Sources of Bias in Inflation Rates and Implications for Inflation Dynamics

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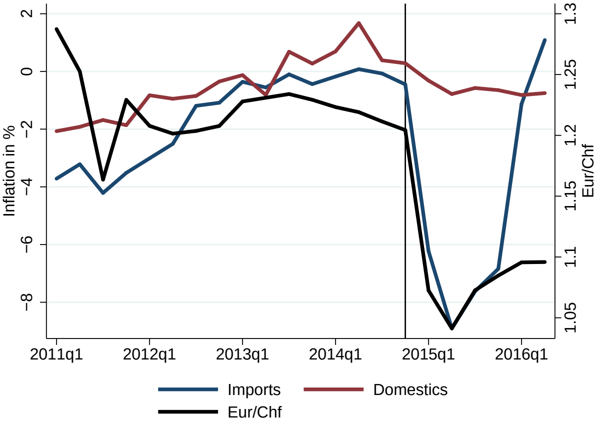
Motivation



- Inflation: cost today of yesterdays consumption basket
- Substitution bias is small + counter-intuitive behaviour $\rightarrow$ missing preference shifts?
- Unified Price Index (UPI) by Redding-Weinstein

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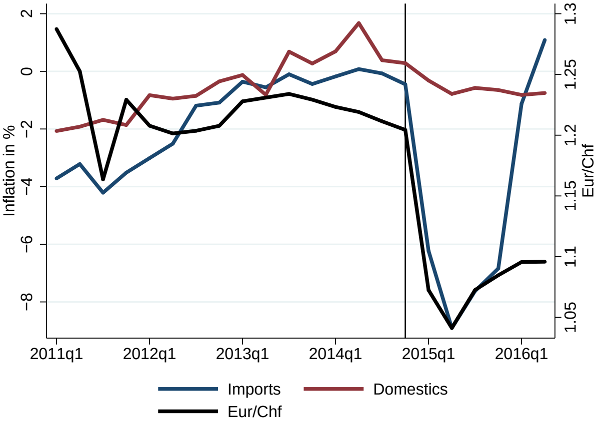

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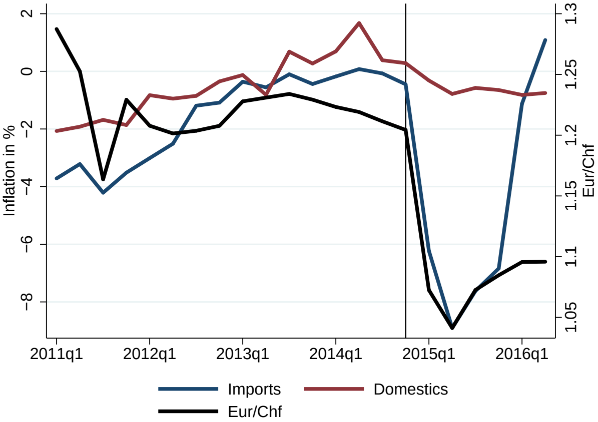

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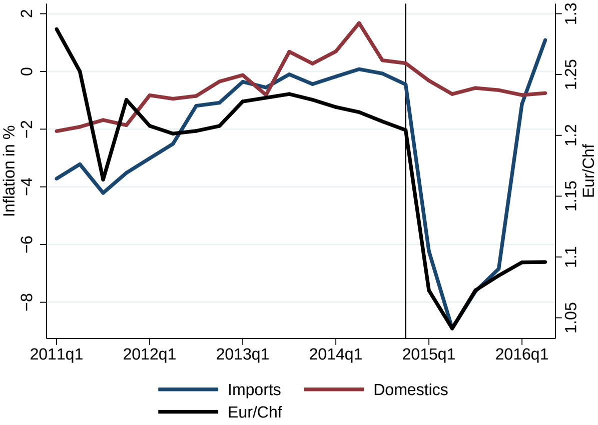

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Contribution and Takeaways

1. The traditional substitution bias resulting from lagged weights is small even after the ER shock
2. There is a significant difference in cost-of-living measures when moving from Laspeyres-type inflation rates to the UPI (4.1PP)
3. Not just level differences, UPI responds **2.6 times more** to the ER shock in 2015 than an index without preference parameter

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2 Methodology
Official Approach
Economic Approach

