Price Trends over the Product Life Cycle and the Optimal Inflation Target[1]

Klaus Adam
University of Oxford and CEPR

Henning Weber
Deutsche Bundesbank

May 2019

[1]The opinions expressed in this presentation are those of the authors and do not necessarily reflect the views of the Deutsche Bundesbank or the Eurosystem.

Introduction

Micro data from modern economies show high rates of product turnover

- Nakamura & Steinsson 2008: Micro data underlying U.S. CPI
- Broda & Weinstein 2010: Product data at barcode level

Work on endogenous growth emphasizes role of product turnover & life cycles in the *real economy* since long (e.g., Aghion & Howitt 1992)

This paper analyzes role of product life cycles in the *monetary economy*

1. provides new facts on trends in relative prices over product life cycle
2. shows how "relative price trends" determine optimal inflation target $\Pi^{\star}$

New Evidence from U.K. Micro Price Data

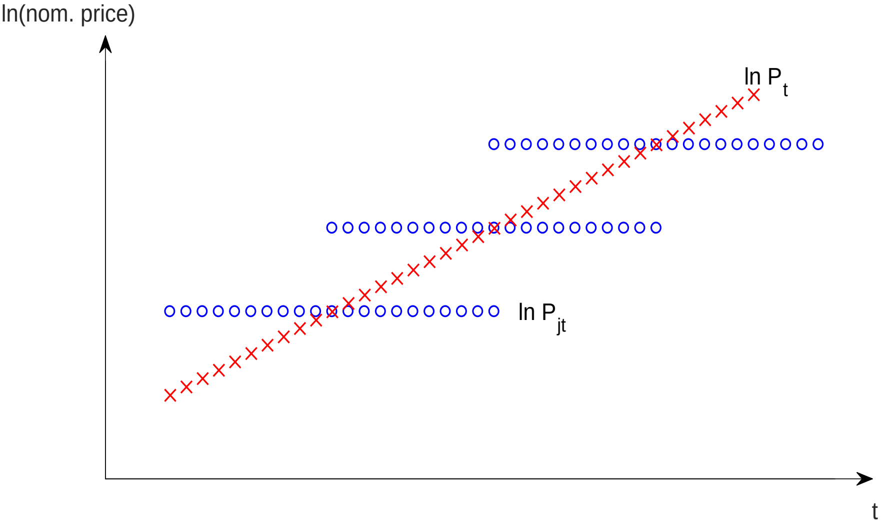
1. Product prices decline with product age, relative to average price in narrow expenditure category
   - *In relative terms*, newly entering products tend to be expensive, but become cheaper once they age
2. Substantial heterogeneity in age trends across expenditure categories
   - E.g., strongly negative age trends in items with "news value" (fashion)
3. Downward trend in relative prices accelerated over past two decades

Normative Consequences – Optimal Inflation Target $\Pi^\star$

- Proposition: Estimated age trend in relative price P_{jt}/P_t is *efficient*
  - Holds in sticky price model with suboptimal inflation and shocks
  - Price stickiness distorts *level*, but not *age trend*, of relative price
- ∞ many ways to arrive at estimated age trend in P_{jt}/P_t
  - Declining P_{jt}, increasing P_t, or any combination thereof
- **Optimal way** to implement estimated age trend is **positive** $\Pi^\star$
  - Changes in P_{jt} distortive $\implies$ P_{jt} constant

  $\implies$ P_t should *increase* at inverse rate of age trend

P_t increases as newly entering products charge high relative prices...



