Product Turnovers and the Price Index under Japan's Deflation

Kozo Ueda[1], Kota Watanabe[2], and Tsutomu Watanabe[3]

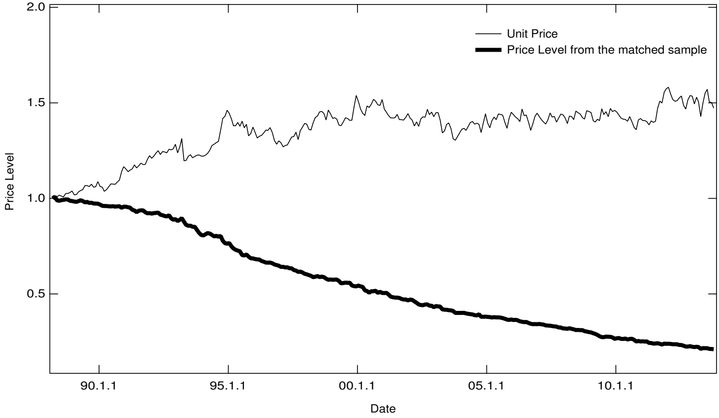
August 2016

[1]Waseda Univ
[2]CIGS and Univ of Tokyo
[3]Univ of Tokyo

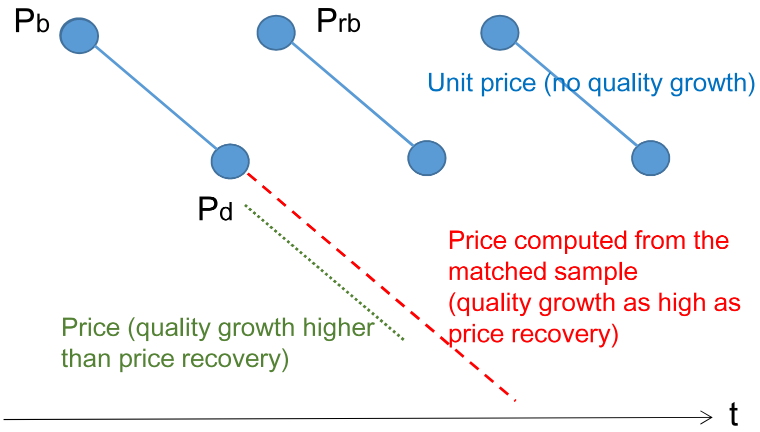
Motivations

- Product turnovers are frequent.
  - Quality improvement. Also, chance to recover fallen prices.
- Source of a bias in the Consumer Price Index (CPI)
  - Hard to collect price information on all the products that are continuously created and destructed ($\sim$100,000 products)
  - Hard to adjust quality changes
- Why was Japan's deflation mild?

The case of shampoo



The pattern of price changes and price indexes



- Our aims
  - We document stylized facts on the product turnovers in Japan.
    - What happened under deflation in the lost decades?
  - We evaluate the effects of product turnovers on the price index.
    - Deflation severer or milder?
    - Implications for the CPI

What We Do

- We use Japan's daily scanner or Point of Sales (POS) data.
  - Covers all the products sold in our sampled retailers.
  - Provides not only price but also quantity information. $\rightarrow$ beneficial to adjust quality.
- We incorporate quality and fashion effects in cacluating the welfare-based cost-of-living index (COLI).
  - Quality growth is evaluated by comparing the sales share between the preriod when a new product enters and that when an old product enters.
  - Fashion effect is then evaluated by comparing the sales share between the preriod when a new product enters and that when an old product exits.

What We Find

1. The rate of product turnovers is about 30 percent annually.
2. An increasing fraction of products end their lives in price declines.
3. The speed of price declines over product lives increases, as their life spans shorten.
4. Successors tend to recover prices.
5. While the fashion effect is increasing, quality growth is declining.
6. The price index measured from the matched sample is a good approximation of the COLI.

Literature Review

- Product turnovers
  - Boskin Commision Report (1996)
- Quality changes
  - COLI: Feenstra (1994) based on Sato (1976), Diewert(1976), and Melser (2006); Broda and Wenstein (2010); Greenlees and McClelland (2011)
  - Decomposition: Abe et al. (2015)
- Fashion effect
  - Bils (2009): 2/3 of price increases are due to quality growth; Kryvtsov (2016)
  - not COLI
- We combine both quality and fashion effects to construct the COLI.