3 Data

4 Results
Scanner Data and Official CPI
Bias Decomposition
Dynamics after Shock

5 Implications for the optimal rate of inflation

6 Conclusion

7 Appendix

Official Approach

Laspeyres:

$$\Phi_t^{Las} = \sum_{k \in \Omega_{t,t-4}} S_{kt-4} \left(\frac{p_{kt}}{p_{kt-4}} \right)$$

$$\text{with } S_{kt-4} = \frac{p_{kt-4} q_{kt-4}}{\sum_l p_{lt-4} q_{lt-4}}$$

$\rightarrow$ overstates inflation

Paasche:

$$\Phi_t^{Paa} = \left[\sum_{k \in \Omega_{t,t-4}} S_{k,t} \left(\frac{p_{kt}}{p_{kt-4}} \right)^{-1} \right]^{-1}$$

$$\text{with } S_{kt} = \frac{p_{kt} q_{kt}}{\sum_l p_{lt} q_{lt}}$$

$\rightarrow$ understates inflation

Official Approach

Laspeyres:

$$\left.\begin{aligned}\Phi_t^{Las} &= \sum_{k \in \Omega_{t,t-4}} S_{kt-4} \left(\frac{p_{kt}}{p_{kt-4}}\right) \\ \text{with } S_{kt-4} &= \frac{p_{kt-4}q_{kt-4}}{\sum_l p_{lt-4}q_{lt-4}}\end{aligned}\right\} \rightarrow \text{overstates inflation}$$

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Official Approach

Fisher:

$$\Phi_t^{Fis} = \left(\Phi_t^{Paa} * \Phi_t^{Las}\right)^{\frac{1}{2}} \left.\vphantom{\Phi_t^{Fis}}\right\} \rightarrow \text{exact}$$

Utility function:

$$\mathbb{U}_t = \left[\sum_{k \in \Omega_{t,t-4}} q_{kt}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

$\Omega_{t,t-4}$ is the set of goods available in both periods t and $t-4$

q_{kt} is the quantity of good k at time t

σ is the elasticity of substitution between the goods

Economic Approach: Sato-Vartia

$$\Phi^{SV}_{t-4,t} = \prod_{k \in \Omega_{t,t-4}} \left(\frac{p_{kt}}{p_{kt-4}} \right)^{\omega^*_{kt}}$$

$$\text{with } \omega^*_{kt} \equiv \frac{\frac{S^*_{kt} - S^*_{kt-4}}{ln(S^*_{kt}) - ln(S^*_{kt-4})}}{\sum_{l \in \Omega_{t,t-4}} \frac{S^*_{lt} - S^*_{lt-4}}{ln(S^*_{lt}) - ln(S^*_{lt-4})}}$$

Economic Approach: The Unified Price Index

Utility function:

$$\mathbb{U}_t^{UPI} = \left[\sum_{k \in \Omega_t} \left(\varphi_{kt} q_{kt} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

Ω_t is the set of all goods available at time t

q_{kt} is the quantity of good k at time t

φ_{kt} is the preference parameter for good k at time t

σ is the elasticity of substitution between the goods

Economic Approach: The Unified Price Index

$$\text{Assumption:} \quad \left(\prod_{k \in \Omega_t} \varphi_{kt} \right)^{\frac{1}{N_t}} = \bar{\varphi}$$

$$\Phi^{UPI}_{t-4,t} \equiv \frac{\mathbb{P}_t}{\mathbb{P}_{t-4}} = \underbrace{\left(\frac{\lambda_{t,t-4}}{\lambda_{t-4,t}} \right)^{\frac{1}{\sigma-1}}}_{\text{Variety Adjustment}} \underbrace{\left[\frac{\mathbb{P}^*_t}{\mathbb{P}^*_{t-4}} \right]}_{\text{Common Goods UPI}}$$

$$= \underbrace{\left(\frac{\lambda_{t,t-4}}{\lambda_{t-4,t}} \right)^{\frac{1}{\sigma-1}}}_{\text{Variety Adjustment}} \left[\underbrace{\frac{\tilde{P}^*_t}{\tilde{P}^*_{t-4}}}_{\text{Jevons}} \underbrace{\left(\frac{\tilde{S}^*_t}{\tilde{S}^*_{t-4}} \right)^{\frac{1}{\sigma-1}}}_{\text{Consumer Valuation}} \right]$$

Variety Adjustment | Jevons | Consumer Valuation

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Variety Adjustment | Jevons | Consumer Valuation

Data

- Daily data from around 5,000 households across Switzerland (AC Nielsen)
- Food, beverages (alcoholic and non-alcoholic), and tobacco
- January 01, 2010 until June 30, 2016

Example of Database Entry

Date	HH	SG	PG	PC	EAN	Shop	P	Q	Size
2011/08/12	1069	dairy	cheese	hard	7610900115228	spec. shop	2.29	1	120g
2014/02/25	563	bakery	bread	nonperish.	24000048	Aldi	0.29	2	500g
2015/02/03	3029	afb[1]	juice	nectar	7616800202754	Migros	0.22	1	1000ml

Notes: (1) The products are classified into supergroups (SG), productgroups (PG) and productclasses (PC). We reclassify them to be as similar as possible to the groups of the SFSO. (2) alcohol free beverages