Normative Consequences – Optimal Inflation Target $\Pi^\star$

- **Monetary policy tradeoff** underlying choice of $\Pi^\star$
  - Estimated age trend in rel prices varies across expenditure categories

    $\Longrightarrow$ optimal inflation $\Pi_z^\star$ varies across categories
  - In sticky price model with prod life cycle, tradeoff optimally resolved as

    $\Pi^\star \approx$ expenditure-weighted average of $\Pi_z^\star$'s
- Estimate $\Pi^\star$ using U.K. micro price data
  - $\Pi^\star$ estimate ranges from 2.6% to 3.2% in 2016
  - $\Pi^\star$ estimate increases by around 1.2% between 1996 and 2016

Outlook

1. U.K. Evidence on Age Trends in Relative Product Prices
2. Sticky Price Model with Product Life Cycles
3. Estimation Results for Optimal Inflation Target

Estimating Age Trends in Relative Product Prices

Employ U.K. micro price data underlying official U.K. CPI

Each product j classified into one of ≈ 1100 item (expenditure) categories

For each item category z, estimate linear panel regression

$$\ln \frac{\widetilde{P}_{jzt}}{P_{zt}} = f_{jz} + \ln(b_z) \cdot s_{jzt} + u_{jzt} \quad (1)$$

- $\widetilde{P}_{jzt}$ = nominal price of product j in item z
- P_{zt} = *quality adjusted* price index for item z
- s_{jzt} = in-sample product age (zero at entry date)
- b_z = common age trend (w/o product turnover, must have $b_z = 1$)

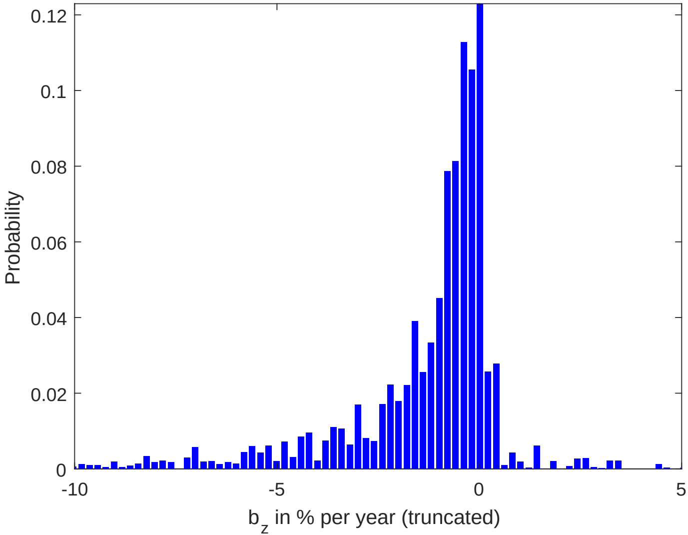
U.K. Micro Price Data Underlying U.K. CPI

- *Kryvtsov & Vincent 2017; Blanco 2018; Marencak & Hahn 2019*
- Monthly sample from Feb 1996 - Dec 2016, 29 million price quotes
- Drop "invalid" & "duplicate" (not uniquely identified) quotes Details
- Replicate official item indices (q adj, weights) excl duplicates Details
- Follow *same* product over time to estimate age trends
  - Split price trajectory of uniquely identified product at (i) substitution flags and (ii) observation gaps larger than one month
- **Baseline sample**: $Z = 1093$ items, 21.2 million price quotes

Number of Products per Item	
Median	925
Mean	1523.5
Number of Price Quotes per Item	
Median	14846
Mean	18739
Length of Price Spell per Product (Months)	
Median	9
Mean	14.5

