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Micro PPI-Based Real Output Forensics

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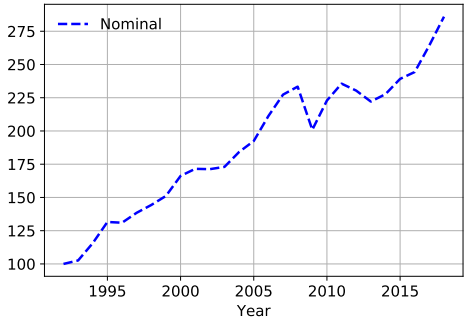
Nominal vs. real gross output in Swedish goods sector



Average annual growth rates 1992–2018

	Nominal output	Inflation	Real output
Goods production	3.9		

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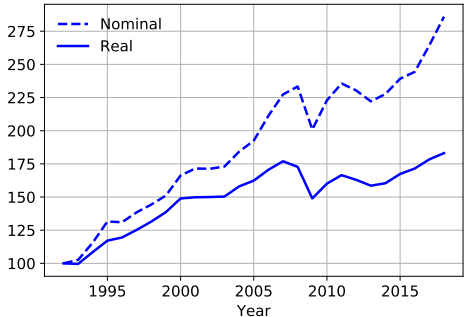

Average annual growth rates 1992–2018

	Nominal output	Inflation	Real output
Goods production	3.9	1.7	2.2

Our goal

Learn about the nature of aggregate real output growth by looking at micro PPI data:

- Shed light on index construction:
  - Choice of statistical index and method of aggregation.
  - Consistency of (economic) theory and (statistical) measurement.
- Compare statistical indices to price levels derived from economic theory.
- Run counterfactuals and quantify effects at the aggregate level.

Our application

Complete picture in the case of Swedish goods- 2004–2019 and services production 2013–2019.

- Access to prices and weights at firm-product-market (*item*) level.
- Enables a reconstruction of the aggregate index - i.e. the forensics of the project.

For today: Focus mainly on goods production (similar conclusions for services production).

Our questions

- How quantitatively important is the prices index construction choices for measured aggregate inflation?
- Which index number is preferred?
- How large would economic-theory based inflation be?

Our findings

- Index construction choices are important!
- International comparability of price measurement questionable, e.g.,
  - Method used in Japan would add 0.48 pp. annual goods output growth
  - Method used in Spain would subtract 0.49 pp. annual goods output growth.
- Economic-theory based index with estimated elasticities suggests 3.94 (2.71) pp. higher annual goods (services) output growth.

Roadmap

Description PPI data

Index construction

Economic-theory based index

Conclusions

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Goods Producer Price Index (PPI) by Statistics Sweden (SCB)

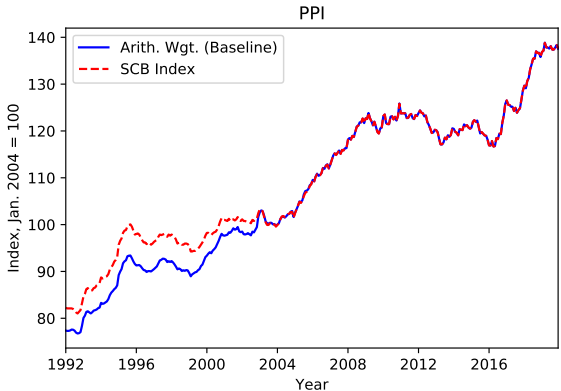
Representative sample of firms (in terms of their goods production) at monthly frequency to report about 6,000 prices of specific goods.

- The observation unit is an Item defined by a Product Code/Firm/Market combination.
- Product code specified at the 8-digit level (Varukod/CN).
- Three markets: Local, Export, Import. PPI measures developments at local and export market.
- Records monthly transaction price for each item, excl. taxes/transfers, in originally denominated currency (SEK, US$, EUR, etc.) and corresponding annual (sales) weights.
- Product group is defined at the 5-digit SPIN code level (similar to NACE).
- The elementary level is a Product group/Market combination.

