Revisiting Taste Change in Cost-of-Living Measurement

Robert S. Martin
Office of Prices and Living Conditions

SI 2020 CRIW
July 14, 2020
All estimates and analyses based on Nielsen data are by the author and not the data provider.
Summary

▶ For the CES model, I derive conditional cost-of-living index (COLI) estimates corresponding to either reference or comparison period preferences.

New interpretations for Lloyd-Moulton index variants

I compare the theory of conditional and unconditional COLI

Reflect different theoretical targets

Capturing taste change effects a la Redding and Weinstein requires strong assumptions.

I apply to retail scanner data for 70 food and beverage product groups.

COLIs that condition on current quarter tastes exceed those that condition on year-ago tastes by 0.5 to 2.9 percentage points per year on average, depending on the category.
Summary

- For the CES model, I derive conditional cost-of-living index (COLI) estimates corresponding to either reference or comparison period preferences
  - New interpretations for Lloyd-Moulton index variants

COLIs that condition on current quarter tastes exceed those that condition on year-ago tastes by 0.5 to 2.9 percentage points per year on average, depending on the category.
Summary

- For the CES model, I derive conditional cost-of-living index (COLI) estimates corresponding to either reference or comparison period preferences
  - New interpretations for Lloyd-Moulton index variants
- I compare the theory of conditional and unconditional COLI
  - Capturing taste change effects a la Redding and Weinstein requires strong assumptions
- I apply to retail scanner data for 70 food and beverage product groups
  - COLIs that condition on current quarter tastes exceed those that condition on year-ago tastes by 0.5 to 2.9 percentage points per year on average, depending on the category
Summary

- For the CES model, I derive conditional cost-of-living index (COLI) estimates corresponding to either reference or comparison period preferences
  - New interpretations for Lloyd-Moulton index variants
- I compare the theory of conditional and unconditional COLI
  - Reflect different theoretical targets
Summary

- For the CES model, I derive conditional cost-of-living index (COLI) estimates corresponding to either reference or comparison period preferences
  - New interpretations for Lloyd-Moulton index variants
- I compare the theory of conditional and unconditional COLI
  - Reflect different theoretical targets
  - Capturing taste change effects a la Redding and Weinstein requires strong assumptions
Summary

▶ For the CES model, I derive conditional cost-of-living index (COLI) estimates corresponding to either reference or comparison period preferences
  ▶ New interpretations for Lloyd-Moulton index variants
▶ I compare the theory of conditional and unconditional COLI
  ▶ Reflect different theoretical targets
  ▶ Capturing taste change effects a la Redding and Weinstein requires strong assumptions
▶ I apply to retail scanner data for 70 food and beverage product groups
Summary

- For the CES model, I derive conditional cost-of-living index (COLI) estimates corresponding to either reference or comparison period preferences
  - New interpretations for Lloyd-Moulton index variants
- I compare the theory of conditional and unconditional COLI
  - Reflect different theoretical targets
  - Capturing taste change effects a la Redding and Weinstein requires strong assumptions
- I apply to retail scanner data for 70 food and beverage product groups
  - COLIs that condition on current quarter tastes exceed those that condition on year-ago tastes by 0.5 to 2.9 percentage points per year on average, depending on the category
Selected references

- Price index manuals

- COLI
  - Konüs (1924), Diewert (1976), Pollak (1989)

- Include models with preference change
  - Fisher and Shell (1972), Samuelson and Swamy (1974),
    Muellbauer (1975), Caves, Christiansen, and Diewert (1982),
    Heien and Dunn (1985), Pollak (1989), Balk (1989), Nevo
    (2003), Feenstra and Reinsdorf (2007)
  - Recently, Ueda, et. al. (2019), Redding and Weinstein (2020),
    Hottman and Monarch (2018), Gábor-Tóth and Vermeulen
Conditional COLI when preferences change

- Static, matched model, constant attributes for each commodity
  - So preference shifts not caused by quality change

\[
\Phi(p_0, p_1, \bar{u}; \psi) = \frac{C(p_1, \bar{u}; \psi)}{C(p_0, \bar{u}; \psi)},
\]

for a given set of preferences \(\psi\) and utility level \(\bar{u}\).