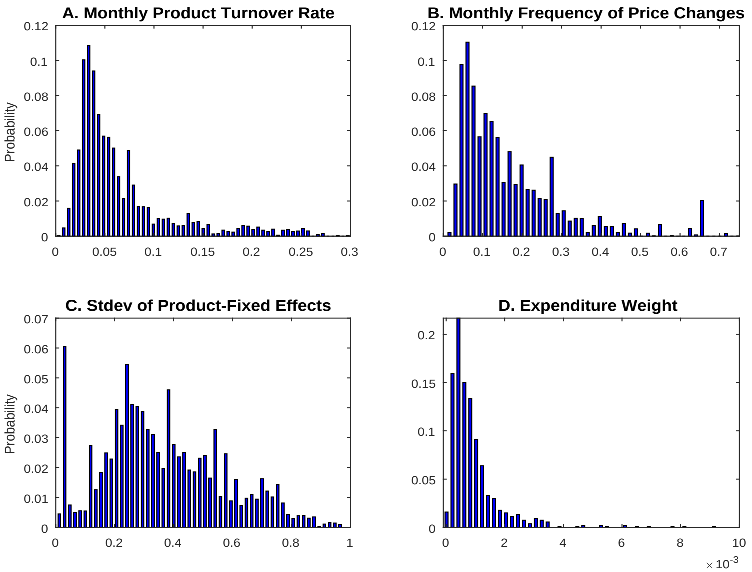
▸ Details

U.K. Evidence on Age Trends in Relative Prices ▸ Details



Item Description	Relative Price Change (in % per year)	Exp. Weight (in %)
Relative Price Increase		
HIFI - 2007	3.28	0.15
WIDESCREEN TV - 2005	2.55	0.31
CAMCORDER-8MM OR VHS-C	2.34	0.16
WASHING MACHINE - 2008	1.82	0.16
WASHING MACH NO DRYER MAX 1800	1.48	0.17
LEISURE CENTRE ANNUAL MSHIP	1.34	0.16
COOKED HAM PREPACKED/SLICED	0.84	0.17
Relative Price Decline		
MENS SHOES TRAINERS	-7.84	0.18
PRE-RECORDED DVD TOP 20	-8.14	0.23
WOMENS SUIT	-8.95	0.17
LADYS SCARF	-20.19	0.17
COMPUTER GAME TOP 20 CHART	-21.69	0.31
WOMENS DRESS-CASUAL 1	-25.55	0.17
PRE-RECORDED DVD (FILM)	-35.03	0.16

Other Dimensions of Heterogeneity across Items



Sticky Price Model with Product Life Cycles

Augmented version of one-sector model in Adam & Weber 2019

- Many expenditure items $z = 1, \ldots Z_t$, exogenous item turnover
- Item-specific product life cycles driven by quality & productivity
  - **Product quality "frontier"** Q_{zt} evolves stochastically over time
  - **Product quality** Q_{jzt} set at entry and constant thereafter
  - **Productivity** G_{jzt} evolves dynamically over product life
- Idiosyn entry / exit shock yields **stochastic product life time**

Relative Price Trends over Product Life Cycle

Calvo-type pricing frictions

- At time of product entry, firm can freely choose product price
- Subsequently, firm faces item-specific price stickiness

Quality adj **optimal reset price** $P^{\star}_{jzt} \equiv \widetilde{P}^{\star}_{jzt} / Q_{jzt}$ has two components:

$$\frac{P^{\star}_{jzt}}{P_{zt}} = \underbrace{\left(\frac{Q_{jzt} \, G_{jzt}}{Q_{zt}} \right)^{-1}}_{\text{Life cycle dynamics}} \times \underbrace{\left(\frac{\theta}{\theta - 1} \frac{1}{1+\tau} \right) \frac{n_{zt}}{d_{zt} \, p_{zt}}}_{\text{stationary forward-looking comp}}$$

- Price stickiness only distorts fwd-looking comp $\implies$ level of $P^{\star}_{jzt} / P_{zt}$
- n_{zt}, d_{zt} are stationary exp disc marginal costs & revenues ▸ Details

Life Cycle Dynamics in Productivity

- Output *quantity* of product j in item z

$$\widetilde{Y}_{jzt} = A_{zt} G_{jzt} \left(K_{zjt}^{1-\frac{1}{\phi}} L_{zjt}^{\frac{1}{\phi}} \right)$$