Data

	Transactions	ExpShare (%)	Products
Full Sample: Ω_t			
Total	13'847'771	100	116'799
Swiss	10'674'822	75.43	59'448
Imports	3'172'949	24.57	57'351
Imports EA	2'385'017	17.53	49'161
Imports ROW	787'932	7.03	8'190
Common Goods: $\Omega_{t-4,t}$			
Total	12'999'401	100	60'263
Swiss	10'168'023	76.55	35'665
Imports	2'831'378	23.45	24'598
Imports EA	2'095'606	16.49	20'625
Imports ROW	735'772	6.96	3'973
Super Common Goods: $\Omega_{\forall t}$			
Total	5'939'412	100	3'138
Swiss	4'756'792	78.13	2'294
Imports	1'182'620	21.87	844
Imports EA	863'190	15.27	605
Imports ROW	319'430	6.60	239

Notes: Transactions are the number of purchases observed, ExpShare is the share of expenditures in total expenditures (in %), and Products shows the number of unique products in the respective sample. Swiss goods are produced and sold in Switzerland, imports are sold but not produced in Switzerland, imports EA denote imports from the euro area and imports ROW are imports from outside the euro area.

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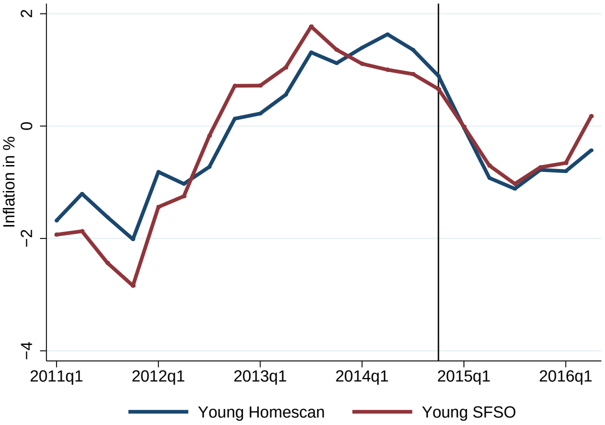
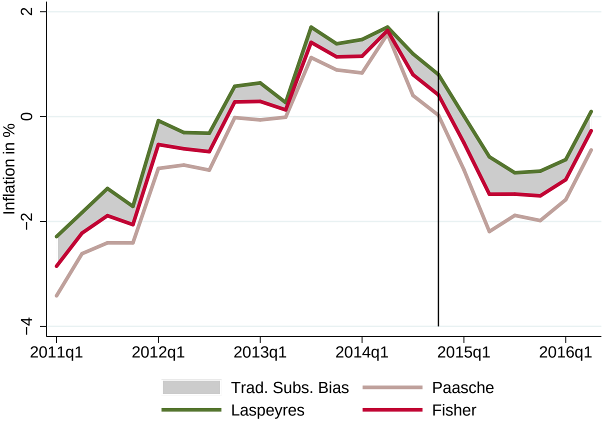
Scanner Data and Official CPI



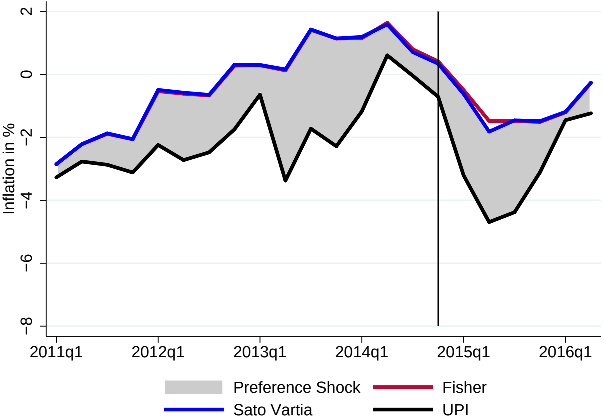
- $k \in \Omega_{\forall t}$
- The official inflation can be reproduced with scanner data.

Bias Decomposition: Traditional Substitution Bias



- $k \in \Omega_{t-4,t}$
- average bias is 0.38PP, which is in line with previous literature (US 0.4PP, CH 0.13PP)

Bias Decomposition: Preference Parameters



- $k \in \Omega_{t-4,t}$
- economic approach identical to official approach without trad. substitution bias
- $ln(\Phi^{SV}_{t-4,t}) = ln(\Phi^{UCG}_{t-4,t}) + \sum_{k \in \Omega_{t,t-4}} \omega^*_{kt} ln\left(\frac{\varphi_{kt}}{\varphi_{kt-4}}\right)$
- average bias is 1.74PP

