Priceless Consumption

Frederico Belo
INSEAD and NBER

Andres Donangelo
University of Texas Austin

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“... [the GNP] does not count the health of our children, the quality of their education, or the joy of their play. It does not include the beauty of our poetry or the strength of our marriages; the intelligence of our public debate or the integrity of our public officials. It measures neither our wit nor our courage; neither our wisdom nor our learning; neither our compassion nor our devotion to our country; it measures everything, in short, except that which makes life worthwhile.”

“...The GNP counts air pollution and cigarette advertising... It counts special locks for our doors and the jails for the people who break them. ....armored cars for the police to fight the riots in our cities. It counts Whitman’s rifle and Speck’s knife...”

—Robert F. Kennedy, 1968
Preamble

“... [the GNP] does not count the health of our children, the quality of their education, or the joy of their play. It does not include the beauty of our poetry or the strength of our marriages; the intelligence of our public debate or the integrity of our public officials. It measures neither our wit nor our courage; neither our wisdom nor our learning; neither our compassion nor our devotion to our country; it measures everything, in short, except that which makes life worthwhile.”

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1. Not everything with consumption value can be bought with money

⇒ Non-marketable consumption is latent
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1. Not everything with consumption value can be bought with money

⇒ Non-marketable consumption is latent

2. We can learn about latent consumption from what we do buy
Priceless consumption (PC)

- Defining properties:
  - Determinant of utility (i.e., has "consumption value")
  - Non marketable → unaccounted for in aggregate measures
  - Affects the composition of measured consumption

- Note that PC does not span the entire universe of latent consumption
- Use the composition of consumption to recover PC

- Illustration: "sunny weather" (SW). How can we use consumption data to learn about SW?
  - Sunglasses \( \uparrow \), umbrellas \( \downarrow \) ⇒ Consumption of SW is high
  - Sunglasses \( \downarrow \), umbrellas \( \uparrow \) ⇒ Consumption of SW is low
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- Use the composition of consumption to recover PC
  - Illustration: “sunny weather” (SW). How can we use consumption data to learn about SW?
    Consider expenditures of sunglasses and umbrellas:
    - Sunglasses ↑, umbrellas ↓ ⇒ Consumption of SW is high
    - Sunglasses ↓, umbrellas ↑ ⇒ Consumption of SW is low
Propose and estimate new demand system

- Flexible intra-temporal preferences
- One non-marketable good (PC)
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- Flexible intra-temporal preferences
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Recover PC from the data
- It represents around a third of measured consumption
- Its importance has been growing over time
- Its growth is very volatile and highly cyclical
Propose and estimate new demand system
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Application: C-CAPM with PC
- Implied RRA (i.e., $\gamma$) drops to between 6.5 and 8.2
- PC contains missing information about systematic risk
Contributions to the Literature


• AP with aggregate consumption: Hansen and Singleton (1982); Breeden, Gibbons, and Litzenberger (1989); Jagannathan and Wang (1996); Lettau and Ludvigson (2001); Bansal and Yaron (2004); Parker and Julliard (2005); Savov (2011)

• AP with heterogeneous goods: Ait-Sahalia, Parker, and Yogo (2004); Yogo (2006); Piazzesi, Schneider, and Tuzel (2007); Binsbergen (2016); Gomes, Kogan, and Yogo (2009); Gorodnichenko and Weber (2016)
Model
Endowment economy with four Lucas trees, each providing a differentiated good:

<table>
<thead>
<tr>
<th>Good</th>
<th>Flow</th>
<th>Stock</th>
<th>Marketable?</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durable ($D$)</td>
<td>$E_t^D$</td>
<td>$Q_t^D = (1 - \delta)Q_{t-1}^D + E_t^D$</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Nondurable ($N$)</td>
<td>$E_t^N$</td>
<td>$Q_t^N = E_t^N$</td>
<td>Yes</td>
<td>$P_t^N$</td>
</tr>
<tr>
<td>Services ($S$)</td>
<td>$E_t^S$</td>
<td>$Q_t^S = E_t^S$</td>
<td>Yes</td>
<td>$P_t^S$</td>
</tr>
<tr>
<td>PC ($L$)</td>
<td>$E_t^L$</td>
<td>$Q_t^L = E_t^L$</td>
<td>No</td>
<td>$P_t^L$ (shadow)</td>
</tr>
</tbody>
</table>
Model Setup

Identical agents’ maximization problem

$$\max_{\{Q_s, A_s\}_{s=t}} \sum_{s=0}^{\infty} E_t [\beta^s U[F[Q_{t+s}]]],$$

subject to

$$\frac{A_t}{R_t^f} \leq A_{t-1} - C_t - \Delta_t^L P_t^L$$
$$Q_t^L \leq E_t^L + \Delta_t^L$$

where:

- $F$ is consumption aggregator over $Q_t = \{Q_t^D, Q_t^N, Q_t^S, Q_t^L\}$.
- $C_t \equiv E_t^D + E_t^N P_t^N + E_t^S P_t^S$ is expenditure in marketable goods
- $A_t$ is allocation in risk free bond with rate $R_t^f$
- $\Delta_t^L \rightarrow 0$ since PC is non marketable
General Solution to Demand System

Expenditure shares give three conditions:

\[
S_t^D \equiv \frac{C_t^D}{C_t} = \frac{E_t^D}{E_t^D + Q_t^N P_t^N + Q_t^S P_t^S} \quad \Rightarrow \text{redundant} \quad (S_t^D = 1 - S_t^N - S_t^S)
\]

\[
S_t^N \equiv \frac{C_t^N}{C_t} = \frac{Q_t^N P_t^N}{E_t^D + Q_t^N P_t^N + Q_t^S P_t^S}
\]

\[
S_t^S \equiv \frac{C_t^S}{C_t} = \frac{Q_t^S P_t^S}{E_t^D + Q_t^N P_t^N + Q_t^S P_t^S}
\]

where

\[
P_t^N = \left( \frac{F_N[Q_t]}{F_D[Q_t]} \right) \Upsilon_t,
\]

\[
P_t^S = \left( \frac{F_S[Q_t]}{F_D[Q_t]} \right) \Upsilon_t,
\]

and

\[
\Upsilon_t = 1 - \frac{1 - \delta}{R_t^f}.
\]
Consumption Aggregator

- Model estimation requires definition of functional form of consumption aggregator $F$
- $F$ must be:
  - “flexible enough” to allow the recovery of PC and explain the dynamics of marketable consumption
  - “simple enough” to be estimated with aggregate data
- The most commonly used CES class (e.g., Cobb-Douglas) is not “flexible enough”
ASIDE: CES Consumption Aggregator

\[ F^{\text{CES}}[Q_t] = (\alpha_D(Q_t^D)\rho + \alpha_N(Q_t^N)\rho + \alpha_S(Q_t^S)\rho + (1 - \alpha_D - \alpha_N - \alpha_S)(Q_t^L)\rho) \frac{1}{\rho} \]

Prices of marketable goods:

\[ P_{t,\text{N,CES}} = \frac{\alpha_N}{\alpha_D} \left( \frac{Q_t^N}{Q_t^D} \right)^{1-\rho} \gamma_t \quad \text{and} \quad P_{t,\text{S,CES}} = \frac{\alpha_S}{\alpha_D} \left( \frac{Q_t^S}{Q_t^D} \right)^{1-\rho} \gamma_t \]

⇒ PC does not affect marketable consumption!
ASIDE: CES Consumption Aggregator

\[ F_{\text{CES}}[Q_t] = (\alpha_D(Q^D_t)^\rho + \alpha_N(Q^N_t)^\rho + \alpha_S(Q^S_t)^\rho + (1 - \alpha_D - \alpha_N - \alpha_S)(Q^L_t)^\rho)^{\frac{1}{\rho}} \]

Prices of marketable goods:

\[ P_{t,\text{CES}}^N = \frac{\alpha_N}{\alpha_D} \left( \frac{Q_t^N}{Q_t^D} \right)^{\frac{1-\rho}{\rho}} \gamma_t \quad \text{and} \quad P_{t,\text{CES}}^S = \frac{\alpha_S}{\alpha_D} \left( \frac{Q_t^S}{Q_t^D} \right)^{\frac{1-\rho}{\rho}} \gamma_t \]

⇒ PC does not affect marketable consumption!

\begin{align*}
\text{Panel A: Durable Goods} & \quad (\text{M.A.E.}/\text{Mean } [S^D] = 39.7\%) \\
\text{Panel B: Nondurable Goods} & \quad (\text{M.A.E.}/\text{Mean } [S^N] = 6.3\%) \\
\text{Panel C: Service Goods} & \quad (\text{M.A.E.}/\text{Mean } [S^S] = 11.1\%)
\end{align*}

⇒ Unable to explain observable consumption dynamics!
Translog Consumption Aggregator