- Product-specific TFP ("experience"):

$$\begin{aligned} G_{jzt} &= \overline{G}_{jzt} \cdot \epsilon^{G}_{jzt}, && \epsilon^{G}_{jzt} \sim \Xi^{G}_{z} \text{ drawn at entry, then constant} \\ \overline{G}_{jzt} &= \begin{cases} 1 & \text{for age } s_{jzt} = 0, \\ g_{zt} \cdot \overline{G}_{jz,t-1} & \text{otherwise,} \end{cases} \\ g_{zt} &= g_{z} \cdot \epsilon^{g}_{zt}, && \epsilon^{g}_{zt} := \text{stationary with } E \ln \epsilon^{g}_{zt} = 0 \end{aligned}$$

- Asspts Quality

Proposition

Consider a stochastic economy with potentially suboptimal inflation Π_t. In price adjustment periods, the **optimal reset price** *satisfies*

$$\ln \frac{P^{\star}_{jzt}}{P_{zt}} = f^{\star}_{jz} - \ln\left(\frac{g_z}{q_z}\right) \cdot s_{jzt} + u^{\star}_{jzt}, \tag{2}$$

where s_{jzt} is product age and $u^{\star}_{jzt}$ a stationary residual with $E[u^{\star}_{jzt}] = 0$.

- Despite sticky prices, age trend only due to life cycle in productivity g_z and quality q_z

  $\Longrightarrow$ Sticky-price firm has profit incentive to track **flex-price trend**

- Eqn (2) resembles previous regression (but: reset vs all prices, q adj)

  $\Longrightarrow$ **Estimated age trends** in U.K. data **are estimates of g_z/q_z!**

Corollary

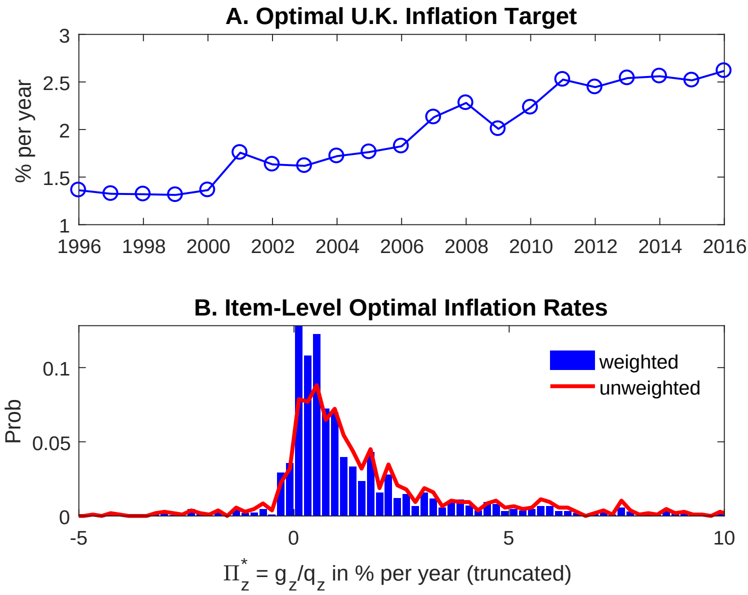
The optimal inflation rate that maximizes steady-state welfare is equal to

$$\Pi^* = \sum_{z=1}^{Z} \psi_z \left(\frac{g_z}{q_z} \frac{\gamma_z}{\gamma} \right) + O(2),$$