Notes:

- Not assuming \(\psi_0 = \psi_1\)
- ...but substitution effects could differ whether \(\psi_0\) or \(\psi_1\) (or another) is used
- Preferred CPI target of ILO (2004), CNSTAT (2002), and BLS...
Conditional COLI when preferences change

▶ Static, matched model, constant attributes for each commodity
  ▶ So preference shifts not caused by quality change

▶ Conditional COLI: the proportional change in minimum expenditure required for an agent to be indifferent between two price situations (e.g., reference period 0 and comparison period 1)

\[
\Phi(p_0, p_1, \bar{u}; \varphi) = \frac{C(p_1, \bar{u}; \varphi)}{C(p_0, \bar{u}; \varphi)},
\]

for a given set of preferences \( \varphi \) and utility level \( \bar{u} \).
Conditional COLI when preferences change

- Static, matched model, constant attributes for each commodity
  - So preference shifts not caused by quality change
- Conditional COLI: the proportional change in minimum expenditure required for an agent to be indifferent between two price situations (e.g., reference period 0 and comparison period 1)

\[
\Phi(p_0, p_1, \bar{u}; \varphi) = \frac{C(p_1, \bar{u}; \varphi)}{C(p_0, \bar{u}; \varphi)},
\]

for a given set of preferences \(\varphi\) and utility level \(\bar{u}\).

- Notes:
  - Not assuming \(\varphi_0 = \varphi_1\) ...
  - ...but substitution effects could differ whether \(\varphi_0\) or \(\varphi_1\) (or another) is used
Conditional COLI when preferences change

- Static, matched model, constant attributes for each commodity
  - So preference shifts not caused by quality change

- Conditional COLI: the proportional change in minimum expenditure required for an agent to be *indifferent* between two *price* situations (e.g., reference period 0 and comparison period 1)

\[
\Phi(p_0, p_1, \bar{u}; \varphi) = \frac{C(p_1, \bar{u}; \varphi)}{C(p_0, \bar{u}; \varphi)},
\]

for a given set of preferences \(\varphi\) and utility level \(\bar{u}\).

- Notes:
  - Not assuming \(\varphi_0 = \varphi_1\) ...
  - ...but substitution effects could differ whether \(\varphi_0\) or \(\varphi_1\) (or another) is used
  - Preferred CPI target of ILO (2004), CNSTAT (2002), and BLS
Parameter-free Conditional COLI

Diewert (2001): The Laspeyres and Paasche indexes bound a COLI that conditions on intermediate levels of tastes and utility → Fisher index as approximation.
Parameter-free Conditional COLI

▶ Diewert (2001): The Laspeyres and Paasche indexes bound a COLI that conditions on intermediate levels of tastes and utility $\rightarrow$ Fisher index as approximation.

▶ Caves, Christensen, and Diewert (1982): With translog expenditure function, the Tornqvist index is exact for the COLI that conditions on the geometric average of tastes and utility.
Parameter-free Conditional COLI

▶ Diewert (2001): The Laspeyres and Paasche indexes bound a COLI that conditions on intermediate levels of tastes and utility → Fisher index as approximation.

▶ Caves, Christensen, and Diewert (1982): With translog expenditure function, the Tornqvist index is exact for the COLI that conditions on the geometric average of tastes and utility

▶ Feenstra and Reinsdorf (2007): With CES expenditure function, the Sato-Vartia index is exact for a COLI that conditions on intermediate (relative) tastes
Unconditional COLI when preferences change

- **Unconditional COLI**: the proportional change in minimum expenditure required to achieve a *constant standard-of-living* between two situations

\[
\Phi_U(p_0, p_1, \bar{u}; \varphi_0, \varphi_1) = \frac{C(p_1, \bar{u}; \varphi_1)}{C(p_0, \bar{u}; \varphi_0)}
\]

for a given \( \bar{u} \).

- E.g., Redding and Weinstein (2020)
Unconditional COLI when preferences change

Unconditional COLI: the proportional change in minimum expenditure required to achieve a constant standard-of-living between two situations

$$
\Phi_U(p_0, p_1, \bar{u}; \varphi_0, \varphi_1) = \frac{C(p_1, \bar{u}; \varphi_1)}{C(p_0, \bar{u}; \varphi_0)}
$$

(2)

for a given $\bar{u}$.

E.g., Redding and Weinstein (2020)

“Unconditional” label comes from models that include observed non-price (e.g., environmental) variables.

But here, preferences $\varphi_0, \varphi_1$ are unobserved parameters.
Unconditional COLI when preferences change

▶ **Unconditional COLI**: the proportional change in minimum expenditure required to achieve a *constant standard-of-living* between two situations

\[
\Phi_U(p_0, p_1, \bar{u}; \varphi_0, \varphi_1) = \frac{C(p_1, \bar{u}; \varphi_1)}{C(p_0, \bar{u}; \varphi_0)}
\]  

(2)

for a given \(\bar{u}\).

▶ E.g., Redding and Weinstein (2020)

▶ “Unconditional” label comes from models that include observed non-price (e.g., environmental) variables.

▶ But here, preferences \(\varphi_0, \varphi_1\) are unobserved parameters

▶ When \(\varphi_0 \neq \varphi_1\), \(\Phi_U\) implicitly assumes:

▶ Cardinal utility
Unconditional COLI when preferences change

- **Unconditional COLI**: the proportional change in minimum expenditure required to achieve a *constant standard-of-living* between two situations

\[
\Phi_U(p_0, p_1, \bar{u}; \varphi_0, \varphi_1) = \frac{C(p_1, \bar{u}; \varphi_1)}{C(p_0, \bar{u}; \varphi_0)}
\]  

(2)

for a given \(\bar{u}\).