In 2017 there are for example:

- 5,534 Items (unique Product code/Firm/Market combinations).
- 1,938 Product codes (8-digit CN).
- 279 Product groups (5-digit SPIN).
- 2,199 Firms.

Replication of Swedish Aggregate PPI Series



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Index construction

Index is constructed in two steps:

- Lower-level aggregation (Elementary index): Individual items are aggregated to the elementary-index level (product group/market level).
- Higher-level aggregation: Elementary indices are aggregated further up.

Lower-level aggregation: 6 methods used across countries for Goods PPI

1. Arithmetic mean
   - Unweighted (Carli): $\frac{1}{n}\sum_i \frac{p_{t,i}}{p_{0,i}}$

     Greece, Hungary, Portugal, Slovenia, Spain
   - Weighted: $\sum_i w_i \frac{p_{t,i}}{p_{0,i}}$

     Australia, France, Germany, Ireland, Israel, Korea, . . . , **Sweden**, Turkey, U.S.
2. Geometric mean
   - Unweighted (Jevons): $\prod_i \left(\frac{p_{t,i}}{p_{0,i}}\right)^{\frac{1}{n}}$

     Austria, Chile, Finland, Italy, Netherlands, Norway, Switzerland
   - Weighted: $\prod_i \left(\frac{p_{t,i}}{p_{0,i}}\right)^{w_i}$

     Denmark, Japan
3. Ratio of arithmetic means:
   - Unweighted (Dutot): $\frac{\frac{1}{n}\sum_i p_{t,i}}{\frac{1}{n}\sum_i p_{0,i}}$

     Estonia, Poland, U.K.
   - Weighted: $\frac{\sum_i w_i p_{t,i}}{\sum_i w_i p_{0,i}}$

     Canada

Inflation across lower-level aggregation methods

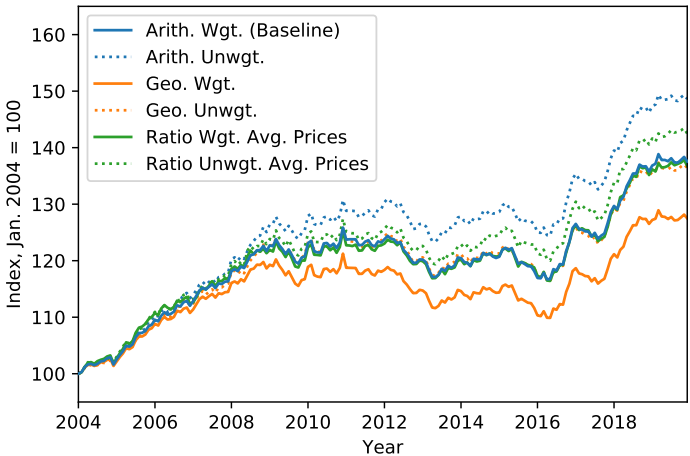

Figure: Goods PPI for different lower-level aggregation methods. $\sigma = 0$.

Inflation across lower-level aggregation methods

Arith. Wgt. (Baseline)	2.01

Difference to **Baseline**	
Arith. Unwgt.	0.49
Geo. Wgt.	-0.48
Geo. Unwgt.	-0.05
Ratio Wgt. Avg. Prices	-0.04
Ratio Unwgt. Avg. Prices	0.22

Table: Annual Goods Inflation in Percent. $\sigma = 0$.

- **Baseline**: Average yearly goods inflation rate of 2.01%.
- **Geometric Weighted aggregation**: Results in 0.48 pp. less goods inflation.
- **Services PPI**: Going from AW to GW results in 0.40 pp. less service inflation.

Lower-level aggregation

- Sizable differences across aggregation methods.
- Indices with arithmetic aggregation result in significantly higher inflation than indices with geometric aggregation (Jensen's Inequality).
- Weighting tends to reduce the inflation rate: Larger weight items have systematically a lower inflation rate.

Upper-level aggregation

- Arithmetic Weighted is the dominant method.