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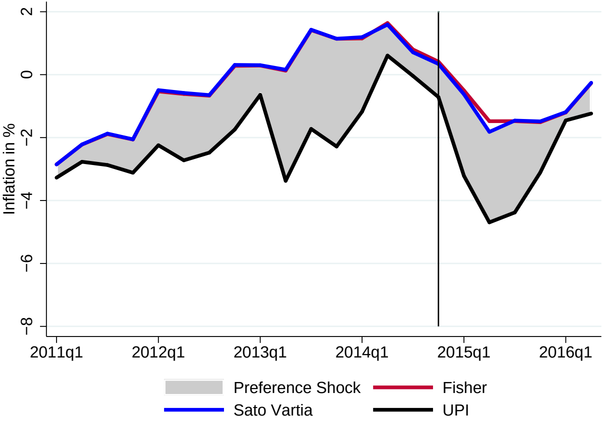

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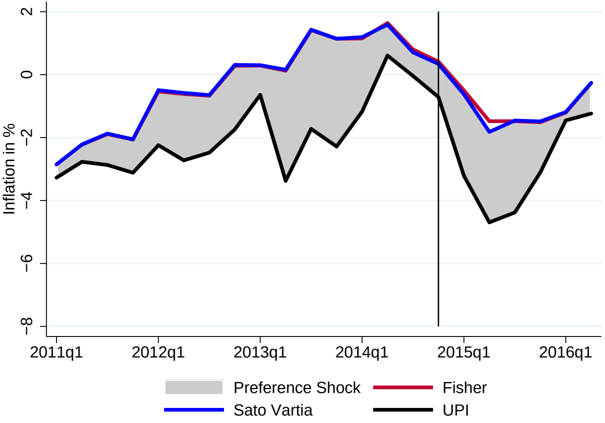

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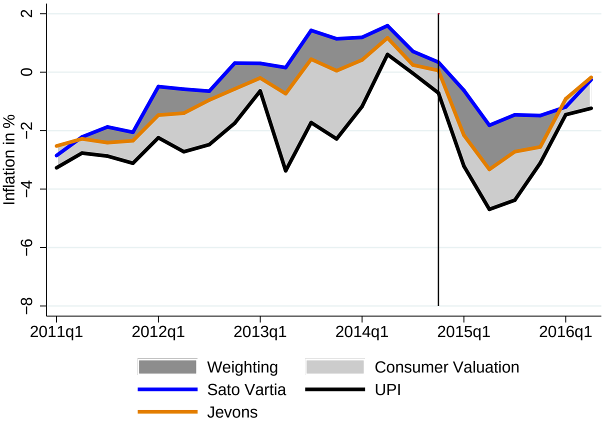

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- Weighting: $ln(\frac{\tilde{P}^*_t}{\tilde{P}^*_{t-4}}) - ln(\Phi^{SV}_{t-4,t})$
- Consumer Valuation: $ln(\Phi^{UCG}_{t-4,t}) - ln(\frac{\tilde{P}^*_t}{\tilde{P}^*_{t-4}})$
- $\tilde{S}^*_t < \tilde{S}^*_{t-4}$ $\forall t$ i.e. shares get more and more unequal
- average bias is 0.64PP (Weight.) and 1.1PP (Cons. Valuation)

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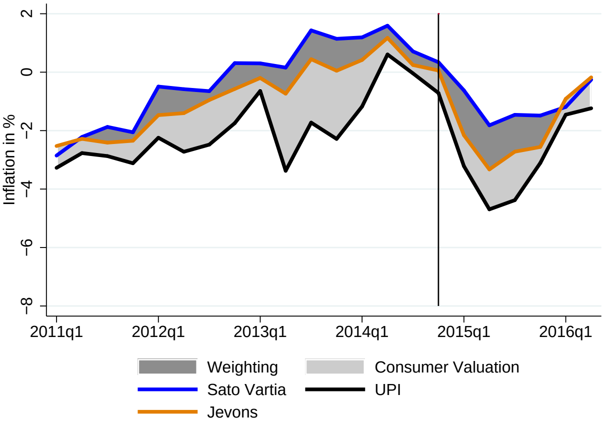

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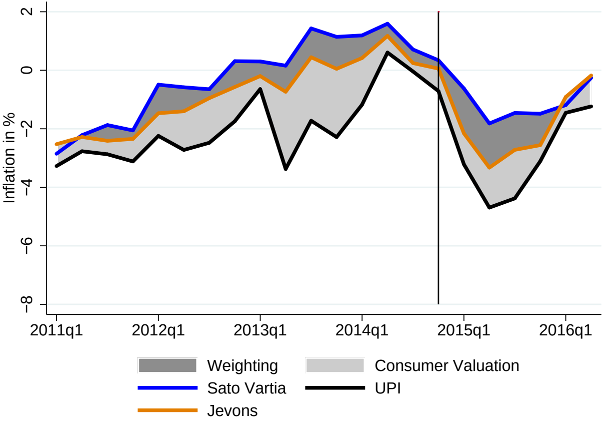