- E.g., Redding and Weinstein (2020)
- “Unconditional” label comes from models that include observed non-price (e.g., environmental) variables.
  - But here, preferences \(\varphi_0, \varphi_1\) are unobserved parameters
- When \(\varphi_0 \neq \varphi_1\), \(\Phi_U\) implicitly assumes:
  - Cardinal utility
  - Restriction on evolution of tastes (e.g., normalization)
Unconditional and conditional COLI

Possible decomposition

\[
\ln \Phi_U(p_0, p_1, \bar{u}; \varphi_0, \varphi_1) = \ln \Phi(p_0, p_1, \bar{u}; \varphi_1) + \ln \left[ \frac{C(p_0, \bar{u}; \varphi_1)}{C(p_0, \bar{u}; \varphi_0)} \right]
\]
Unconditional and conditional COLI

Possible decomposition

\[
\ln \Phi_U(p_0, p_1, \bar{u}; \varphi_0, \varphi_1) = \ln \Phi(p_0, p_1, \bar{u}; \varphi_1) + \ln \left[ \frac{C(p_0, \bar{u}; \varphi_1)}{C(p_0, \bar{u}; \varphi_0)} \right]
\]

(3)

Conditional COLIs contain the full contribution of changing prices
CES Preferences

Assume:

\[
C(p, \bar{u}; \varphi) = \bar{u} \left[ \sum_{i \in I} \left( \frac{p_i}{\varphi_i} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}
\] (4)

- Elasticity of substitution $\sigma$ constant between 0 and 1
- $I$ has dimension N
- Homothetic preferences $\rightarrow$ can focus on unit expenditure
  \[
c(p; \varphi) \equiv C(p, 1; \varphi)
\]
- Expenditure shares: For $i \in I$, $t = 0, 1$
  \[
s_i(p_t; \varphi_t) = \frac{(p_{it}/\varphi_{it})^{1-\sigma}}{[c(p_t, \varphi_t)]^{1-\sigma}} = \frac{p_{it}q_{it}}{\sum_{j \in I} p_{jt}q_{jt}} \equiv s_{it}
\] (5)
## CES Indexes with Taste Change

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>COLI target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lloyd-Moulton</td>
<td>$P_{LM} = \left{ \sum_{i \in I} s_{i0} \left( \frac{p_{i1}}{p_{i0}} \right)^{1-\sigma} \right}^{\frac{1}{1-\sigma}} \Phi(\varphi_0)$</td>
<td>$\Phi(\varphi_0)$</td>
</tr>
</tbody>
</table>
## CES Indexes with Taste Change

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>COLI target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lloyd-Moulton</td>
<td>[ P_{LM} = \left{ \sum_{i \in I} s_i 0 \left( \frac{p_{i1}}{p_{i0}} \right)^{1-\sigma} \right}^{\frac{1}{1-\sigma}} ]</td>
<td>[ \Phi(\varphi_0) ]</td>
</tr>
<tr>
<td>Backwards L.M.</td>
<td>[ P_{BLM} = \left{ \sum_{i \in I} s_i 1 \left( \frac{p_{i0}}{p_{i1}} \right)^{1-\sigma} \right}^{\frac{-1}{1-\sigma}} ]</td>
<td>[ \Phi(\varphi_1) ]</td>
</tr>
</tbody>
</table>

Lloyd (1975) and Moulton (1996)

Lloyd (1975)
### CES Indexes with Taste Change

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>COLI target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lloyd-Moulton</td>
<td>[ P_{LM} = \left{ \sum_{i \in I} s_i 0 \left( \frac{p_i 1}{p_i 0} \right)^{1-\sigma} \right} \frac{1}{1-\sigma} \Phi(\varphi_0) ]</td>
<td>[ \Phi(\varphi_0) ]</td>
</tr>
<tr>
<td>Backwards L.M.</td>
<td>[ P_{BLM} = \left{ \sum_{i \in I} s_i 1 \left( \frac{p_i 0}{p_i 1} \right)^{1-\sigma} \right} \frac{-1}{1-\sigma} \Phi(\varphi_1) ]</td>
<td>[ \Phi(\varphi_1) ]</td>
</tr>
<tr>
<td>LMM</td>
<td>[ P_{LMM} = \sqrt{P_{LM}P_{BLM}} ] [ \sqrt{\Phi(\varphi_0)\Phi(\varphi_1)} ]</td>
<td>[ \sqrt{\Phi(\varphi_0)\Phi(\varphi_1)} ]</td>
</tr>
</tbody>
</table>