Outline of Today's Talk

- Introduction (done)
- Model (before data)
- Data
- Cost-of-living index, quality, fashion

Model

Follow Feenstra (1994) and Melser (2006) with Bils (2009).
Suppose the CES cost function (COLI) over a changing domain of products $i \in I_t$:

$$C(p(t), I_t) = \Big[\sum_{i \in I_t} c_i(t)\Big]^{1/(1-\sigma)}, \tag{1}$$

where

$$c_i(t) = \begin{cases} \phi_i(t_i) b_i \left[p_i(t)\right]^{1-\sigma} & \text{if } t_i < \tau \\ b_i \left[p_i(t)\right]^{1-\sigma} & \text{otherwise.} \end{cases} \tag{2}$$

Here $\sigma > 1$ and t_i, b_i and $\phi_i(t_i)$ represent time elapsed after the birth, quality, and fashion effect for product i, respectively. The fashion effect increases the utility for a limited period, while quality does permanently as long as the product remains.
Convenient relationship:

$$\frac{p_i(t) q_i(t)}{\sum_{j \in I_t} p_j(t) q_j(t)} = \frac{c_i(t)}{\sum_{j \in I_t} c_j(t)}. \tag{3}$$

This holds for any $j \in I_t$. The left-hand side is the sales share of product i, which is observable.

The change in the COLI is

$$
\frac{C(p(t), I_t)}{C(p(t-1), I_{t-1})} = \frac{\left[\sum_{i \in I_t} c_i(t)\right]^{1/(1-\sigma)}}{\left[\sum_{i \in I_{t-1}} c_i(t-1)\right]^{1/(1-\sigma)}}
$$

$$
= \left[\frac{\sum_{i \in I_t} c_i(t)}{\sum_{i \in I_{t-1} \cap I_t} c_i(t)} \frac{\sum_{i \in I_{t-1} \cap I_t} c_i(t)}{\sum_{i \in I_{t-1} \cap I_t} c_i(t-1)} \frac{\sum_{i \in I_{t-1} \cap I_t} c_i(t-1)}{\sum_{i \in I_{t-1}} c_i(t-1)} \right]^{1/(1-\sigma)}
$$

$$
= \left[\frac{\sum_{i \in I_t} p_i(t) q_i(t)}{\sum_{i \in I_{t-1} \cap I_t} p_i(t) q_i(t)} \frac{\sum_{i \in I_{t-1} \cap I_t} c_i(t)}{\sum_{i \in I_{t-1} \cap I_t} c_i(t-1)} \frac{\sum_{i \in I_{t-1} \cap I_t} p_i(t-1) q_i(t-1)}{\sum_{i \in I_{t-1}} p_i(t-1) q_i(t-1)} \right]^{1/} \tag{4}
$$

- By Feenstra (1994).
- The invsere of the first term represents one minus the fraction of the sales of newly born products in t to total sales in t.
- The third term represents one minus the fraction of the sales of the products in $t-1$ that exit in t.
- However, the numertor and denominator in the second-term do not necessarily have common preference parameters, as long as the fashion effect is present. The denominator is subject to the fashion effect. Thus, we cannot simply compare their prices $p_i(t)/p_i(t-1)$ by regarding them as being in a matched sample.

The following formula makes the second-term be in a matched sample and yields the approximate COLI with the fashion effect.

$$
\begin{aligned}
\frac{C(p(t), I_t)}{C(p(t-1), I_{t-1})} &= \frac{\left[\sum_{i\in I_t} c_i(t)\right]^{1/(1-\sigma)}}{\left[\sum_{i\in I_{t-1}} c_i(t-1)\right]^{1/(1-\sigma)}} \\
&= \left[\frac{\sum_{i\in I_t} c_i(t)}{\sum_{i\in I_{t-\tau-1}\cap I_{t-1}\cap I_t} c_i(t)} \frac{\sum_{i\in I_{t-\tau-1}\cap I_{t-1}\cap I_t} c_i(t)}{\sum_{i\in I_{t-\tau-1}\cap I_{t-1}\cap I_t} c_i(t-1)} \frac{\sum_{i\in I_{t-\tau-1}\cap I_{t-1}\cap I_t} c_i(t-1)}{\sum_{i\in I_{t-1}\cap I_t} c_i(t-1)} \right. \\
&= \left[\frac{\frac{\sum_{i\in I_t} p_i(t)q_i(t)}{\sum_{i\in I_{I_{t-\tau-1}}\cap I_{t-1}\cap I_t} p_i(t)q_i(t)} \frac{\sum_{i\in I_{t-\tau-1}\cap I_{t-1}\cap I_t} c_i(t)}{\sum_{i\in I_{t-\tau-1}\cap I_{t-1}\cap I_t} c_i(t-1)}}{\frac{\sum_{i\in I_{t-\tau-1}\cap I_{t-1}\cap I_t} p_i(t-1)q_i(t-1)}{\sum_{i\in I_{t-1}\cap I_t} p_i(t-1)q_i(t-1)}} \right]^{1/(1-\sigma)} . \qquad (5)
\end{aligned}
$$