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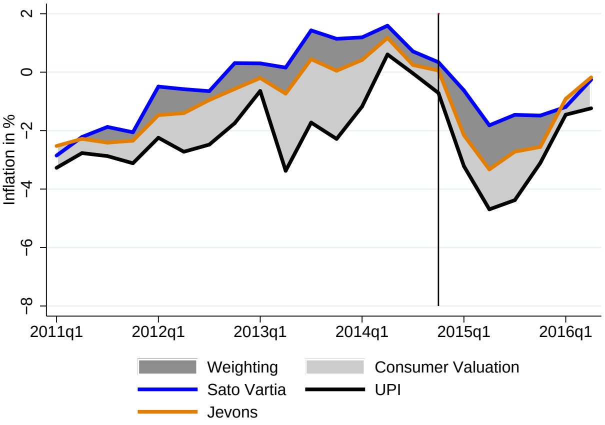

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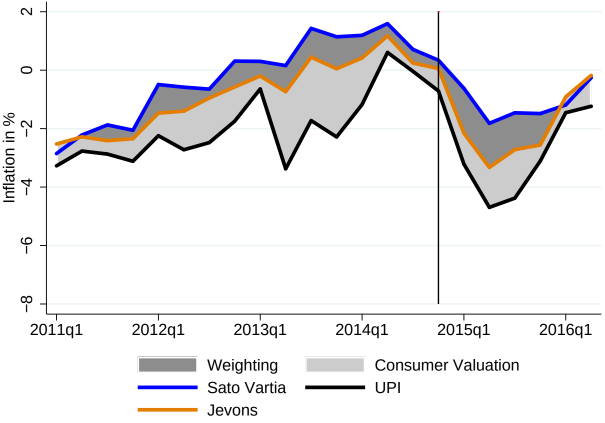

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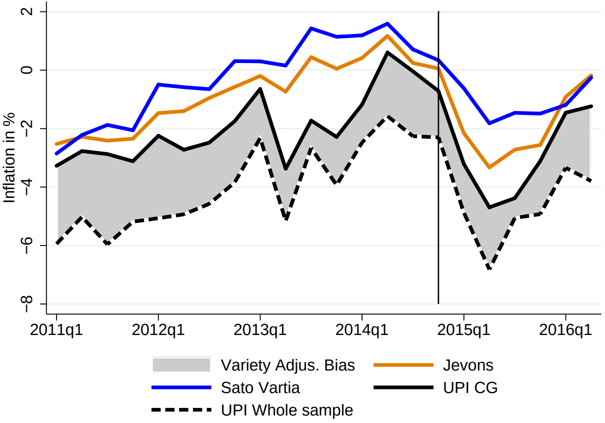
Bias Decomposition: Variety Adjustment



- $k \in \Omega_t$
- $ln(\Phi^{U}_{t-4,t}) =$
  $\frac{1}{\sigma-1} * ln\left(\frac{\lambda_{t,t-1}}{\lambda_{t-1,t}}\right) + ln(\Phi^{UCG}_{t-4,t})$
- $\lambda_{t,t-1} < \lambda_{t-1,t}$ $\forall t$ i.e. new goods have lower prices (preference adjusted) and/or are more numerous than exiting goods
- average bias is 2PP

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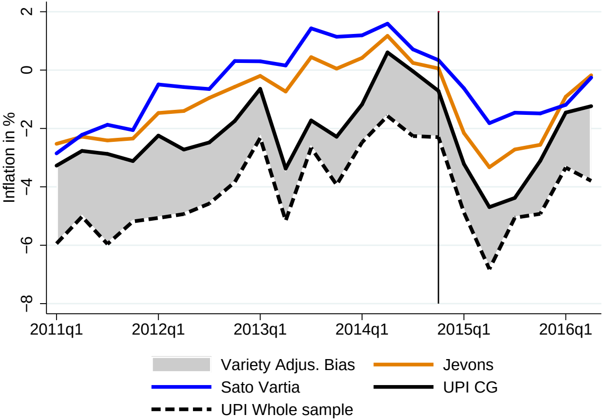

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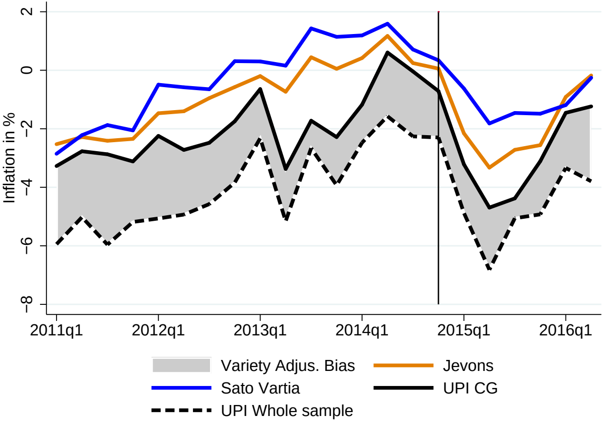