Lloyd (1975) and Moulton (1996)

Lloyd (1975)


Equals Quadratic Mean of Order \( r \) Index (Diewert, 1976) where \( r = 2(1 - \sigma) \)
### CES Indexes with Taste Change (continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>COLI target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sato-Vartia(^1)</td>
<td>( P_{SV} = \prod_{i \in I} \left( \frac{p_{i1}}{p_{i0}} \right)^{w_i} )</td>
<td>( \Phi(\bar{\varphi}) )</td>
</tr>
</tbody>
</table>

Sato (1976) and Vartia (1976). \( \varphi_{i0} / \prod_{i \in I} \varphi_{i0} \leq \varphi_i \leq \varphi_{i1} / \prod_{i \in I} \varphi_{i1} \) (Feenstra and Reinsdorf, 2007)
CES Indexes with Taste Change (continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>COLI target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sato-Vartia(^1)</td>
<td>( P_{SV} = \prod_{i \in \mathcal{I}} \left( \frac{p_{i1}}{p_{i0}} \right)^{w_i} )</td>
<td>( \Phi(\bar{\varphi}) )</td>
</tr>
</tbody>
</table>

Sato (1976) and Vartia (1976). \( \varphi_i / \prod_{i \in \mathcal{I}} \varphi_i \leq \varphi_i \leq \varphi_i / \prod_{i \in \mathcal{I}} \varphi_i \) (Feenstra and Reinsdorf, 2007)

| CCV                | \( P_{CCV} = \prod_i \left( \frac{p_{i1}}{p_{i0}} \right)^{\frac{1}{N}} \left( \frac{s_{i1}}{s_{i0}} \right)^{\frac{1}{N(\sigma-1)}} \) | \( \Phi_U(\bar{\varphi}_0, \bar{\varphi}_1) \) |

Redding and Weinstein (2020). \( \bar{\varphi}_{it} \) normalized to have time-constant unweighted geometric mean.

\(^1w_i = [(s_{i1} - s_{i0})/(\ln s_{i1} - \ln s_{i0})] / [\sum_{k \in \mathcal{I}}(s_{k1} - s_{k0})/(\ln s_{k1} - \ln s_{k0})] \)
Application to Retail Scanner Data

- Nielsen Scantrack: Retail point-of-sale data from Sept. 2005-Sept. 2010 for mainly chain grocery and drug stores. Looking at 70 food and beverage product groups from 8 departments. Weekly revenues, quantities, unique items (e.g., UPCs), brand information, some characteristics.
Application to Retail Scanner Data

- Nielsen Scantrack: Retail point-of-sale data from Sept. 2005-Sept. 2010 for mainly chain grocery and drug stores. Looking at 70 food and beverage product groups from 8 departments. Weekly revenues, quantities, unique items (e.g., UPCs), brand information, some characteristics.

- As in RW, product group-level \((g)\) indexes track price change from quarter \(t - 4\) to \(t\).

- Basket \(I_g\) is all UPC’s available in both \(t\) and \(t - 4\) (as in RW, 2018).
Application to Retail Scanner Data

- Nielsen Scantrack: Retail point-of-sale data from Sept. 2005-Sept. 2010 for mainly chain grocery and drug stores. Looking at 70 food and beverage product groups from 8 departments. Weekly revenues, quantities, unique items (e.g., UPCs), brand information, some characteristics.

- As in RW, product group-level \((g)\) indexes track price change from quarter \(t - 4\) to \(t\).

- Basket \(\mathcal{I}_g\) is all UPC’s available in both \(t\) and \(t - 4\) (as in RW, 2018).

- Estimation of the \(\sigma_g\) follows Broda and Weinstein (2010), based on Feenstra (1994).

- Presenting index averages weighted by expenditure share of the product group in quarter \(t\).
Mean CES Price Indexes (percent change versus year ago)
Mean CES Price Indexes for Food and Bev. Departments

- **Alcoholic Beverages**
- **Dairy**
- **Deli**
- **Dry Grocery**
- **Fresh Meat**
- **Fresh Produce**
- **Frozen Foods**
- **Packaged Meat**

Legend:
- CCV
- SV
- LMM
- LM
- BLM
### Mean CES Index Differences by Dept. (percentage points)