- The inverse of the first term represents one minus the fraction of the sales of the products in period t that are born from period $t-\tau$ to t.
- The third term represents one minus the fraction of the products in perod $t-1$ that are born from period $t-\tau$ to $t-1$ or exit in period t.
- In the second term, their quality and fashion effect are the same, because the products are born at or before $t-\tau-1$. Computed by using $p_i(t)/p_i(t-1)$.

Quality growth

Quality growth is evaluated by comparing the sales share between the preriod t when a new product enters and that t' when an old product enters.
At birth, $c_i(t) = \phi_i(t_i) b_i \left[p_i(t)\right]^{1-\sigma}$. Suppose that its precedessor i' is born in t' as $c_{i'}(t') = \phi_{i'}(t_{i'}) b_{i'} \left[p_{i'}(t')\right]^{1-\sigma}$ and exit in $t-1$.
Suppose also $\phi_i(0) = \phi_{i'}(0) = \phi$. That is, for the same product category, the fashion effect is the same.
Then, we have

$$\frac{b_i}{b_{i'}} = \left[\frac{\frac{p_i(t) q_i(t)}{\sum_{j \in I_{t'-\tau} \cap I_t} p_j(t) q_j(t)}}{\frac{\sum_{i \in I_t} p_{i'}(t') q_{i'}(t')}{\sum_{j \in I_{t-\tau} \cap I_t} p_i(t') q_i(t')}} \right] \left[\frac{p_{i'}(t')}{p_i(t)} \right]^{1-\sigma} \left[\frac{\sum_{j \in I_{t'-\tau} \cap I_t} c_j(t)}{\sum_{j \in I_{t'-\tau} \cap I_t} c_j(t')} \right]. \tag{6}$$

Fashion effect

Fashion effect is then evaluated by comparing the sales share between the preriod t when a new product enters and that $t-1$ when an old product exits.

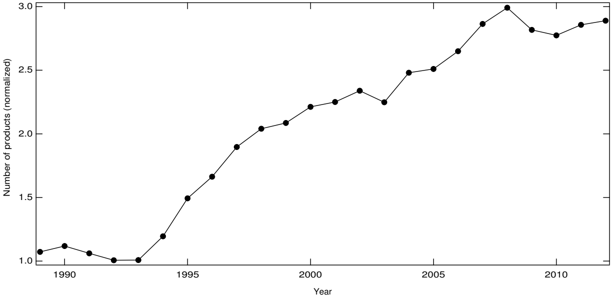
$$\phi_i(0)\frac{b_i}{b_{i'}} = \left[\frac{\frac{p_i(t)q_i(t)}{\sum_{j\in I_{t-\tau-1}\cap I_t} p_j(t)q_j(t)}}{\frac{\sum_{i\in I_t} p_{i'}(t-1)q_{i'}(t-1)}{\sum_{j\in I_{t-\tau-1}\cap I_t} p_i(t-1)q_i(t-1)}}\right]\left[\frac{p_{i'}(t-1)}{p_i(t)}\right]^{1-\sigma}\left[\frac{\sum_{j\in I_{t-\tau-1}\cap I_t} c_j(t)}{\sum_{j\in I_{t-\tau-1}\cap I_t} c_j(t-1)}\right]. \quad (7)$$

Fashion is also welfare improving, albeit temporarily.