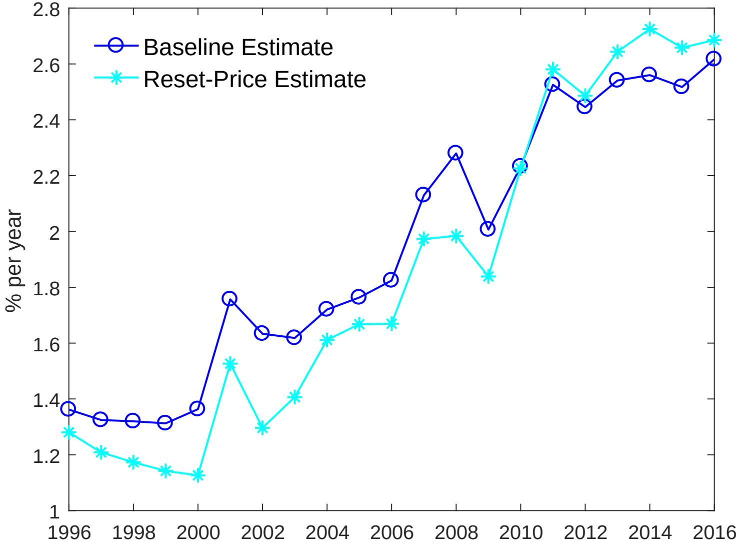
where ψ_z is spending share and γ_z/γ relative growth of item z. Prop

1. **Optimality**: P_{zt} = inverse age trend $\implies \Pi_z^\star = g_z/q_z$
2. **New policy tradeoff**: One instrument $\Pi^\star$ but many different $\Pi_z^\star$'s
   - Wolman 2011 studies related tradeoff in model with $g_z/q_z = 1$
3. **Estimation**: Age trends in relative prices in U.K. data inform $\Pi^\star$
   - Allow for item turnover $Z_t \implies$ gradual time variation in $\Pi^\star$

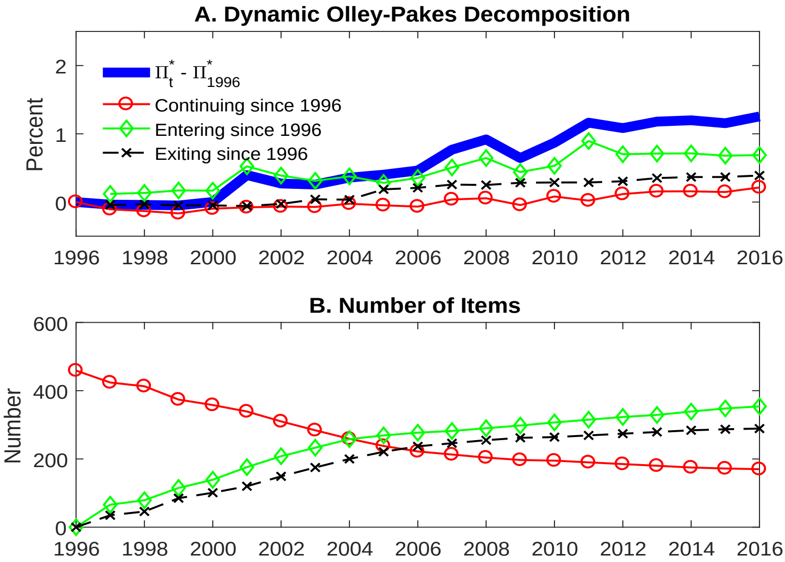
Baseline Results - $\Pi^{\star}$ Estimate Using All Prices



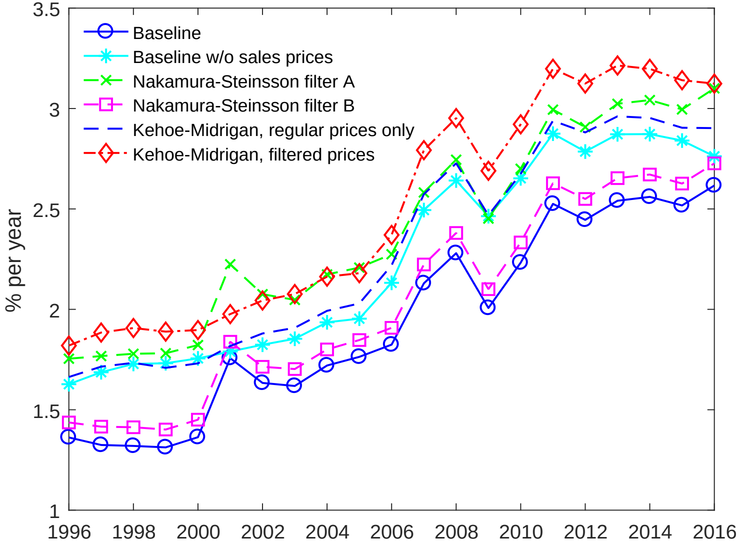
$\Pi^{\star}$ Estimate Using All Prices (Baseline) vs Reset Prices