<table>
<thead>
<tr>
<th>Department</th>
<th>SV − CCV</th>
<th>SV − LMM</th>
<th>SV − BLM</th>
<th>BLM − LM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcoholic Beverages</td>
<td>1.7740</td>
<td>0.0302</td>
<td>−0.4167</td>
<td>0.8912</td>
</tr>
<tr>
<td>Dairy</td>
<td>1.5146</td>
<td>0.0409</td>
<td>−1.2250</td>
<td>2.4992</td>
</tr>
<tr>
<td>Deli</td>
<td>3.4615</td>
<td>0.0477</td>
<td>−0.6147</td>
<td>1.3201</td>
</tr>
<tr>
<td>Dry Grocery</td>
<td>6.6622</td>
<td>0.4250</td>
<td>−1.0722</td>
<td>2.9221</td>
</tr>
<tr>
<td>Fresh Meat</td>
<td>4.3377</td>
<td>−0.0096</td>
<td>−0.6363</td>
<td>1.2490</td>
</tr>
<tr>
<td>Fresh Produce</td>
<td>3.1727</td>
<td>−0.0114</td>
<td>−1.0365</td>
<td>2.0388</td>
</tr>
<tr>
<td>Frozen Foods</td>
<td>11.5876</td>
<td>0.0460</td>
<td>−0.4386</td>
<td>0.9644</td>
</tr>
<tr>
<td>Packaged Meat</td>
<td>2.2057</td>
<td>0.0092</td>
<td>−0.2619</td>
<td>0.5413</td>
</tr>
<tr>
<td><strong>All</strong></td>
<td>5.6359</td>
<td>0.2437</td>
<td>−0.9297</td>
<td>2.3014</td>
</tr>
</tbody>
</table>

Note: Based on data provided by The Nielsen Company (U.S.), LLC. Statistics are average differences between product group-level indexes weighted by the product group's share of expenditure in the comparison period. CCV refers to RW's CES Common Varieties Index, SV refers to Sato-Vartia, LM refers to Lloyd-Moulton, BLM refers to Backwards Lloyd-Moulton, and LMM refers to the geometric mean of LM and BLM.
Conclusions and Extensions

- Conditional COLI can vary by choice of taste parameter
- Whether to characterize as “bias” depends on intended target
- Under cardinal utility and this specific normalization, taste effects often dominate price effects in unconditional COLI estimates

- More research needed into robustness of $P_{CCV}$, $P_{LM}$, $P_{BLM}$
Conclusions and Extensions

- Conditional COLI can vary by choice of taste parameter
- Whether to characterize as “bias” depends on intended target
- Under cardinal utility and this specific normalization, taste effects often dominate price effects in unconditional COLI estimates
- In paper: accounting for variety-level tastes is infeasible given current BLS data collection constraints. Category-level tastes may have relatively little impact on conditional COLI estimates using U.S. CPI data

▶ More research needed into robustness of \( \text{PCCV}, \text{PLM}, \text{PBLM} \)

Conclusions and Extensions

- Conditional COLI can vary by choice of taste parameter
- Whether to characterize as “bias” depends on intended target
- Under cardinal utility and this specific normalization, taste effects often dominate price effects in unconditional COLI estimates
- In paper: accounting for variety-level tastes is infeasible given current BLS data collection constraints. Category-level tastes may have relatively little impact on conditional COLI estimates using U.S. CPI data
- More research needed into robustness of $P_{CCV}$, $P_{LM}$, $P_{BLM}$
  - Kurtzon (2020). ”Examining the Robustness of Normalizing Time-varying Preferences.”
CONTACT INFORMATION

Robert S. Martin  
Division of Price and Index Number Research  
Bureau of Labor Statistics  
2 Massachusetts Ave, NE  
Washington, DC 20212  
Email: Martin.Robert@bls.gov
\[ \Phi(p_0, p_1, 1; \varphi_s) = \frac{.48}{.44} = 1.097 \]

\[ C(p_0, 1; \varphi_s) = .44 \]

\[ u_s(q; \varphi_s) = 1 \]

\[ C(p_1, 1; \varphi_s) = .48 \]
\[ u_0(q_D, q_A; \varphi_0) = \left[ .1^{1/2} q_D^{1/2} + .1^{1/2} q_A^{1/2} \right]^2 \]

\[ u_1(q_D, q_A; \varphi_1) = \left[ .06^{1/2} q_D^{1/2} + .167^{1/2} q_A^{1/2} \right]^2 \]

\[ C(p_1, 1; \varphi_1) = .484 \]

\[ \Phi_U(p_0, p_1, 1; \varphi_0, \varphi_1) = \frac{.484}{.5} = .968 \]
$p_0 = p_1 = p$