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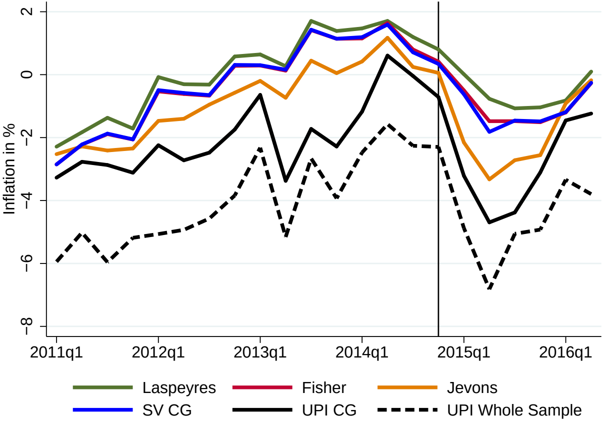
Dynamics after Shock



- UPI declines the most after shock

  $\Delta Lasp = 1.57$, $\Delta Fish = 1.89$

  $\Delta Jev = 3.38$

  $\Delta SV_{CG} = 2.15$

  $\Delta UPI_{CG} = 3.98$, $\Delta UPI = 4.52$

  $(\Delta = 2015Q2 - 2014Q4)$

Dynamics after the Shock

Reason why $\Delta Fish < \Delta Jev$:

Weights

Fisher: **expenditure share** weighted average of prices

$$0.23 * \underbrace{p^{Imp}}_{\downarrow} + 0.77 * \underbrace{p^{Dom}}_{\rightarrow}$$

Jevons: **equally** weighted average of prices

$$0.4 * \underbrace{p^{Imp}}_{\downarrow} + 0.6 * \underbrace{p^{Dom}}_{\rightarrow}$$

Dynamics after Shock

	2011-2014	Δ2014Q4-2015Q2
Fisher-UPI	3.95	2.63
shares		
Weighting	0.18	0.57
Consumer Valuation	0.29	0.23
Variety Adjustment	0.53	0.20

Notes: The first line shows the PP difference between the Fisher index and the UPI, on average for years 2011-2014 (first column) and between periods 2014Q4 and 2015Q2 (second column). The shares are calculated as $1 = \frac{Weighting}{Fisher-UPI} - \frac{ConsumerValuation}{Fisher-UPI} - \frac{VarietyAdjustment}{Fisher-UPI}$

Implications for the optimal rate of inflation

Should central banks **adjust inflation targets** if official inflation calculations do not consider

Preference Shifts (constant φ) $\rightarrow$ **No**

- Schmitt-Grohé and Uribe (2010): quality bias should not be incorporated into the inflation target
- Here: preference parameters can be interpreted as "personal" quality change $\rightarrow$ optimal inflation equals zero

Variety Adjustment (no entry/exit) $\rightarrow$ **Yes**

- Bilbiee et al (2014): in the presence of endogenous product entry variety adjustment bias should be incorporated 1:1 in the inflation target (only) if preference are in the form of Dixit-Stiglitz
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- Here: preference parameters can be interpreted as "personal" quality change $\rightarrow$ optimal inflation equals zero

Variety Adjustment (no entry/exit) $\rightarrow$ **Yes**

- Bilbiee et al (2014): in the presence of endogenous product entry variety adjustment bias should be incorporated 1:1 in the inflation target (only) if preference are in the form of Dixit-Stiglitz
- Here: Dixit-Stiglitz-preferences $\rightarrow$ optimal inflation equals variety adjustment bias

Conclusion

1. Large price/quantity data allows to construct inflation measures in real time
2. Traditional substitution bias is relatively small, biases resulting from neglecting preference parameters and entry/exit are bigger
3. UPI declines much more after the ER shock

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Thank you

Variety Adjustment

$$\lambda_{t,t-4} = \frac{\sum_{k \in \Omega_{t-4,t}} (P_{kt}/\varphi_{kt})^{1-\sigma}}{\sum_{k \in \Omega_t} (P_{kt}/\varphi_{kt})^{1-\sigma}},$$

$$\lambda_{t-4,t} = \frac{\sum_{k \in \Omega_{t-4,t}} (P_{kt-1}/\varphi_{kt-4})^{1-\sigma}}{\sum_{k \in \Omega_{t-4}} (P_{kt-4}/\varphi_{kt-4})^{1-\sigma}},$$

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Variety Adjustment

$\frac{\lambda_{t,t-4}}{\lambda_{t-4,t}} < 1$ if

- $\#$ new goods $>$ $\#$ exiting goods, and/or
- new goods have lower preference adjusted prices than exiting goods
- Price index falls ($\sigma > 1$) because consumers have more variety or have more appealing goods.