$\Pi^\star$ Trend Decomposition (Melitz Polanec 2015)



$\Pi^{\star}$ Estimate For Alternative Treatment of Sales Prices



Conclusions

Provided new evidence from U.K. micro price data that

- relative product prices decline with product age
- age trends differ widely across expenditure categories

Showed that age trends determine optimal inflation target $\Pi^{\star}$:

- New monetary policy tradeoff underlying choice of $\Pi^{\star}$
- For U.K. data, $\Pi^{\star}$ estimates in 2016 range from 2.6% to 3.2%
- $\Pi^{\star}$ estimate increased by 1.2% between 1996 and 2016

Relevance of Weighting Scheme for Estimated $\Pi^\star$

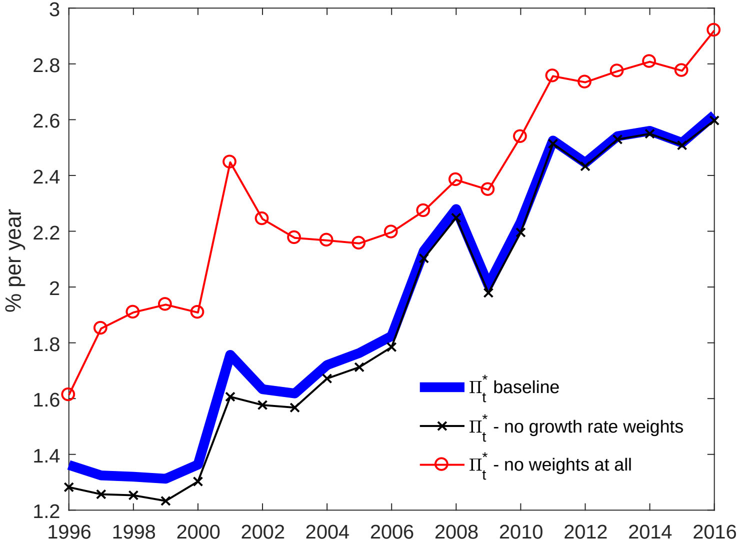
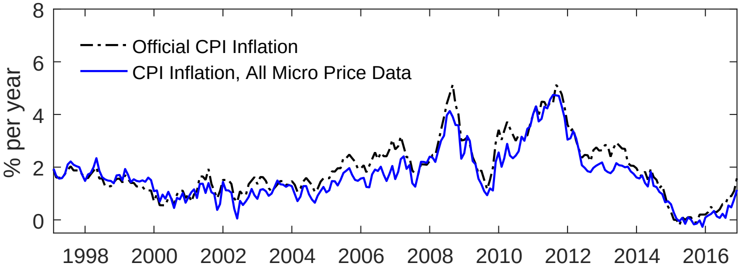
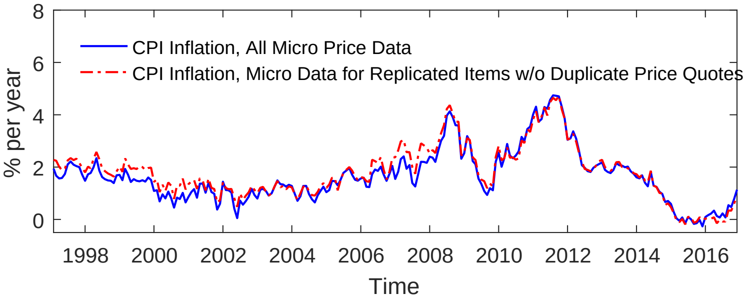


