Storable Goods, Chain Drifts, and the Cost of Living Index: New Methodology and Application to Japanese Data

Kozo Ueda, Kota Watanabe and Tsutomu Watanabe

Waseda University, The Canon Institute for Global Studies&University of Tokyo

May 8, 2019
Very very very preliminary
Illustrative Figure of Scanner Data

- Daily, from 1988 to 2013
- Quantity and sales sold for product $i$ at retailer $r$ on date $t$
- Processed food and domestic articles (17 percent of household’s expenditure)

A cup noodle $i$ sold at retailer $r$
Goods are not perishable but storable

The key: a discrepancy between purchase and consumption

- Previous studies on price indices typically assume that goods are perishable.
- An important implication of storability is that the purchase of goods does not coincide with the consumption of goods.
  - Scanner data includes information about purchase, not necessarily consumption.
  - Temporary sales often increase purchase more than consumption.
  - The discrepancy between purchase and consumption is reflected in changes in household inventory.
- In the context of price index construction, goods storability yields chain drifts.
  - It may be inappropriate to use purchase based weights. We should use consumption based weights.
  - It may be inappropriate to use purchase price. We should use consumption price.
What the paper does

- Report empirical evidences associated with storable goods.
  - Huge bias in the **purchase-based** chained price index, consistent with theory
  - Evidence of household inventory, consistent with theory
- Construct a quasi dynamic model for storable goods
  - Incorporate stockpiling behavior by households
  - Explain the facts
- Propose a procedure to estimate consumption/inventory from the scanner data (purchase data)
  - Bias is mitigated by **consumption-based** index, but not perfectly.
It is known that the Törnqvist price index is a good approximation of the Cost of Living Index (COLI),

Changes in the Törnqvist price index between \( t - dt \) and \( t \) is defined as

\[
\pi_{t,dt}^{C,T} = \sum_{k \in K_{t-dt} \cap K_t} \frac{W_t^k(K_{t-dt} \cap K_t) + W_t^k(K_{t-dt} \cap K_t)}{2} \log \left( \frac{p_t^k}{p_{t-dt}^k} \right),
\]

where the weight share

\[
W_t^k(K_{t-dt} \cap K_t) \equiv p_t^k x_t^k / \sum_{k' \in K_{t-dt} \cap K_t} p_t^k x_t^{k'}.
\]

Also changes in the price indices based on Logarithmic Laspeyres and Logarithmic Paasche are defined as

\[
\pi_{t,dt}^{C,L} = \sum_{k \in K_{t-dt} \cap K_t} W_t^k(K_{t-dt} \cap K_t) \log \left( \frac{p_t^k}{p_{t-dt}^k} \right),
\]

\[
\pi_{t,dt}^{C,P} = \sum_{k \in K_{t-dt} \cap K_t} W_t^k(K_{t-dt} \cap K_t) \log \left( \frac{p_t^k}{p_{t-dt}^k} \right).
\]
Unchained index

- Timeseries of $\pi_{t,dt}^{C,T}$, $dt = 365$ days,
  $t \in [\text{Apr.1, 1989, Oct.31, 2013}]$
$P_t^X = \exp \left( \sum_{s=1}^t \pi_{s,dt}^{c,X} \right), \ dt = 1 \text{day}, \ X = \{T, L, P\}.$

*The missing prices are interpolated by the estimated regular price.*
Suggestive thought experiment by Haan and van der Grient (2011)

Estimate the price inflation from the following table. $0 < r < 1$

<table>
<thead>
<tr>
<th></th>
<th>$t=0$</th>
<th>$t=1$</th>
<th>$t=2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item A</strong></td>
<td><strong>Price</strong></td>
<td>$p_A$</td>
<td>$(1-r)p_A$</td>
</tr>
<tr>
<td></td>
<td><strong>Share</strong></td>
<td>$w_0$</td>
<td>$w_1$</td>
</tr>
<tr>
<td><strong>Item B</strong></td>
<td><strong>Price</strong></td>
<td>$p_B$</td>
<td>$p_B$</td>
</tr>
<tr>
<td></td>
<td><strong>Share</strong></td>
<td>$1-w_0$</td>
<td>$1-w_1$</td>
</tr>
</tbody>
</table>

- if $w_2 < w_0 < w_1 \rightarrow$ Paasche $<$ Törnqvist $<$ 0% $<$ Laspeyres.
- The household have enough inventory on the day after the sale ends, then they do not buy much on that day.
Movement of prices (left) and quantities (right) over a sales period

Comparison with the price/quantity just before sales ($L = 0$). (more analysis needed to test statistical significance)
This causes the chain drift
left) Changes in sales share, right) Chained weighted changes.
About 4,000 households in total (about 400 hhs in each period).

Daily, from 1998 to present

Food only

Records

- who, what, when and where purchased, **when and who consumed**, **when and why consumption ends** (used up, wasted, etc.).

- no price information

Consumption pattern of a salt product for a household (purchased on \( t = 19 \), started using on \( t = 22 \) and finished using on \( t = 144 \).
Consumption pattern of items in beer category for a particular household (the last use in green).
Consumption pattern of items in beer category for a particular household (the last use in green).
Closely follow Hendel and Nevo (2006), in which goods are storable and prices change stochastically between the high level (i.e. regular price) and the low level (i.e. sale price).

- Introduce warehouse firms in order to separate capability of inventory from the household.
- A household can purchase good from a producer or warehouse.
- Quantities consumed deviate from quantities purchased because goods are stockpiled during a sale period.
- Consumption price deviates from purchase price because the warehouse firms sell at prices between $P_L$ and $P_H$ during an effective sale duration.
Algorithm to estimate consumption

1. Estimate the price elasticity $\sigma$ for each product category.

2. Calculate $m$ for each sale event of each product as:

$$m = \frac{P_H - P_L}{P_L} \frac{\sigma - 1}{1 - (P_H/P_L)^{-\sigma+1}} I_L,$$

where $X_L = (P_L/P_H)^{-\sigma} X_H$ and $I_L = \sum_{j=1}^T X_j - TX_L$ are the quantity consumed in each day of the sale and the level of inventory on the sale ends.

3. Calculate the consumption price: $r_{H,j} = (j/m)(P_H - P_L) + P_L$, and the quantity consumed: $c_j = (r_{H,j}/P_L)^{-\sigma} X_L$ for $j \in [1, m]$.

A cup noodle at a retailer
Milder chain drift, but not completely disappeared (roughly −10% annually).
Concluding remarks

- Summarize stylized facts associated with storable goods
- Construct an economic model for storable goods
- Estimate consumption from purchase data and construct the consumption-based price index.
  - Bias (Serious drift) is mitigated but not perfectly.
  - As for an asymmetric price up-and-down due to the non-negative constraint of inventory and purchase, the price index like Törnqvist is still biased even in the consumption-base.

Things to be done in the near future
- More careful analysis on whether implications of the model are consistent with the actual data.
- More careful comparison of our consumption based price index with other indices including GEKS proposed by Ivanvic et al. (2011).
- More careful treatment with things such as quality adjustment and price imputation.