$\Phi_U(p, p, 1; \varphi_0, \varphi_1) = \frac{.46}{.5} = .92$

$q_{\text{Dasani}} (20 \text{ oz bottles})$

$C(p, 1; \varphi_1) = .46$

$C(p, 1; \varphi_0) = .5$

$u_1 = 1$

$u_0 = 1$
\[ u_0(q_D, q_A; \varphi_0) = \left[ .1^{1/2} q_D^{1/2} + .1^{1/2} q_A^{1/2} \right]^2 \]

\[ u_1(q_D, q_A; \varphi_1) = \left[ .06^{1/2} q_D^{1/2} + .167^{1/2} q_A^{1/2} \right]^2 \]
\[ u_0(q_D, q_A; \varphi_0) = \left[ 0.1^{1/2} q_D^{1/2} + 1.1^{1/2} q_A^{1/2} \right]^2 \]

\[ u_1(q_D, q_A; \varphi_1) = \left[ 0.06^{1/2} q_D^{1/2} + 1.67^{1/2} q_A^{1/2} \right]^2 \]

\[ C(p_0, 1; \varphi_0) = 0.5 \]

\[ \Phi_U(p_0, p_1, 1; \varphi_0, \varphi_1) = \frac{0.484}{0.5} = 0.968 \]

- \( q_{\text{Aquafina}} \) (20 oz bottles)
- \( q_{\text{Dasani}} \) (20 oz bottles)
\[ u_0(q_D, q_A; \varphi_0) = \left[ 1^{1/2} q_D^{1/2} + 1^{1/2} q_A^{1/2} \right]^2 \]

\[ u_1'(q_D, q_A; \varphi_1') = \left[ 0.057^{1/2} q_D^{1/2} + 1.58^{1/2} q_A^{1/2} \right]^2 \]

\[ C(p_0, 1; \varphi_0) = 0.5 \]

\[ \Phi_U(p_0, p_1, 1; \varphi_0, \varphi_1') = \frac{0.509}{0.5} = 1.019 \]

\[ C(p_1, 1; \varphi_1') = 0.509 \]
Alternative “constant standard-of-living”

- Balk (1989)

\[
\Phi_{U^*}(p_0, p_1, q_r; \varphi_0, \varphi_1) = \frac{C(p_1, u_1(q_r); \varphi_1)}{C(p_0, u_0(q_r); \varphi_0)}
\]  

(6)

for a given \(q_r\), where \(u_t(q)\) is the direct utility function

- Between two situations, the change in minimum expenditure required for an agent to reach an indifference curve passing through a fixed bundle

- See also Gábor-Tóth and Vermeulen (2018)
Laspeyres: \( P_L = \frac{\sum_{i \in I} p_i q_i}{\sum_{i \in I} p_i q_i} \)

Paasche: \( P_P = \frac{\sum_{i \in I} p_i q_i}{\sum_{i \in I} p_i q_i} \)

Fisher: \( P_F = \sqrt{P_L P_P} \)

Tornqvist: \( P_T = \prod_{i \in I} \left( \frac{p_i}{p_i} \right)^{0.5(s_{i0}+s_{i1})} \),
\[
 s_{it} = \frac{p_i q_i}{\sum_{j \in I} p_j q_j}, \quad t = 0, 1.
\]

Sato-Vartia: \( P_{SV} = \prod_{i \in I} \left( \frac{p_i}{p_i} \right)^{w_i} \),
\[
 w_i = \left[ \frac{s_{i1}-s_{i0}}{\ln s_{i1}-\ln s_{i0}} \right] / \left[ \sum_{k \in I} \frac{s_{k1}-s_{k0}}{\ln s_{k1}-\ln s_{k0}} \right]
\]
## Scantrack Data by Department

<table>
<thead>
<tr>
<th>Department</th>
<th># PG</th>
<th># UPC</th>
<th>Exp.</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcoholic Beverages</td>
<td>4</td>
<td>46,656</td>
<td>0.073</td>
<td></td>
</tr>
<tr>
<td>Dairy</td>
<td>12</td>
<td>46,686</td>
<td>0.153</td>
<td></td>
</tr>
<tr>
<td>Deli</td>
<td>1</td>
<td>22,061</td>
<td>0.022</td>
<td></td>
</tr>
<tr>
<td>Dry Grocery</td>
<td>40</td>
<td>412,319</td>
<td>0.541</td>
<td></td>
</tr>
<tr>
<td>Fresh Meat</td>
<td>1</td>
<td>1,934</td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td>Fresh Produce</td>
<td>1</td>
<td>20,244</td>
<td>0.052</td>
<td></td>
</tr>
<tr>
<td>Frozen Foods</td>
<td>12</td>
<td>64,635</td>
<td>0.115</td>
<td></td>
</tr>
<tr>
<td>Packaged Meat</td>
<td>1</td>
<td>18,401</td>
<td>0.039</td>
<td></td>
</tr>
<tr>
<td><strong>All</strong></td>
<td><strong>72</strong></td>
<td><strong>632,936</strong></td>
<td><strong>1.000</strong></td>
<td></td>
</tr>
</tbody>
</table>

Note: Based on data provided by The Nielsen Company (U.S.), LLC.
Scantrack vs. Official Sources

Table: Food and Beverage Expenditures (Billions of Dollars)

