

# Theoretical Foundations of Buffer Stock Saving

Chris Carroll

Johns Hopkins University

September 12, 2019

Powered By



# Drawbacks of Numerical Solutions

## A Black Box

- Can Construct Solution to Model Without Really Understanding It
- Hard Even To Be Sure Your Numerical Solution Is *Right*
- Little Intuition for How Results Might Change With
  - Calibration
  - Structure
- *Very Hard To Teach!*

## I Am A *Big* Fan Of Numerical Methods

- Have Done A Good Deal Of Work With Them Myself
- But As A Result, Have Felt All These Drawbacks Keenly

# Drawbacks of Numerical Solutions

## A Black Box

- Can Construct Solution to Model Without Really Understanding It
- Hard Even To Be Sure Your Numerical Solution Is *Right*
- Little Intuition for How Results Might Change With
  - Calibration
  - Structure
- *Very Hard To Teach!*

## I Am A *Big* Fan Of Numerical Methods

- Have Done A Good Deal Of Work With Them Myself
- But As A Result, Have Felt All These Drawbacks Keenly

# Drawbacks of Numerical Solutions

## A Black Box

- Can Construct Solution to Model Without Really Understanding It
- Hard Even To Be Sure Your Numerical Solution Is *Right*
- Little Intuition for How Results Might Change With
  - Calibration
  - Structure
- Very Hard To Teach!

## I Am A *Big* Fan Of Numerical Methods

- Have Done A Good Deal Of Work With Them Myself
- But As A Result, Have Felt All These Drawbacks Keenly

# Drawbacks of Numerical Solutions

## A Black Box

- Can Construct Solution to Model Without Really Understanding It
- Hard Even To Be Sure Your Numerical Solution Is *Right*
- Little Intuition for How Results Might Change With
  - Calibration
  - Structure
- Very Hard To Teach!

## I Am A *Big* Fan Of Numerical Methods

- Have Done A Good Deal Of Work With Them Myself
- But As A Result, Have Felt All These Drawbacks Keenly

# The Gap This Paper Fills

Foundations For Microeconomic Household's Problem With

- Uncertain Labor Income
- No Liquidity Constraints
- CRRA Utility
- (Problem with Liquidity Constraints Is A Limiting Case)

# The Gap This Paper Fills

Foundations For Microeconomic Household's Problem With

- Uncertain Labor Income
- No Liquidity Constraints
- CRRA Utility
- (Problem with Liquidity Constraints Is A Limiting Case)

# Key Result

Restrictions On Parameter Values Such That

- Problem Defines A Contraction Mapping
  - $\Rightarrow \exists$  A Unique Consumption Function  $c(m)$
- There Is A 'Target' Ratio Of Assets to Permanent Income
  - Requires A Key 'Impatience' Condition To Hold
  - Good News
    - Condition Is Weaker (Easier To Satisfy) Than Previous Papers Imposed



# Key Result

## Restrictions On Parameter Values Such That

- Problem Defines A Contraction Mapping
  - $\Rightarrow \exists$  A Unique Consumption Function  $c(m)$
- There Is A 'Target' Ratio Of Assets To Permanent Income
  - Requires A Key 'Impatience' Condition To Hold
  - Good News
    - Condition Is Weaker (Easier To Satisfy) Than Previous Papers Imposed

# Key Result

Restrictions On Parameter Values Such That

- Problem Defines A Contraction Mapping
  - $\Rightarrow \exists$  A Unique Consumption Function  $c(m)$
- There Is A 'Target' Ratio Of Assets To Permanent Income
  - Requires A Key 'Impatience' Condition To Hold
  - Good News
    - Condition Is Weaker (Easier To Satisfy) Than Previous Papers Imposed