- Christensen, Jorgenson and Lau (1975):

\[ F[Q_t] \equiv \text{Exp} \left[ \log[Q_t] \times a + \frac{1}{2} \log[Q_t] \times B \times \log[Q_t]' \right], \]

where

\[ a \equiv \begin{bmatrix} a_D \\ a_N \\ a_S \\ a_L \end{bmatrix} \in [0, 1]^{4 \times 1}, \quad \text{and} \quad B \equiv \begin{bmatrix} b_{DD} & b_{DN} & b_{DS} & b_{DL} \\ b_{ND} & b_{NN} & b_{NS} & b_{NL} \\ b_{SD} & b_{SN} & b_{SS} & b_{SL} \\ b_{LD} & b_{LN} & b_{LS} & b_{LL} \end{bmatrix} \in \mathbb{R}^{4 \times 4}. \]

- Standard normalizations: symmetry and homotheticity:

\[ \sum_{i \in \{D, N, S, L\}} a_i = 1 \quad \text{and} \quad \sum_{i \in \{D, N, S, L\}} b_{k,i} = 0, \quad \forall k \in \{D, N, S, L\}. \]

- “Simple enough”: 9 free parameters after normalizations
Parametric Solution with Translog Aggregator

• Translog form for $F$ implies the equalities for expenditure shares:

$$S^N_t \equiv \frac{C^N_t}{C_t} = \frac{Q_t^N P^N_t}{E_t^D + Q_t^N P^N_t + Q_t^S P^S_t}$$

$$S^S_t \equiv \frac{C^S_t}{C_t} = \frac{Q_t^S P^S_t}{E_t^D + Q_t^N P^N_t + Q_t^S P^S_t}$$

where ($q \equiv \log(Q)$):

$$P^N[Q_t] = \frac{Q_t^D}{Q_t^N} \left( \frac{a_N + b_{ND} q_t^D + b_{NN} q_t^N + b_{SN} q_t^S - q_t^L b_N}{a_D + b_{DD} q_t^D + b_{ND} q_t^N + b_{SD} q_t^S - q_t^L b_D} \right) \Upsilon_t$$

$$P^S[Q_t] = \frac{Q_t^D}{Q_t^S} \left( \frac{a_S + b_{SD} q_t^D + b_{SN} q_t^N + b_{SS} q_t^S - q_t^L b_S}{a_D + b_{DD} q_t^D + b_{ND} q_t^N + b_{SD} q_t^S - q_t^L b_D} \right) \Upsilon_t$$

• Combine two conditions to eliminate latent $q^L_t$:

$$\frac{\hat{S}^N_t \hat{\Phi}^D_t - \hat{S}^D_t \hat{\Phi}^N_t}{\hat{S}^N_t b_D - \hat{S}^D_t b_N} \Upsilon_t = \frac{\hat{S}^S_t \hat{\Phi}^D_t - \hat{S}^D_t \hat{\Phi}^S_t}{\hat{S}^S_t b_D - \hat{S}^D_t b_S} \Upsilon_t$$

⇒ Identifying condition
Model Estimation
Data Used in Estimation

- **NIPA tables used:**
  - Table 2.4.3U (Real Expenditures by Type of Product)
  - Table 2.4.3U (Price Indexes by Type of Product)
  (series above are normalized by price of durables)

- **Sample coverage:**
  - Goods: *DDUR* (durables), *DNDG* (nondurables), and *DSER* (services)
  - Period: 1959 to 2018, annual frequency

- **Constructed variables**
  - Quantity flow: expenditures / prices
  - Quantity stock for durables: perpetual inventory method

- **Proxy for** $\hat{\Upsilon}_t = 1 - (1 - \delta)(\hat{R}_t)^{-1}$:
  - Proxy for $\hat{R}_t$: nominal T-Bill rate deflated by price of durable good
Estimation Strategy: Objective Function

- Minimization of average squared deviations of expenditure shares from data and implied by model
- FOCs from minimization represent the moment conditions
- GMM loss function

\[ \hat{\theta} = \arg\min_{\theta} \left( g \left[ \hat{X}_t | \theta \right] W g \left[ \hat{X}_t | \theta \right]' \right), \]

where \( W \) is the identity matrix.
Estimation Results

Estimated Parameters

\[
F[Q_t] \equiv \text{Exp} \left[ \log[Q_t] \times a + \frac{1}{2} \log[Q_t] \times B \times \log[Q_t]' \right]
\]

<table>
<thead>
<tr>
<th>Panel A: Vector (a)</th>
<th>(a_D)</th>
<th>(a_N)</th>
<th>(a_S)</th>
<th>(a_L)</th>
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<tbody>
<tr>
<td>(0.10)</td>
<td>(0.48)</td>
<td>(0.04)</td>
<td>(0.38)</td>
<td></td>
</tr>
<tr>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.10)</td>
<td>(0.13)</td>
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</table>