<table>
<thead>
<tr>
<th>Source</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE</td>
<td>465.2</td>
<td>471.3</td>
<td>505.8</td>
<td>506.1</td>
</tr>
<tr>
<td>PCE</td>
<td>699.8</td>
<td>736.9</td>
<td>768.7</td>
<td>772.6</td>
</tr>
<tr>
<td>Scantrack</td>
<td>767.2</td>
<td>802.1</td>
<td>834.4</td>
<td>841.9</td>
</tr>
<tr>
<td>Scantrack/CE</td>
<td>1.65</td>
<td>1.70</td>
<td>1.65</td>
<td>1.66</td>
</tr>
<tr>
<td>Scantrack/PCE</td>
<td>1.10</td>
<td>1.09</td>
<td>1.09</td>
<td>1.09</td>
</tr>
</tbody>
</table>

Note: Based on data provided by The Nielsen Company (U.S.), LLC.
CE = Consumer Expenditure Survey (BLS)
PCE = Personal Consumption Expenditures (BEA)
Summary Statistics for $p_{it}/p_{i,t-4}$ by Department

<table>
<thead>
<tr>
<th>Department</th>
<th>Obs</th>
<th>Mean</th>
<th>StDev</th>
<th>Skew</th>
<th>Kurt</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcoholic Beverages</td>
<td>343,007</td>
<td>1.021</td>
<td>0.118</td>
<td>0.415</td>
<td>7.163</td>
<td>0.270</td>
<td>2.098</td>
</tr>
<tr>
<td>Dairy</td>
<td>383,519</td>
<td>1.037</td>
<td>0.137</td>
<td>0.908</td>
<td>6.577</td>
<td>0.469</td>
<td>2.256</td>
</tr>
<tr>
<td>Deli</td>
<td>128,081</td>
<td>1.025</td>
<td>0.117</td>
<td>0.322</td>
<td>6.578</td>
<td>0.500</td>
<td>1.635</td>
</tr>
<tr>
<td>Dry Grocery</td>
<td>2,941,985</td>
<td>1.036</td>
<td>0.141</td>
<td>0.777</td>
<td>9.977</td>
<td>0.210</td>
<td>2.782</td>
</tr>
<tr>
<td>Fresh Meat</td>
<td>12,162</td>
<td>1.028</td>
<td>0.117</td>
<td>0.767</td>
<td>6.633</td>
<td>0.557</td>
<td>1.759</td>
</tr>
<tr>
<td>Fresh Produce</td>
<td>113,895</td>
<td>1.033</td>
<td>0.165</td>
<td>0.844</td>
<td>6.490</td>
<td>0.458</td>
<td>1.992</td>
</tr>
<tr>
<td>Frozen Foods</td>
<td>454,187</td>
<td>1.027</td>
<td>0.125</td>
<td>0.253</td>
<td>6.360</td>
<td>0.281</td>
<td>1.807</td>
</tr>
<tr>
<td>Packaged Meat</td>
<td>148,512</td>
<td>1.025</td>
<td>0.106</td>
<td>0.516</td>
<td>5.623</td>
<td>0.625</td>
<td>1.618</td>
</tr>
<tr>
<td>All</td>
<td>4,525,348</td>
<td>1.033</td>
<td>0.136</td>
<td>0.74</td>
<td>9.254</td>
<td>0.21</td>
<td>2.782</td>
</tr>
</tbody>
</table>

Note: Based on data provided by The Nielsen Company (U.S.), LLC.
### Summary Statistics for $s_{it} / s_{i,t-4}$ by Department

<table>
<thead>
<tr>
<th>Department</th>
<th>Obs</th>
<th>Mean</th>
<th>StDev</th>
<th>Skew</th>
<th>Kurt</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcoholic Bev.</td>
<td>343,007</td>
<td>1.444</td>
<td>2.808</td>
<td>39.6</td>
<td>5798.3</td>
<td>0.002</td>
<td>570.0</td>
</tr>
<tr>
<td>Dairy</td>
<td>383,519</td>
<td>1.303</td>
<td>2.163</td>
<td>44.2</td>
<td>6005.1</td>
<td>0.000</td>
<td>412.3</td>
</tr>
<tr>
<td>Deli</td>
<td>128,081</td>
<td>1.515</td>
<td>2.692</td>
<td>7.4</td>
<td>74.4</td>
<td>0.003</td>
<td>52.0</td>
</tr>
<tr>
<td>Dry Grocery</td>
<td>2,941,985</td>
<td>1.471</td>
<td>5.160</td>
<td>129.2</td>
<td>29494.4</td>
<td>0.000</td>
<td>1796.8</td>
</tr>
<tr>
<td>Fresh Meat</td>
<td>12,162</td>
<td>1.354</td>
<td>2.416</td>
<td>12.5</td>
<td>256.5</td>
<td>0.002</td>
<td>81.6</td>
</tr>
<tr>
<td>Fresh Produce</td>
<td>113,895</td>
<td>2.090</td>
<td>5.808</td>
<td>8.9</td>
<td>103.9</td>
<td>0.003</td>
<td>125.4</td>
</tr>
<tr>
<td>Frozen Foods</td>
<td>454,187</td>
<td>1.426</td>
<td>4.463</td>
<td>113.5</td>
<td>24294.4</td>
<td>0.000</td>
<td>1256.3</td>
</tr>
<tr>
<td>Packaged Meat</td>
<td>148,512</td>
<td>1.258</td>
<td>1.481</td>
<td>6.6</td>
<td>61.5</td>
<td>0.006</td>
<td>24.8</td>
</tr>
<tr>
<td><strong>All</strong></td>
<td>4,525,348</td>
<td>1.460</td>
<td>4.632</td>
<td>127.8</td>
<td>31713.4</td>
<td>0.000</td>
<td>1796.8</td>
</tr>
</tbody>
</table>