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Jevons

$$\tilde{P}_t^* = \left(\prod_{k \in \Omega_{t,t-1}} p_{kt} \right)^{\frac{1}{N_{t,t-4}}}$$

If $\tilde{P}_t^* < \tilde{P_{t-4}^*}$ prices in t are lower on average and therefore consumers need less money to achieve the same utility.

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Consumer Valuation

$$\tilde{S}_t^{\,*} = \left(\prod_{k \in \Omega_{t,t-1}} \frac{(P_{kt}/\varphi_{kt})^{1-\sigma}}{\sum_{l \in \Omega_{t,t-1}} (P_{lt}/\varphi_{lt})^{1-\sigma}} \right)^{\frac{1}{N_{t,t-1}}}$$

$\tilde{S}_t^* < \tilde{S}_{t-4}^*$ if

- expenditure shares become more uneven
- Cost of living falls ($\sigma > 1$)

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Derivation UPI

To calculate the UPI, it is necessary to estimate the elasticity of substitution σ and and the preference parameters φ first.

1.
$$\frac{\mathbb{P}_t}{\mathbb{P}_{t-1}} = \left(\frac{\lambda_{t-1,t}}{\lambda_{t,t-1}}\right)^{\frac{1}{\sigma-1}} \Theta^F_{t-1,t} \left[\sum_{k\in\Omega_{t,t-1}} S^*_{kt-1} \left(\frac{P_{kt}}{P_{kt-1}}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$$

2.
$$\frac{\mathbb{P}_t}{\mathbb{P}_{t-1}} = \left(\frac{\lambda_{t-1,t}}{\lambda_{t,t-1}}\right)^{\frac{1}{\sigma-1}} (\Theta^B_{t-1,t})^{-1} \left[\sum_{k\in\Omega_{t,t-1}} S^*_{kt} \left(\frac{P_{kt}}{P_{kt-1}}\right)^{-(1-\sigma)}\right]^{-\frac{1}{1-\sigma}}$$

Derivation UPI

They also make the identifying assumptions that

$$\Theta^F_{t,t-1} = (\Theta^B_{t,t-1})^{-1} = 1$$

The preference parameters φ are replaced by the shares.

$$\frac{\varphi_{kt}}{\bar{\varphi}} = \frac{P_{kt}}{\tilde{P}_t}\left(\frac{S_{kt}}{\tilde{S}_t}\right)^{\frac{1}{\sigma-1}}$$

Two moment consitions:

$$\Theta^F_{t,t-1} - 1 = \left[\frac{\sum_{k\in\Omega t,t-1} S^*_{kt-1} \left(\frac{P_{kt}}{P_{kt-1}}\right)^{1-\sigma} \left(\frac{\frac{P_{kt}}{\tilde{P}_t}\left[\frac{S_{kt}}{\tilde{S}_t}\right]^{\frac{1}{\sigma-1}}}{\frac{P_{kt-1}}{\tilde{P}_{t-1}}\left[\frac{S_{kt-1}}{\tilde{S}_{t-1}}\right]^{\frac{1}{\sigma-1}}} \right)^{(\sigma-1)}}{\sum_{k\in\Omega t,t-1} S^*_{kt-1} \left(\frac{P_{kt}}{P_{kt-1}}\right)^{1-\sigma}} \right]^{\left(\frac{1}{1-\sigma}\right)} - 1 = 0$$

$$(\Theta^B_{t,t-1})^{-1} - 1 = \left[\frac{\sum_{k\in\Omega t,t-1} S^*_{kt} \left(\frac{P_{kt-1}}{P_{kt}}\right)^{1-\sigma} \left(\frac{\frac{P_{kt-1}}{\tilde{P}_{t-1}}\left[\frac{S_{kt-1}}{\tilde{S}_{t-1}}\right]^{\frac{1}{\sigma-1}}}{\frac{P_{kt}}{\tilde{P}_t}\left[\frac{S_{kt}}{\tilde{S}_t}\right]^{\frac{1}{\sigma-1}}} \right)^{(\sigma-1)}}{\sum_{k\in\Omega t,t-1} S^*_{kt} \left(\frac{P_{kt-1}}{P_{kt}}\right)^{1-\sigma}} \right]^{-\left(\frac{1}{1-\sigma}\right)} - 1 = 0$$

Derivation UPI

Since there is only one unknown σ_{RW}, it can be estimated with a general method of moments estimator (GMM).