<table>
<thead>
<tr>
<th>Panel B: Matrix (B)</th>
<th>(b_D)</th>
<th>(b_N)</th>
<th>(b_S)</th>
<th>(b_L)</th>
</tr>
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<tbody>
<tr>
<td>(b_{D_1})</td>
<td>-1.32</td>
<td>-1.24</td>
<td>1.28</td>
<td>1.28</td>
</tr>
<tr>
<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.00)</td>
<td>(0.12)</td>
<td></td>
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<tr>
<td>(b_{N_1})</td>
<td>-1.24</td>
<td>-0.87</td>
<td>0.91</td>
<td>1.21</td>
</tr>
<tr>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.00)</td>
<td>(0.06)</td>
<td></td>
</tr>
<tr>
<td>(b_{S_1})</td>
<td>1.28</td>
<td>0.91</td>
<td>-0.85</td>
<td>-1.34</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td></td>
</tr>
<tr>
<td>(b_{L_1})</td>
<td>1.28</td>
<td>1.21</td>
<td>-1.34</td>
<td>-1.15</td>
</tr>
<tr>
<td>(0.12)</td>
<td>(0.06)</td>
<td>(0.05)</td>
<td>(0.16)</td>
<td></td>
</tr>
</tbody>
</table>

\(L=\)priceless consumption, \(D=\)durables, \(N=\)nondurables, \(S=\)services
Estimation Results: Model Fit

Panel A: Durable Goods
(M.A.E./Mean $[S^D] = 5.5\%$)

Panel B: Nondurable Goods
(M.A.E./Mean $[S^N] = 2.6\%$)

Panel C: Service Goods
(M.A.E./Mean $[S^S] = 2.3\%$)

- Average M.A.E./Mean$[S]$: 3.5\%
- Average M.A.E./Mean$[S]$ with CES aggregator: 19.0\%
Recovered Priceless Consumption
Model-Implied Priceless Consumption

Estimated parameters $\hat{\theta}$ + observables $\hat{X}_t$ allow the recovery of the latent series:

- **Log quantity of PC:**
  $$q^L[\hat{X}_t|\hat{\theta}] = \frac{\hat{S}_t^N (\hat{a}_S + \hat{b}_{SD}\hat{q}_t^D + \hat{b}_{SN}\hat{q}_t^N + \hat{b}_{SS}\hat{q}_t^S) - \hat{S}_t^S (\hat{a}_N + \hat{b}_{ND}\hat{q}_t^D + \hat{b}_{NN}\hat{q}_t^N + \hat{b}_{SN}\hat{q}_t^S)}{\hat{S}_t^N b_S - \hat{S}_t^S b_N}$$

- **Shadow price of PC**
  $$P^L[\hat{X}_t|\hat{\theta}] = \frac{\hat{Q}_t^D}{\hat{Q}_t^L} \left( \frac{\hat{a}_L + \hat{b}_{LD}\hat{q}_t^D + \hat{b}_{LL}q^L[\hat{X}_t|\hat{\theta}] - \hat{b}_N\hat{q}_t^N - \hat{b}_S\hat{q}_t^S}{\hat{a}_D + \hat{b}_{DD}\hat{q}_t^D + \hat{b}_{LD}q^L[\hat{X}_t|\hat{\theta}] + \hat{b}_{ND}\hat{q}_t^N + \hat{b}_{SD}\hat{q}_t^S} \right) \hat{Y}_t,$$

- **Shadow expenditure share of PC**
  $$S^L[\hat{X}_t|\hat{\theta}] = \frac{\text{Exp}\left[q^L[\hat{X}_t|\hat{\theta}]\right] P^L[\hat{X}_t|\hat{\theta}]}{C_t^{DNS}}$$
Recovered PC Series

Log Quantity

Shadow Price

Shadow Expenditure Share

L=priceless consumption, D=durables, N=nondurables, S=services
Priceless Consumption over Time

$L$=priceless consumption, $D$=durables, $N$=nondurables, $S$=services

⇒ $PC$ is economically significant and has been increasing over the past decades
PC and Consumption Growth Volatility

Volatility of PC Growth

Volatility of Aggregate Consumption Growth

L=priceless consumption, D=durables, N=nondurables, S=services

⇒ Priceless Consumption is very volatile
# Cyclical Properties of PC

<table>
<thead>
<tr>
<th></th>
<th>Expansions</th>
<th>Recessions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std</td>
</tr>
<tr>
<td>$\Delta c_{DNS}$</td>
<td>2.80</td>
<td>1.17</td>
</tr>
<tr>
<td>$\Delta c_{L}$</td>
<td>7.45</td>
<td>12.42</td>
</tr>
<tr>
<td>$\Delta c_{DNSL}$</td>
<td>3.78</td>
<td>2.93</td>
</tr>
</tbody>
</table>