Limit as horizon  $T$  goes to infinity of

$$v_{T-n} = \max \mathbb{E}_t \left[ \sum_{i=0}^n \beta^i u(c_{t+i}) \right]$$

$$a_t = m_t - c_t$$

$$k_{t+1} = a_t$$

$$b_{t+1} = k_{t+1}R$$

$$p_{t+1} = p_t \underbrace{\Phi \Psi_{t+1}}_{\equiv \Phi_{t+1}}$$

$$m_{t+1} = b_{t+1} + p_{t+1} \xi_{t+1},$$

$$\xi_{t+n} = \begin{cases} 0 & \text{with probability } \wp > 0 \\ \theta_{t+n}/(1 - \wp) & \text{with probability } (1 - \wp) \end{cases} \quad (1)$$

$$\bullet \quad u(\bullet) = \bullet^{1-\rho}/(1-\rho); \mathbb{E}_t[\Psi_{t+n}] = \mathbb{E}_t[\xi_{t+n}] = 1 \quad \forall \quad n > 0; \beta < 1, \rho > 1$$

# Surely This Problem Has Been Solved?

No.

- Can't Use Stokey et. al. theorems because CRRA utility
- Lit thru Matkowski and Nowak (2011) Can't Handle Permanent Shocks
- Must Use Boyd's 'Weighted' Contraction Mapping Theorem
- Surprisingly Subtle

Fortunately, the Conclusions Are Simple!

# Surely This Problem Has Been Solved?

No.

- Can't Use Stokey et. al. theorems because CRRA utility
- Lit thru Matkowski and Nowak (2011) Can't Handle Permanent Shocks
- Must Use Boyd's 'Weighted' Contraction Mapping Theorem
- Surprisingly Subtle

Fortunately, the Conclusions Are Simple!

# Surely This Problem Has Been Solved?

No.

- Can't Use Stokey et. al. theorems because CRRA utility
- Lit thru Matkowski and Nowak (2011) Can't Handle Permanent Shocks
- Must Use Boyd's 'Weighted' Contraction Mapping Theorem
- Surprisingly Subtle

Fortunately, the Conclusions Are Simple!

## Benchmark: Perfect Foresight Model

Definitions:

Absolute Patience Factor	$\mathbf{P}$	=	$(R\beta)^{1/\rho}$
Return Patience Factor	$\mathbf{P}_R$	=	$\mathbf{P}/R$
Perfect Foresight Growth Patience Factor	$\mathbf{P}_\Phi$	=	$\mathbf{P}/\Phi$

Name	Condition	Implication
(AIC) Absolute Impatience Condition	$\mathbf{P} < 1$	$c \downarrow$ over time
(RIC) Return Impatience Condition	$\mathbf{P}_R < 1$	$c/a \downarrow$ over time
(GIC) Growth Impatience Condition	$\mathbf{P}_\Phi < 1$	$c/p \downarrow$ over time

# When Does A Useful Limiting Solution Exist?

Finite Human Wealth (FHWC) condition:

$$\Phi < R \quad (2)$$

Return Impatience Condition:

$$\bar{p}_R < R \quad (3)$$



# When Does A Useful Limiting Solution Exist?

Finite Human Wealth (FHWC) condition:

$$\Phi < R \quad (2)$$

Return Impatience Condition:

$$\bar{p}_R < R \quad (3)$$

# What If There Are Liquidity Constraints?

- FHWC is *not* necessary for solution to exist
- Other Key Condition For Useful Solution is  
'Perfect Foresight Finite Value of Autarky Condition (PF-FVAC)':

$$\beta \Phi^{1-\rho} < 1 \quad (4)$$

- Without RIC, Constraints Are Irrelevant
  - Because Wealth Always Wants To Rise, So Constraint Never Binds

## What If There Are Liquidity Constraints?

- FHWC is *not* necessary for solution to exist
- Other Key Condition For Useful Solution is  
'Perfect Foresight Finite Value of Autarky Condition (PF-FVAC)':

$$\beta \Phi^{1-\rho} < 1 \quad (4)$$

- Without RIC, Constraints Are Irrelevant
  - Because Wealth Always Wants To Rise, So Constraint Never Binds