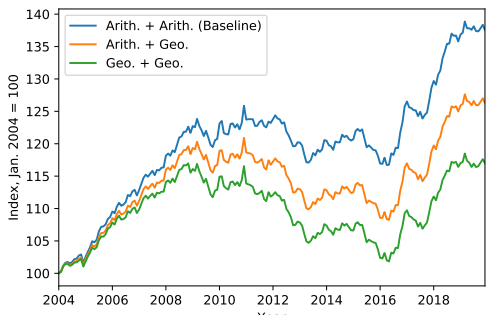

Figure: Goods PPI for different aggregation methods at the higher level. ”Arith. + Geo.” refers to arithmetic wgt. averaging at the elementary level and geometric wgt. averaging at the higher level.

Upper-level aggregation

Counterfactual Goods inflation: Higher-level aggregation method

	PPI (2004–2019)
Arith. Wgt. + Arith. Wgt. (Baseline)	2.01
Difference to Baseline	
Arith. Wgt.+ Geo. Wgt.	-0.54
Geo. Wgt. + Geo. Wgt.	-1.03

Table: Annualized inflation rate. ”Lower + Higher.” -level methods.

- Sizeable differences for higher-level method as well! Again, geometric aggregation decreases inflation relative to arithmetic aggregation (Jensen’s Inequality).

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Economic-theory based index

- Total output is produced by a CES production structure over different elementary groups indexed by g:

$$Y = \left(\sum_{g=1}^{G} \omega_g^{\frac{1}{\sigma}} y_g^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}},$$

  where, in turn, the production of each elementary group is described by a CES composite of the items in that elementary group indexed by i

$$y_g = \left(\sum_{i=1}^{N} \omega_i^{\frac{1}{\sigma_g}} y_i^{\frac{\sigma_g-1}{\sigma_g}} \right)^{\frac{\sigma_g}{\sigma_g-1}}.$$

Economic-theory based price index

- Given the production technology we can compute an exact price index.
- The exact price index at the elementary level can be calculated as

$$\frac{P_{t,g}}{P_{0,g}} = \left(\sum_{i=1}^{N} w_{i,0} \left(\frac{p_{i,t}}{p_{i,0}} \right)^{1-\sigma_g} \right)^{\frac{1}{1-\sigma_g}}.$$

- Nests two statistical indices as special cases (Konüs and Byushgens, 1926):
  - $\sigma_g = 0$ (Leontief production): Arithmetic weighted average.
  - $\sigma_g \to 1$ (Cobb-Douglas production): Geometric weighted average.

Estimating elasticities

- Large dataset (IVP) with prices and quantities of Swedish goods production.
- Apply GMM approach as in Hottman, Redding and Weinstein (2016) to estimate σ_g values within 318 elementary groups ($\hat{\sigma_g} \in \{1.38, 43.11\}$) and then for the cross-elementary group elasticity σ ($\hat{\sigma} = 1.24$).
- We can then aggregate up to arrive at inflation at the aggregate level.

Economic theory-based price index with estimated elasticities

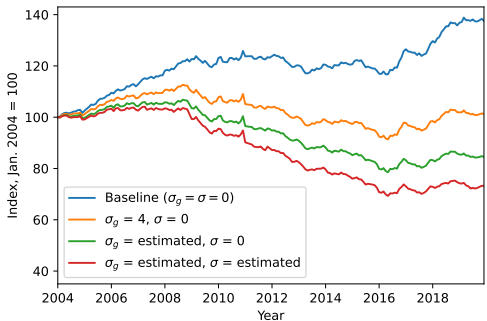

Figure: Goods PPI with estimated elasticities of substitution at the higher and lower level.

Economic theory-based exact price index with estimated elasticities

Counterfactual goods inflation: Estimated elasticities

	PPI (2004–2019)
$\sigma_g = 0, \sigma = 0$	2.01
Difference to $\sigma_g = 0, \sigma = 0$	
$\sigma_g = 4, \sigma = 0$	-1.94
$\sigma_g =$ estimated, $\sigma = 0$	-3.06
$\sigma_g =$ estimated, $\sigma =$ estimated	-3.94

Table: Annualized inflation rate.

