E}[\log \mathbf{C}_t] + \eta \mathbf{E}[\Delta \log \mathbf{Y}_{t+1}] + \alpha \mathbf{E}[A_t]$$

Expectations:Dep Var Independent Variables			OLS or IV	2nd Stage $\bar{R}^2$	IV F p-val IV OID
Frictionless: $\Delta \log \mathbf{C}_{t+1}$					
$\Delta \log \mathbf{C}_t$	$\Delta \log \mathbf{Y}_{t+1}$	A_t			
0.022 (0.010)			OLS	0.000	
	0.028 (0.016)		IV	0.000	0.000 0.030
		-0.0008 (0.0004)	OLS	0.000	
0.019 (0.010)	0.028 (0.016)	-0.0005 (0.0004)	IV	0.000	

Small Open Economy: Sticky

$$\Delta \log \mathbf{C}_{t+1} \quad = \quad \varsigma + \chi\Delta\mathbf{E}[\log \mathbf{C}_t] + \eta\mathbf{E}[\Delta \log \mathbf{Y}_{t+1}] + \alpha\mathbf{E}[A_t]$$

Expectations:Dep Var Independent Variables			OLS or IV	2nd Stage $\bar{R}^2$	IV F p-val IV OID
$\Delta \log \bar{\mathbf{C}}_t$	$\Delta \log \bar{\mathbf{Y}}_{t+1}$	$\bar{A}_t$			
0.345			OLS	0.121	
(0.009)					
0.805			IV	0.363	0.000
(0.014)					0.000
	1.150		IV	0.352	0.000
	(0.015)				0.000
0.498	0.496	−0.0007	IV	0.375	
(0.028)	(0.040)	(0.0005)			0.000
Memo: For instruments $\mathbf{Z}_t$, $\Delta \log \mathbf{C}_{t+1} = \mathbf{Z}_t\zeta$, $\bar{R}^2 =$				0.390	

Empirical Results for U.S.

$$\Delta \log \mathbf{C}_{t+1} = \varsigma + \chi \Delta \log \mathbf{C}_t + \eta \mathbf{E}[\Delta \log \mathbf{Y}_{t+1}] + \alpha A_t$$

Consumption Series	χ	η	α	Method OLS/IV	$\bar{R}^2_2$	IV F p-val IV OID
Nondurables and Services						
	0.358***			OLS	0.123	
	(0.066)					
		0.577***		IV	0.172	0.000
		(0.118)				0.702
			0.0006	OLS	0.002	
			(0.0006)			
	0.826***			IV	0.143	0.000
	(0.147)					0.714
	0.731***	0.071	0.0000	IV	0.135	
	(0.230)	(0.118)	(0.0003)			0.482
Memo:	For instruments $\mathbf{Z}$, $\Delta \log \mathbf{C}_{t+1} = \mathbf{Z}\zeta$, $\bar{R}^2 = 0.168$					

Instruments: `L(2/3).diffcons L(2/3).wyRatio L(2/3).bigTheta L(2/3).dfedfunds L(2/3).ics`
Time frame: 1960Q1–2004Q3, $\sigma^2_\Psi = .0000429$, $\sigma^2_\Theta = .0000107$

ABEL, ANDREW B. (1990): "Asset Prices under Habit Formation and Catching Up with the Joneses," *American Economic Review*, 80(2), 38–42.

BLANCHARD, OLIVIER J. (1985): "Debt, Deficits, and Finite Horizons," *Journal of Political Economy*, 93(2), 223–247.

CALVO, GUILLERMO A. (1983): "Staggered Contracts in a Utility-Maximizing Framework," *Journal of Monetary Economics*, 12, 383–98.

CAMPBELL, JOHN Y., AND ANGUS S. DEATON (1989): "Why Is Consumption So Smooth?," *Review of Economic Studies*, 56, 357–74.

CAMPBELL, JOHN Y., AND N. GREGORY MANKIW (1989): "Consumption, Income, and Interest Rates: Reinterpreting the Time-Series Evidence," in *NBER Macroeconomics Annual, 1989*, ed. by Olivier J. Blanchard, and Stanley Fischer, pp. 185–216. MIT Press, Cambridge, MA.

CARRASCO, RAQUEL, JOSÈ M. LABEAGA, AND J. DAVID LÒPEZ-SALIDO (2005): "Consumption and Habits: Evidence from Panel Data," *Economic Journal*, 115(500), 144–165, available at http://ideas.repec.org/a/ecj/econjl/v115y2005i500p144-165.html.

Carroll, Christopher D. (2003): "Macroeconomic Expectations of Households and Professional Forecasters," *Quarterly Journal of Economics*, 118(1), 269–298, `http://econ.jhu.edu/people/ccarroll/epidemiologyQJE.pdf`.

Constantinides, George M. (1990): "Habit Formation: A Resolution of the Equity Premium Puzzle," *Journal of Political Economy*, 98, 519–43.

Dynan, Karen E. (2000): "Habit Formation in Consumer Preferences: Evidence from Panel Data," *American Economic Review*, 90(3).

Flavin, Marjorie J., and Shinobu Nakagawa (2005): "A Model of Housing in the Presence of Adjustment Costs: A Structural Interpretation of Habit Persistence," *Manuscript UCSD*.

FUHRER, JEFFREY C. (2000): "An Optimizing Model for Monetary Policy: Can Habit Formation Help?," *American Economic Review*, 90(3).

LUCAS, ROBERT E. (1973): "Some International Evidence on Output-Inflation Tradeoffs," *American Economic Review*, 63, 326–334.

MANKIW, N. GREGORY, AND RICARDO REIS (2002): "Sticky Information Versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve," *Quarterly Journal of Economics*, 117(4), 1295–1328.

MEGHIR, COSTAS, AND GUGLILELMO WEBER (1996): "Intertemporal Non-Separability or Borrowing Restrictions? A Disaggregate Analysis Using a U.S. Consumption Panel," *Econometrica*, 64(5), 1151–82.

MUTH, JOHN F. (1960): "Optimal Properties of Exponentially Weighted Forecasts," *Journal of the American Statistical Association*, 55(290), 299–306.

PISCHKE, JÖRN-STEFFEN (1995): "Individual Income, Incomplete Information, and Aggregate Consumption," *Econometrica*, 63(4), 805–40.

REIS, RICARDO (2003): "Inattentive Consumers," *Manuscript, Harvard University*.

ROTEMBERG, JULIO J., AND MICHAEL WOODFORD (1997): "An Optimization-Based Econometric Model for the Evaluation of Monetary Policy," in *NBER Macroeconomics Annual, 1997*, ed. by Benjamin S. Bernanke, and Julio J. Rotemberg, vol. 12, pp. 297–346. MIT Press, Cambridge, MA.

SIMS, CHRISTOPHER A. (2003): "Implications of Rational Inattention," *Journal of Monetary Economics*, 50(3), 665–690, available at http://ideas.repec.org/a/eee/moneco/v50y2003i3p665-690.html.

SOMMER, MARTIN (2001): "Habits, Sentiment and Predictable Income in the Dynamics of Aggregate Consumption," *Manuscript, The Johns Hopkins University*, http://econ.jhu.edu/pdf/papers/wp458.pdf.

WOODFORD, MICHAEL (2001): “Imperfect Common Knowledge and the Effects of Monetary Policy,” *NBER Working Paper Number 8673*.