Table: Number of Price Quotes and ONS Product Identifiers

Price quotes in raw data	28.995.064
ONS product identifiers	736078
Price quotes excluding duplicate quotes	24.525.632
ONS product identifiers	687212
Price quotes excluding duplicate & invalid quotes	22.825.052
ONS product identifiers	682747
Price quotes w/o duplicate & invalid quote for replicated items	21.215.430
ONS product identifiers	613031

Back


% per year
Official CPI Inflation
CPI Inflation, All Micro Price Data
8
6
4
2
0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016


% per year
CPI Inflation, All Micro Price Data
CPI Inflation, Micro Data for Replicated Items w/o Duplicate Price Quotes
8
6
4
2
0
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Time

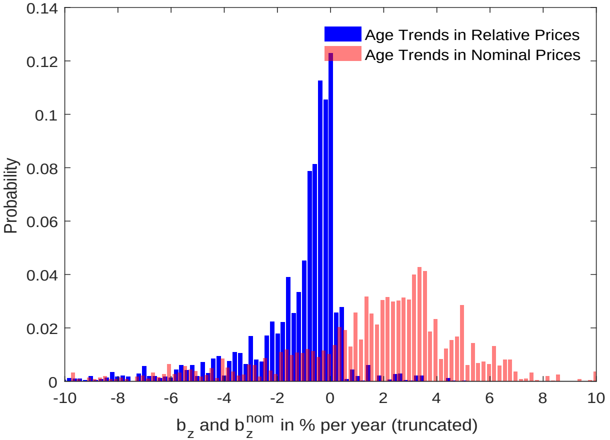
Back

Table: Substitution & Turnover Rates: Products and Product Identifiers

Substitution within ONS Product Identifiers	Monthly Rate in %
Comparable substitutions	5.74
Non-comparable substitutions	0.31
Turnover for ONS Product Identifiers	
Entry rate	2.44
Exit rate	2.44

Back

Age Trends in Relative Prices vs Nominal Prices



- Mean increases by 2.3% reflecting aggr inflation (2% in sample)
- Melser & Syed 2016: Mixed evidence for nominal product prices Back

Division Description	Relative Price Trend (in % per year)	Exp. Weight in 2016 (in %)	Number of Items (full smpl)
Food & Non-Alcoholic Beverages	-1.00	18.07	282
Alcoholic Beverages & Tobacco	-0.41	8.03	66
Clothing & Footwear	-9.36	11.92	149
Housing, Water, Electricity & Gas	-0.83	0.75	38
Furniture, Equip. & Maintenance	-1.67	9.98	146
Health	-0.73	3.82	26
Transport	-0.79	6.99	41
Communications	-6.97	0.11	7
Recreation & Culture	-3.98	9.44	157
Restaurants & Hotels	-0.36	18.82	79
Miscellaneous Goods & Services	-1.68	12.54	90

Optimal Quality-Adjusted Reset Price

$$\frac{P^{\star}_{jzt}}{P_{zt}} = \left(\frac{Q_{jzt}G_{jzt}}{Q_{zt}}\right)^{-1}\left(\frac{\theta}{\theta-1}\frac{1}{1+\tau}\right)\frac{N_{zt}}{D_{zt}}\frac{P_t}{P_{zt}}$$

$$N_{zt} = \frac{MC_t}{P_t A_{zt} Q_{zt}} + \alpha_z(1-\delta_z)E_t[\Omega_{t,t+1}\Pi^{\theta-1}_{z,t+1}\Pi_{t+1}\left(\frac{Y_{t+1}}{Y_t}\right)\left(\frac{q_{z,t+1}}{g_{z,t+1}}\right)N_{z,t+1}]$$

$$D_{zt} = 1 + \alpha_z(1-\delta_z)E_t[\Omega_{t,t+1}\Pi^{\theta-1}_{z,t+1}\left(\frac{Y_{t+1}}{Y_t}\right)D_{zt+1}]$$

with marginal costs MC_t ; discount factor $\Omega_{t,t+1}$; output subsidy τ Back