- Annual services inflation rate falls by 2.7 percentage units visavi its baseline rate (1.2) ($\sigma_g = 1, \sigma = 0$) when using estimated elasticities on both levels.

Log-normal approximation

- Results above points to a tension between (economic) theory and (statistical) measurement.
- The statistical agency can't publish the full micro data. Practical solution is then to assume a joint log-normal distribution of price-growth factors and weights within groups.
- Implies that the exact price index can be computed for any assumptions on σ and σ_g from three moments on the elementary level and corresponding weights.

Proposition 1

Suppose that price-growth factors $\frac{p_{t,i}}{p_{0,i}}$ and weights $w_{0,i}$ follow a joint log-normal distribution, where i denotes an item belonging to elementary group g. The exact price index for elementary group g is then given by

$$\frac{P_{t,g}}{P_{0,g}} = \exp\left(\mu_{t,g} + \frac{1-\sigma_g}{2}\delta_{t,g} + \rho_{t,g}\right)$$

where $\mu_{t,g}$ denotes the mean of $\ln\left(\frac{p_{t,i}}{p_{0,i}}\right)$, $\delta_{t,g}$ the variance of $\ln\left(\frac{p_{t,i}}{p_{0,i}}\right)$, and $\rho_{t,g}$ the covariance between $\ln\left(\frac{p_{t,i}}{p_{0,i}}\right)$ and $\ln(w_{0,i})$.

Log-normal approximation

- Approximation error from log-normal assumption is an order of magnitude smaller than $\sigma_g = 0$ vs. $\sigma_g = 4$ difference! Similar for services.

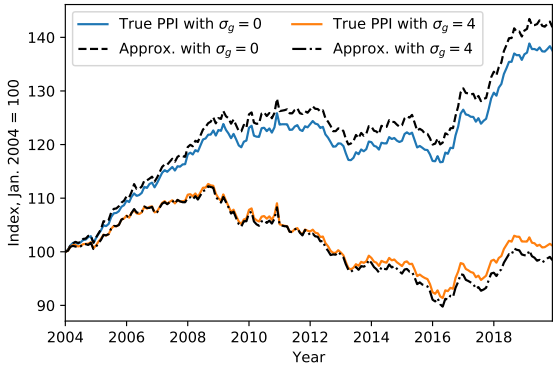

Figure: Comparison of true goods PPI and log-normal approximation ($\sigma = 0$).

Summary for today

- Large international heterogeneity in method of index computation, specifically on the lower level.
- Methods have an economically significant effect on measured aggregate inflation rate.
- Economic theory-based index suggests about 3.9 (2.7) percentage units lower annual goods (service) inflation and accordingly higher growth.
- Tension between (economic) theory and (statistical) measurement can be resolved by assuming a log-normal distribution between price-growth factors and weights within product groups.

Backup Slides

Economic theory-based price index with estimated elasticities

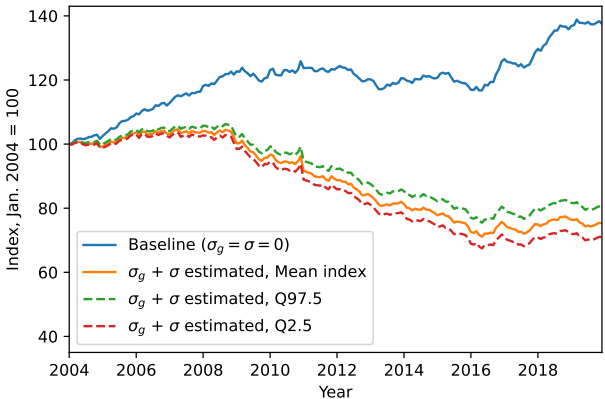

Figure: PPI index with bootstrapped elasticities of substitution at the lower and higher level, σ_g and σ.