Households:
Households exhibit the following lifetime utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t U(a_t, h_t)$$

a_t is the amount of the composite good that the households want to consume, h_t is hours worked. The demand for good i can be derived from the cost-minimization problem for the composite good and yields

$$q_{it} = \frac{a_t}{\varphi_{it}} (p_{it}/\varphi_{it})^{-\sigma} \left[\sum_{k \in \Omega_t} (p_{kt}/\varphi_{kt})^{1-\sigma} \right]^{\frac{\sigma}{1-\sigma}} = \frac{a_t}{\varphi_{it}} \left[\frac{f_{it}}{F_t} \right]^{-\sigma}$$

with $f_{it} = p_{it}/\varphi_{it}$ and $F_t = \left[\sum_{k \in \Omega_t} (f_{kt})^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$. φ_{it} are the preference shocks for good i.

Derivation Optimal Inflation

Firms:
Monopolistic competitive firms exhibit linear production functions with labor as the only input, i.e. $z_t h_{it}$ where z_t is an aggregate productivity shock. w_{t+j} is the nominal wage rate. Firms can only change price with probability θ. Firms therefore maximize the expected present discounted value of profits

$$\max_{\tilde{p_{it}}} \quad \sum_{j=0}^{\infty} E_t r_{t,t+j} \theta^j \left[\tilde{p_{it}} q_{it+j} - w_{t+j} h_{it+j} \right]$$

subject to

$$q_{it} = z_t h_{it}$$

where $r_{t,t+j}$ is a nominal stochastic discount factor and $\tilde{p_{it}}$ is the optimal price if a firm can change price.

The FOC is:

$$\sum_{j=0}^{\infty} E_t r_{t,t+j}\theta^j \left[\frac{\partial q_{it+j}}{\partial \tilde{p_{it}}}\left(\tilde{p_{it}} - \frac{w_{t+j}}{z_{t+j}}\right) + q_{it+j}\right] = 0$$

Note that since firms preference shocks hit firms by surprise $E_t(\varphi_{it+j}) = \bar{\varphi}$ for $j > 0$. Hence

$$q_{it+j} = \frac{a_{t+j}}{E_t(\varphi_{it+j})}\left[\frac{\frac{\tilde{p_{it}}}{E_t(\varphi_{it+j})}}{\left(\sum_{i\in\Omega_t}\left(\frac{\tilde{p_{it}}}{E_t(\varphi_{it+j})}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}\right]^{-\sigma}$$

$$= \frac{a_{t+j}}{\bar{\varphi}}\left[\frac{\tilde{p_{it}}}{\left(\sum_{i\in\Omega_t}(\tilde{p_{it}})^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}\right]^{-\sigma}$$

Derivation Optimal Inflation

Thus

$$\frac{\partial q_{it+j}}{\partial \tilde{p_{it}}} = -q_{it+j}\frac{\sigma}{\tilde{p_{it}}}$$

Plugging this back in the FOC

$$\sum_{j=0}^{\infty} E_t r_{t,t+j}\theta^j \left[-q_{it+j}\frac{\sigma}{\tilde{p_{it}}}\left(\tilde{p_{it}} - \frac{w_{t+j}}{z_{t+j}}\right) + q_{it+j}\right]$$

$$= \sum_{j=0}^{\infty} E_t r_{t,t+j}\theta^j \left[-q_{it+j}\sigma\left(1 - \frac{w_{t+j}}{\tilde{p_{it}} z_{t+j}}\right) + q_{it+j}\right]$$

$$= \sum_{j=0}^{\infty} E_t r_{t,t+j}\theta^j \left[\frac{a_{t+j}}{\bar{\varphi}}\left[\frac{\tilde{p_{it}}}{\left(\sum_{i\in\Omega_t}(\tilde{p_{it}})^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}\right]^{-\sigma}\left(\frac{\sigma-1}{\sigma}\tilde{p_{it}} - \frac{w_{t+j}}{z_{t+j}}\right)\right] = 0$$

This is the same expression as in Schmitt-Groh and Urib and hence we can follow their conclusions.

Data

	Transactions	ExpShare (%)	Products
Common Goods: $\Omega_{t-4,t}$			
Total	12'999'401	100	60'263
Swiss	10'168'023	76.55	35'665=60%
Imports	2'831'378	23.45	24'598=40%
Imports EA	2'095'606	16.49	20'625
Imports ROW	735'772	6.96	3'973

Notes: Transactions are the number of purchases observed, ExpShare is the share of expenditures in total expenditures (in %), and Products shows the number of unique products in the respective sample. Swiss goods are produced and sold in Switzerland, imports are sold but not produced in Switzerland, imports EA denote imports from the euro area and imports ROW are imports from outside the euro area.

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