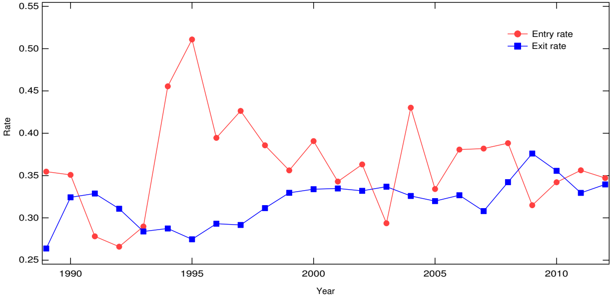
Data

Data

- Scanner or Point of Sales (POS)
- Daily, from March 1, 1988 to October 31, 2013
  - No data in November and December 2003
- 14 retailers that exist throughout the sample period
  - to study true product turnovers
- Processed food and domestic articles
- Quantity and sales for product i at shop s on date t
- Product i is identified by the Japanese Article Number (JAN) and the Nikkei's 3- and 6-digits
  - 860,000 products in total; 100,000 products per year; 30,000 products per year a shop

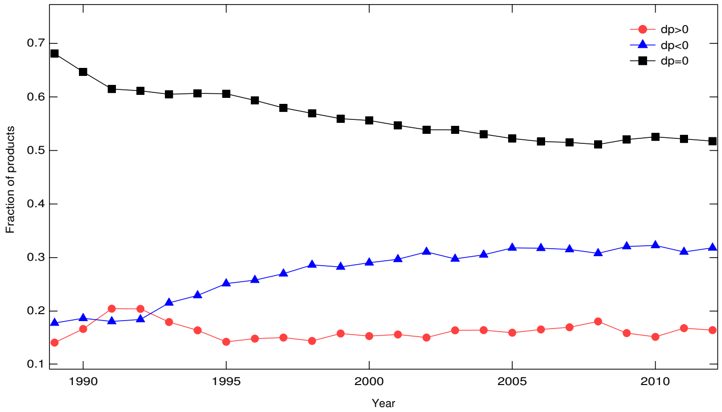


Number of products (normalized)
Year

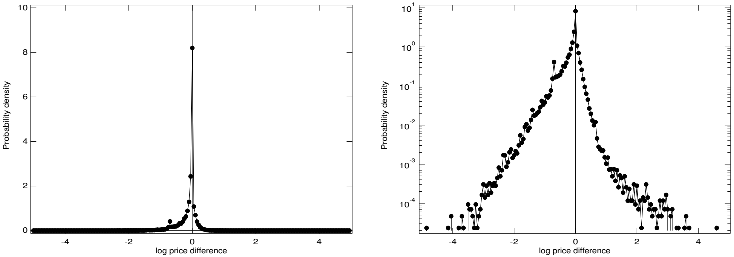


Entry rate
Exit rate
Rate
Year

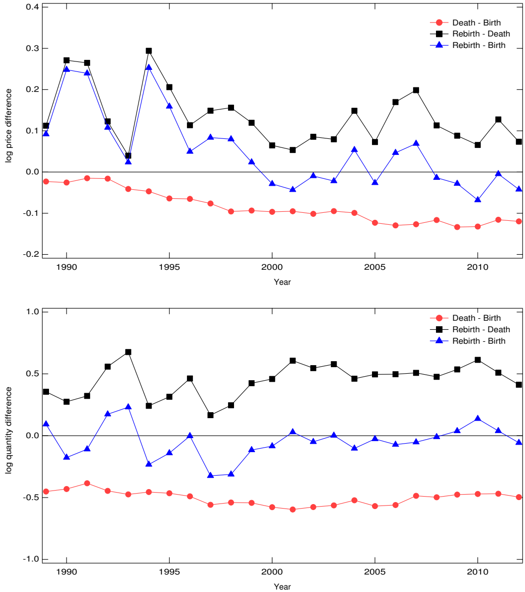
Price changes from birth to dealth



Density function of price changes

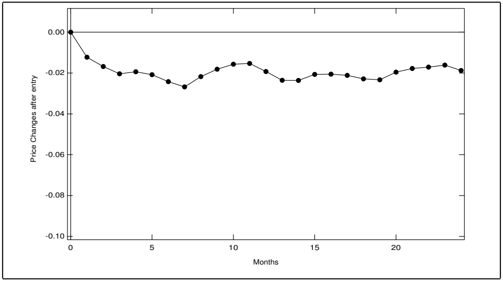


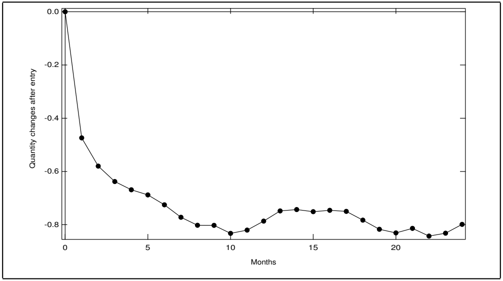
Price and quantity changes over product cycles