$\text{L=priceless consumption, D=durables, N=nondurables, S=services}$

⇒ Procylical Growth, Countercyclical Volatility
### Cyclical Properties of PC

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th>Recessions</th>
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<tr>
<td></td>
<td>Mean</td>
<td>Std</td>
<td>Mean</td>
<td>Std</td>
</tr>
<tr>
<td>$\Delta c_{DNS}$</td>
<td>2.80</td>
<td>1.17</td>
<td>0.41</td>
<td>1.69</td>
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<tr>
<td>$\Delta c_L$</td>
<td>7.45</td>
<td>12.42</td>
<td>-8.80</td>
<td>25.64</td>
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<tr>
<td>$\Delta c_{DNSL}$</td>
<td>3.78</td>
<td>2.93</td>
<td>-1.31</td>
<td>5.74</td>
</tr>
</tbody>
</table>

$L=$priceless consumption, $D=$durables, $N=$nondurables, $S=$services

$\Rightarrow$ Procyclical Growth, Countercyclical Volatility
Application: C-CAPM
Application: C-CAPM

Motivation

- PC represents significant component that is missing from measured consumption
- Natural question: are we also missing information about systematic risk when we ignore PC?
- Simple check: How is C-CAPM with CRRA affected by considering PC?
  - Goal is not to solve the equity premium puzzle
  - Analysis in the spirit of Savov (2011)
Priceless Consumption and C-CAPM

- Standard Euler equation from C-CAPM

\[ \mathbb{E} \left[ \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\gamma} R_{t+1}^i \right] = 1. \]

- Estimate C-CAPM with different measures of \( C_t \)
  - 2 measures that include PC
  - 3 measures that ignore PC

- Compare implied RRA \( \gamma \) and RFR
### Priceless Consumption and C-CAPM

#### Implied Risk Aversion and RFR Estimates

**Definition of Consumption**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>$C^{DNS} + C^L$</td>
<td>1</td>
<td>$C^{NS} + C^L$</td>
<td>$C^{DNS}$</td>
<td>$C^{NS}$</td>
<td>$C^G$</td>
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</table>

**Panel A: Market Factor**

<table>
<thead>
<tr>
<th></th>
<th>RRA ($\gamma$)</th>
<th>RFR</th>
<th>RMSE</th>
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</thead>
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<tr>
<td>1</td>
<td>8.21</td>
<td>20.00</td>
<td>2.66</td>
</tr>
<tr>
<td>2</td>
<td>8.20</td>
<td>20.20</td>
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<tr>
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<td>58.14</td>
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<tr>
<td>4</td>
<td>31.64</td>
<td>97.98</td>
<td>2.73</td>
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<tr>
<td>5</td>
<td>17.32</td>
<td>17.19</td>
<td>3.85</td>
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</table>

**Panel B: 25 Size-B/M Portfolios**

<table>
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<tr>
<th></th>
<th>RRA ($\gamma$)</th>
<th>RFR</th>
<th>RMSE</th>
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<tr>
<td>1</td>
<td>6.51</td>
<td>18.48</td>
<td>2.66</td>
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<td>6.49</td>
<td>18.69</td>
<td>2.70</td>
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<tr>
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<td>19.11</td>
<td>51.48</td>
<td>2.61</td>
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<td>29.95</td>
<td>92.21</td>
<td>2.73</td>
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<tr>
<td>5</td>
<td>22.31</td>
<td>13.65</td>
<td>3.85</td>
</tr>
</tbody>
</table>

L=priceless consumption, D=durables, N=nondurables, S=services, G=garbage
Priceless Consumption and C-CAPM
Pricing Errors vs RRA ($\gamma$)

$C^{DNS}$

$C^{G}$

$C^{DNS} + C^{L}$

$L$=priceless consumption, $D$=durables, $N$=nondurables, $S$=services, $G$=garbage

Belo and Donangelo

Priceless Consumption
Conclusion

• Propose methodology to recover latent consumption (“PC”) from the cross-section of consumption

• Present evidence that PC
  – Is economically significant
  – Has been increasing over the decades
  – Has interesting dynamics

• Application: study C-CAPM
  – PC has unique priced risk
  – Proxy of *true* total consumption significantly improves performance of C-CAPM

• Work in progress: What is PC exactly?
Appendix
What is PC?
References