# Liquidity Constraints and Uncertainty

- Introduce permanent shocks to income
- Finite Value of Autarky Condition Becomes

$$\begin{aligned} \underline{\underline{\underline{\Xi}}} &= \text{VAF} \\ \text{FVAC: } 0 &< \overbrace{\beta \underline{\underline{\underline{\Phi}}}^{1-\rho}} < 1 \\ 0 &< \beta < \underline{\underline{\underline{\Phi}}}^{\rho-1}, \end{aligned} \tag{5}$$

## Contraction Mapping Requirements

Finite Value of Autarky Condition: Same As In Liq Constr Problem!

$$\begin{aligned} \underline{\underline{\pi}} &= \text{VAF} \\ \text{FVAC: } 0 &< \overbrace{\beta \underline{\underline{\Phi}}^{1-\rho}} < 1 \\ 0 &< \beta < \underline{\underline{\Phi}}^{\rho-1}, \end{aligned} \quad (6)$$

'Weak Return Impatience Condition' (WRIC)

$$0 \leq \phi^{1/\rho} \mathbf{P}_R < 1 \quad (7)$$

## Requirement For Existence Of A Target

Definitions: 'Uncertainty-Adjusted' Growth:

$$\underline{\Phi} \equiv \Phi \underline{\Psi} < \Phi$$

Adjusted Growth Patience Factor:

$$\text{GPF-Mod: } \mathbf{P}_{\underline{\Phi}} = \mathbf{P} / \underline{\Phi} = \mathbb{E}[\mathbf{P} / (\Phi \Psi)] \quad (8)$$

Growth Impatience Condition:

$$\text{GIC-Mod: } \mathbf{P}_{\underline{\Phi}} < 1, \quad (9)$$

Why? Because it can be shown that

$$\lim_{m_t \rightarrow \infty} \mathbb{E}_t \left[ \frac{m_{t+1}}{m_t} \right] = \mathbf{P}_{\underline{\Phi}} \quad (10)$$

# Five Propositions

- 1  $\lim_{m_t \rightarrow \infty} \mathbb{E}_t[c_{t+1}/c_t] = \mathbf{P}$
- 2  $\lim_{m_t \rightarrow 0} \mathbb{E}_t[c_{t+1}/c_t] = \infty$
- 3  $\exists$  a unique target value of  $m$ , called  $\check{m}$
- 4  $\mathbb{E}_t[c_{t+1}/c_t | m_t = \check{m}] = \Phi - \epsilon$
- 5  $\left( \frac{d\mathbb{E}_t[c_{t+1}/c_t]}{dm_t} \right) < 0$