Price and quantity changes after birth

Horizontal axis: months after entry



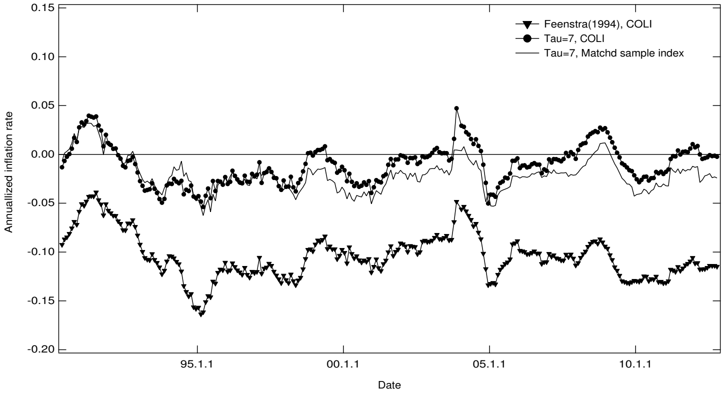


Cost-of-living index, quality, fashion

Calibration

- $\sigma = 11.5$ following Broda and Weinstein (2010). They also mention that the typical demand elasticity lies between 4 and 7.
- $\tau = 7$.

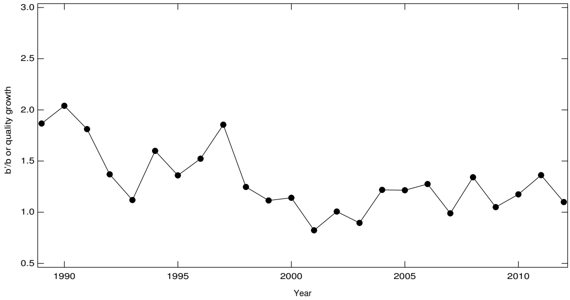
COLI time-series

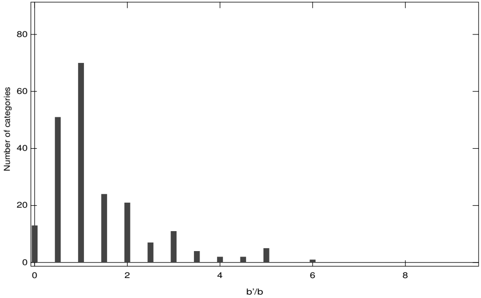


Reason for the gap between Feenstra and ours

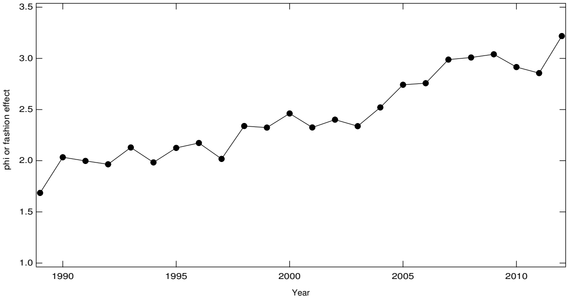
- Quality growth lowers the COLI permanently.
- Fashion lowers the COLI only in the short run, like temporary sales.
  - In the COLI equation, the sales of the products that are born in period t are compared to those that exit in the same period, which generates the quality growth.
  - The fashion effect influences both the first and third terms almost equally through the sales of the products in period t that are born in period t and those in period $t-1$ that are born in period $t-1$, respectively. Because their ratio matters for the change in the price index, the fashion effect is partially cancelled out.