*Note: Based on data provided by The Nielsen Company (U.S.), LLC.*
# Elasticity of Substitution Estimates by Department

<table>
<thead>
<tr>
<th>Prod. Gr.</th>
<th>P25</th>
<th>Med</th>
<th>P75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcoholic Beverages</td>
<td>4</td>
<td>5.96</td>
<td>7.06</td>
</tr>
<tr>
<td>Dairy</td>
<td>10</td>
<td>3.31</td>
<td>3.65</td>
</tr>
<tr>
<td>Deli</td>
<td>1</td>
<td>3.96</td>
<td>3.96</td>
</tr>
<tr>
<td>Dry Grocery</td>
<td>40</td>
<td>3.85</td>
<td>4.68</td>
</tr>
<tr>
<td>Fresh Meat</td>
<td>1</td>
<td>3.37</td>
<td>3.37</td>
</tr>
<tr>
<td>Fresh Produce</td>
<td>1</td>
<td>2.94</td>
<td>2.94</td>
</tr>
<tr>
<td>Frozen Foods</td>
<td>12</td>
<td>3.31</td>
<td>3.94</td>
</tr>
<tr>
<td>Packaged Meat</td>
<td>1</td>
<td>3.12</td>
<td>3.12</td>
</tr>
<tr>
<td>All</td>
<td>70</td>
<td>3.39</td>
<td>4.32</td>
</tr>
</tbody>
</table>

Note: Based on data provided by The Nielsen Company (U.S.), LLC.
## Mean CES Indexes by Department (percent change)

<table>
<thead>
<tr>
<th>Department</th>
<th>CCV</th>
<th>SV</th>
<th>LMM</th>
<th>LM</th>
<th>BLM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcoholic Beverages</td>
<td>0.0845</td>
<td>1.8585</td>
<td>1.8283</td>
<td>1.3839</td>
<td>2.2751</td>
</tr>
<tr>
<td>Dairy</td>
<td>1.3019</td>
<td>2.8165</td>
<td>2.7756</td>
<td>1.5423</td>
<td>4.0415</td>
</tr>
<tr>
<td>Deli</td>
<td>−2.4059</td>
<td>1.0556</td>
<td>1.0079</td>
<td>0.3502</td>
<td>1.6703</td>
</tr>
<tr>
<td>Dry Grocery</td>
<td>−3.4241</td>
<td>3.2381</td>
<td>2.8131</td>
<td>1.3882</td>
<td>4.3103</td>
</tr>
<tr>
<td>Fresh Meat</td>
<td>−2.0699</td>
<td>2.2678</td>
<td>2.2774</td>
<td>1.6551</td>
<td>2.9040</td>
</tr>
<tr>
<td>Fresh Produce</td>
<td>−2.0258</td>
<td>1.1468</td>
<td>1.1583</td>
<td>0.1446</td>
<td>2.1833</td>
</tr>
<tr>
<td>Frozen Foods</td>
<td>−9.6467</td>
<td>1.9408</td>
<td>1.8948</td>
<td>1.4150</td>
<td>2.3794</td>
</tr>
<tr>
<td>Packaged Meat</td>
<td>−1.0369</td>
<td>1.1688</td>
<td>1.1596</td>
<td>0.8894</td>
<td>1.4307</td>
</tr>
<tr>
<td>All</td>
<td>−2.9549</td>
<td>2.6810</td>
<td>2.4373</td>
<td>1.3093</td>
<td>3.6107</td>
</tr>
</tbody>
</table>

Note: Based on data provided by The Nielsen Company (U.S.), LLC. Statistics are averages of product group-level indexes weighted by the product group’s share of expenditure in the comparison period. CCV refers to RW’s CES Common Varieties Index, SV refers to Sato-Vartia, LM refers to Lloyd-Moulton, BLM refers to Backwards Lloyd-Moulton, and LMM refers to the geometric mean of LM and BLM.