# The Target Saving Figure

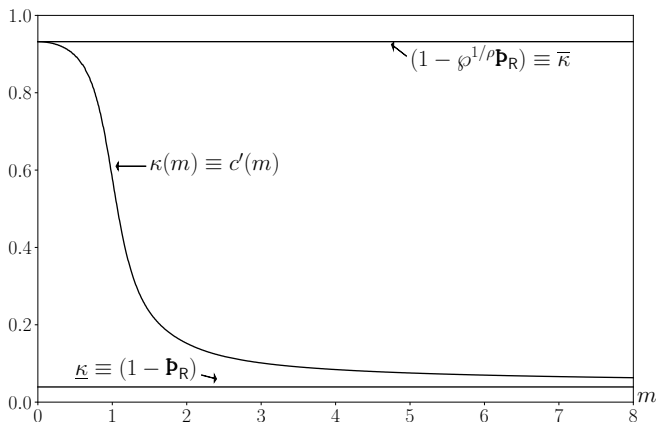




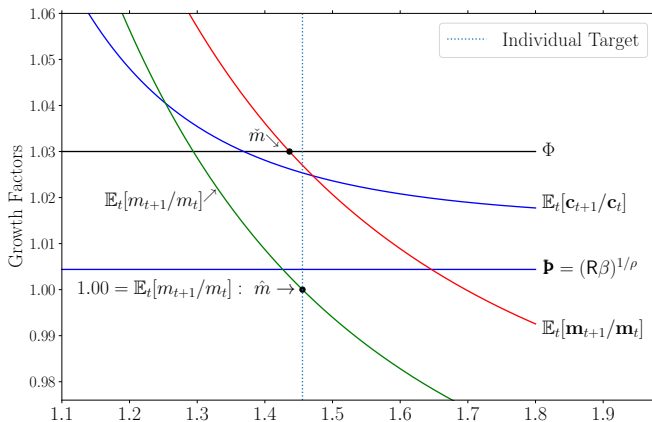
# Bounds On the Consumption Function



# The Marginal Propensity to Consume



# The Consumption Function and Target Wealth



# Convergence To The Invariant Distribution

Szeidl (2013) Proves Existence of an Invariant Distribution of  $m, c, a$ , etc.



# Balanced Growth Equilibrium

Achieved When Cross Section Distribution Reaches Invariance

$$Y_{t+1}/Y_t = C_{t+1}/C_t = \Phi \quad (11)$$

Fisherian Separation Fails, Even Without Liquidity Constraints!

Insight:

- Precautionary Saving  $\approx$  Liquidity Constraints
- If  $\hat{c}(m)$  is solution for constrained consumer,

$$\lim_{\varphi \downarrow 0} c(m; \varphi) = \hat{c}(m) \quad (12)$$

# Balanced Growth Equilibrium

Achieved When Cross Section Distribution Reaches Invariance

$$Y_{t+1}/Y_t = C_{t+1}/C_t = \Phi \quad (11)$$

Fisherian Separation Fails, Even Without Liquidity Constraints!

Insight:

- Precautionary Saving  $\approx$  Liquidity Constraints
- If  $\hat{c}(m)$  is solution for constrained consumer,

$$\lim_{\varphi \downarrow 0} c(m; \varphi) = \hat{c}(m) \quad (12)$$

## Balanced Growth Equilibrium

Achieved When Cross Section Distribution Reaches Invariance

$$Y_{t+1}/Y_t = C_{t+1}/C_t = \Phi \quad (11)$$

Fisherian Separation Fails, Even Without Liquidity Constraints!

Insight:

- Precautionary Saving  $\approx$  Liquidity Constraints
- If  $\hat{c}(m)$  is solution for constrained consumer,

$$\lim_{\varphi \downarrow 0} c(m; \varphi) = \hat{c}(m) \quad (12)$$

# The MPC Out Of Permanent Shocks

<https://www.econ2.jhu.edu/people/ccarroll1/papers/MPCPerm.pdf>

Lots of Recent Papers Trying to Measure the MPCP

Paper Proves:

- $MPCP < 1$
- But not a lot less:
  - 0.75 to 0.95 (annual rate) for wide range of parameter values



- Defined Conditions Under Which Widely Used Problem Has Solution
  - Finite Value of Autarky Condition Guarantees Contraction (with WRIC)
  - Growth Impatience Condition Prevents  $m \rightarrow \infty$
- Economy Of Buffer Stock Consumers Exhibits Balanced Growth
  - Even In Absence of General Equilibrium Adj of Interest Rate

MATKOWSKI, JANUSZ, AND ANDRZEJ S. NOWAK (2011): "On Discounted Dynamic Programming With Unbounded Returns," *Economic Theory*, 46, 455–474.

SZEIDL, ADAM (2013): "Stable Invariant Distribution in Buffer-Stock Saving and Stochastic Growth Models," *Manuscript, Central European University*, Available at [http://www.personal.ceu.hu/staff/Adam\\_Szeidl/papers/invariant\\_revision.pdf](http://www.personal.ceu.hu/staff/Adam_Szeidl/papers/invariant_revision.pdf).