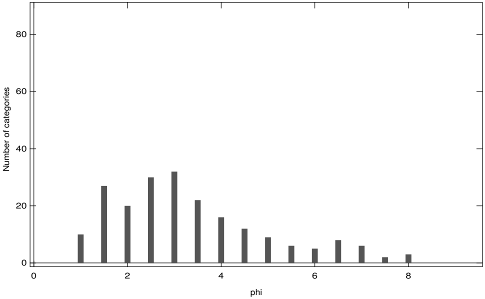
Quality growth



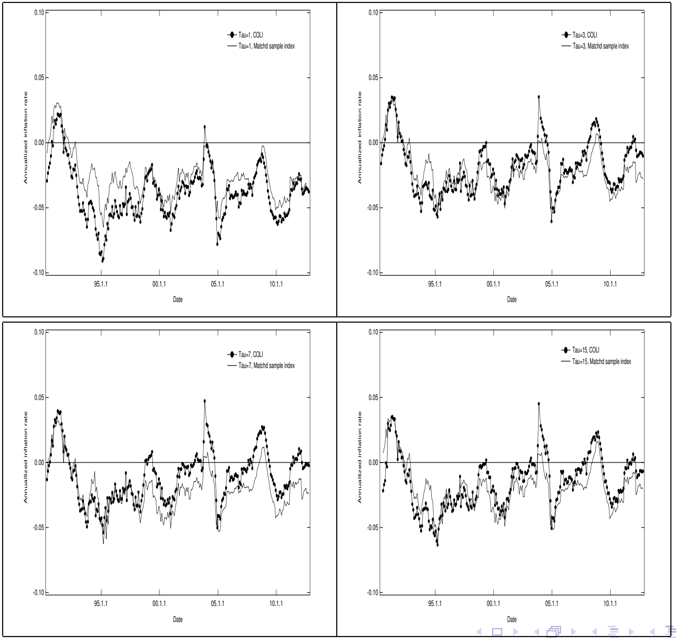


Fashion effect





Robustness to $\tau = 1, 3, 7$, and 15



Concluding Remarks

- Our study addresses why the size of deflation was mild.
  - Quality growth lowers the COLI, but at the same time, justifies the price recovery from the declined price of its predecessor in a nominal term.
  - The stable fashion effect also justifies price recovery.
- Future work
  - Link between the predecessor and successor products.
    - conditioning manufacturer firms, one month lag, product types
  - Other products that are not included in the POS such as services and durable goods

Appendix

Method: Aggregation

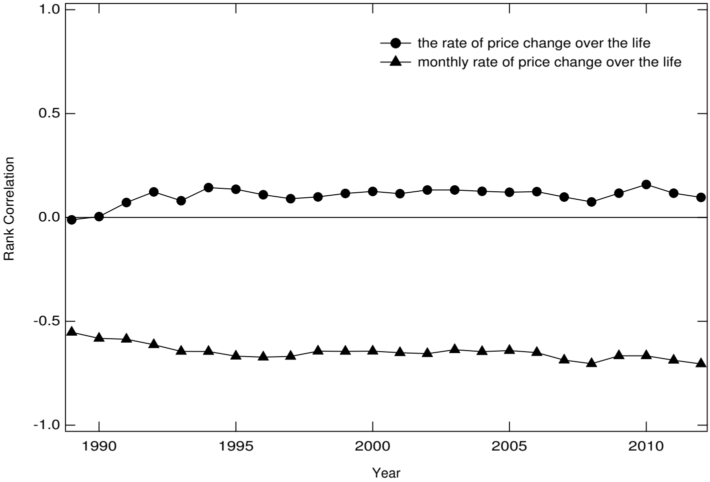
In this study, we aggregate variables of interest over days, products, and shops in the following way.

1. We aggregate a variable, such as sales and quantities of each product, over shops.
2. We take its average by dividing it by number of days in each month.
3. Except of the COLI, we take its logarithm, unless the variable is a change or ratio, then aggregate it over products with an equal weight for each product.

Method: Identifying Old and New Products

- New products
  - The earliest day t^B when new products are sold (born).
  - Denoting the days of the month t^M, we examine variables per day by dividing $t^M - t^B + 1$.
- Old products
  - The last day t^D when old products are sold (die).
  - We examine variables per day by dividing t^D.
- Link between the predecessor and successor
  - The same 3-digit code such as yogurt, beer, tobacco, and toothbrush
  - Not neccesarily the same company (this assumption is fine for the COLI from the perspective of household)
  - One month lag: A new product is born one month after an old product.
- Note that measurement error is large near the beginning and end of sample periods.

Correlation between the length of life span and the rate of price change over the life



The rate of inflation by life span