Life Cycle Dynamics in Product Quality

$$C_{zt} = \left(\int_0^1 \left({\color{red}Q_{jzt}} \widetilde{C}_{jzt} \right)^{\frac{\theta-1}{\theta}} \mathrm{dj} \right)^{\frac{\theta}{\theta-1}}$$

- Quality of a new product j entering in time t is

$$Q_{jzt} = Q_{zt} \cdot \epsilon^{Q}_{jzt}, \quad \epsilon^{Q}_{jzt} \sim \Xi^{Q}_{z} \text{ drawn at entry, then constant}$$

- Quality of product j stays constant over product life,

$$Q_{jzt} = Q_{jz,t-s_{jzt}} \quad \text{with} \quad s_{jzt} := \text{product age}$$

- Quality "frontier" evolves as

$$Q_{zt} = q_{zt} Q_{zt-1} \quad \text{with} \quad q_{zt} = {\color{red}q_z} \epsilon^{q}_{zt}$$

${\color{red}q_z}$:= mean quality growth; ϵ^{q}_{zt} := stationary with $E \ln \epsilon^{q}_{zt} = 0$ Back

Theorem

Assume $-1 < \tau \leq 1/(\theta - 1)$ *and consider the limit* $\beta(\gamma)^{1-\sigma} \to 1$. *Then, the welfare maximizing steady-state inflation rate is given by*

$$\Pi^\star = \sum_{z=1}^{Z} \omega_z \left(\frac{g_z}{q_z} \frac{\gamma_z}{\gamma} \right), \tag{3}$$

where $\gamma_z/\gamma = a_z q_z / \prod_{z=1}^{Z} (a_z q_z)^{\psi_z}$ *and weights* $\omega_z \geq 0$ *are given by*

$$\omega_z = \frac{\tilde{\omega}_z}{\sum_{z=1}^{Z} \tilde{\omega}_z}, \text{ where}$$

$$\tilde{\omega}_z = \frac{\theta \psi_z \alpha_z (1-\delta_z) (\frac{\gamma}{\gamma_z} \Pi^\star)^\theta (\frac{g_z}{q_z})^{-1}}{\left[1 - \alpha_z (1-\delta_z) (\frac{\gamma}{\gamma_z} \Pi^\star)^\theta (\frac{g_z}{q_z})^{-1}\right] \left[1 - \alpha_z (1-\delta_z) (\frac{\gamma}{\gamma_z} \Pi^\star)^{\theta-1}\right]}.$$

back

Robustness to Imperfect Quality Adjustment

- Define *not* quality adjusted item price level

$$\widetilde{P}_{zt} = \left(\int_0^1 (\widetilde{P}_{jzt})^{1-\theta} \mathrm{dj} \right)^{\frac{1}{1-\theta}}$$

- Show $\widetilde{\Pi}_z = q_z \Pi_z \implies \widetilde{\Pi}_z$ too high w/o quality adj if $q_z > 1$

- Estimate *biased* age trend: $\ln(\widetilde{P}^\star_{jzt} / \widetilde{P}_{zt}) = \widetilde{f}^\star_{jz} - \ln(g_z) \cdot s_{jzt}$

- Set optimal target w/o quality adj: $\ln \widetilde{\Pi}^\star = \sum_{z=1}^{Z} \psi_z \ln \left(g_z \frac{\gamma_z^e}{\gamma^e} \right)$

- This monetary policy achieves $\ln \Pi = \ln \Pi^\star$