



Lower-Level Substitution Bias in the Japanese Consumer Price Index: Evidence from Government Micro Data

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Hitotsubashi University

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Motivations

- Measurement Errors in the Japanese CPI:
 - Insufficient accumulation of quantitative assessment in Japan
 - Misconception: Boskin report & US unique way of CPI compilation
- Lower-level Substitution Bias:
 - No quantitative assessment: Unavailability of micro data for Retail Price Survey
 - Japan's problems: One-specification for one-item
 - This Paper: First trial using micro data for RPS

Today's Talk

1. Overview of Measurement Problem in CPI
2. Retail Price Survey and Data Used in This Paper
3. Price Substitution Simulation
4. Simple Analysis on Lower-level Substitution Bias (aggregation formula)
5. Case Study on Typical Items
6. Tentative Assessment and Some Proposals

Sources of Measurement Errors

Quantitative Assessment

Substitution effects

- Upper-level substitution
- Lower-level substitution

Quality changes

New products

Outlet substitutions

Others

Components of Price index

Price index formula

- Index formula for aggregating the upper-level items
- Aggregation of individual prices surveyed into item levels

Accuracy of prices surveyed

- Quality-adjustment methods
- Price survey method
- Structural changes in retail markets
- Service prices: OOH, medical expenses...

Accuracy of weights

- Coverage of Expenditure Survey

Measurement Errors in CPI

	Japan			United States		
	Shiratsuka (1999)	Shiratsuka (2006)	Broda & Weinstein (2007)	Boskin Report (1996)	Lebow & Rudd (2003)	Broda & Weinstein (2007)
Upper-level substitution	0.00	→	0.2	0.15	0.30	0.0
Lower-level substitution	0.10	→	0.4	0.25	0.05	0.0
Quality changes/ new products	0.70	↓	0.8+0.2	0.60	0.37	0.8
Outlet substitution	0.10	↘	0.2	0.10	0.05	0.2
Weighting	---	---	---	---	0.10	---
Total	0.90	↓	1.8	1.10	0.87	1.0

Source: Shiratsuka (2007)

Misconception on ME Problem

- Common General Framework:
- But Country-by-Country Factors in Quantitative Assessment:
 - Practical differences in CPI compilation methods
 - Most significant differences in individual price measurement
 - Eg.: Counterargument by Shiratsuka (2007) against Broda and Weinstein (2007)

How to Address ME Problem

- Aggregation into an Overall Index:
 - Substitution effects
 - Workable solutions: Approximation of superlative index formula in a real time basis
- Measurement of Individual Prices:
 - Quality adjustment, New products, ...
 - Difficult issues in both conceptual and practical basis: decomposition of nominal value into quantity and quality-adjusted price

Misconception on LLS Bias in JPN

- Misconception: Not Same as Boskin Report
 - Different CPI compilation method: US method is rather unique
 - Not due to random sampling
 - But due to one-specification for one-item policy: Elementary aggregation accuracy vs. Price repetitiveness
- Practical & Empirical Issues:
 - Very few previous studies due to limited data availability: Suga (2005), CPI Now

Japanese CPI

- One-Specification for One-Item Policy:
 - Collecting few, but highly representative and homogeneous product prices
 - Balancing high elementary aggregation accuracy and price representativeness
- No Quantitative Assessment on Item-by-Item Problems:
 - Not just conceptual but practical difficulties
 - But unavailability of micro source data for CPI

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Retail Price Survey

← Source Data for CPI

Survey Group	Surveyor	Types of Products	Items	# of Prices Surveyed
A	enumerator	Shopped nearby	Food, daily necessities	42
B		Shopped at large retailers	Clothing, electric appliances, ...	21
C		Small price differences at outlets	Recreational goods, ..	12
D	Prefectural Government	Utility charges at local level	Water charges, ...	
E	Statistics Bureau	Utility charges at nationwide level	Electricity, Telephone charges, ...	
S	enumerator	No specific survey districts	Gasoline, ...	

Data

- Narrowing Focus in This Paper:
 - Tokyo Metropolitan Area: Available both CPI and RPS in an item level.
 - Jan 2015 to Dec 2019: 2015 base-year CPI

Retail Price Survey

	Number of items			Weight		
	Number	Share		Weight	Share	
		in total	in category		in total	in category
CPI (Tokyo metropolitan)	582			10,000		
Total	462	79.4%	79.4%	4,392	43.9%	43.9%
Goods	402	69.1%	91.2%	3,287	32.9%	76.1%
Every 10-day survey	44	7.6%	97.8%	332	3.3%	99.6%
Services	60	10.3%	42.6%	1,105	11.0%	19.4%

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Limit for RPS Micro Data

- Collection of Prices Surveyed in Each Month:
 - A lot of discontinuation in individual price series
 - No information on how to link discontinued individual prices
- ↓
- Large Differences b/w CPI and RPS in Some Items

Implied Quality Index

$$\text{CPI: } CPI_{i,t} = \frac{RPS_{i,t}/QAL_{i,t}}{RPS_{i,0}} = \frac{\widehat{RPS}_{i,t}}{RPS_{i,0}}$$

$$\text{Implied Quality Index: } QAL_{i,t} = \frac{RPS_{i,t}/RPS_{i,0}}{CPI_{i,t}}$$

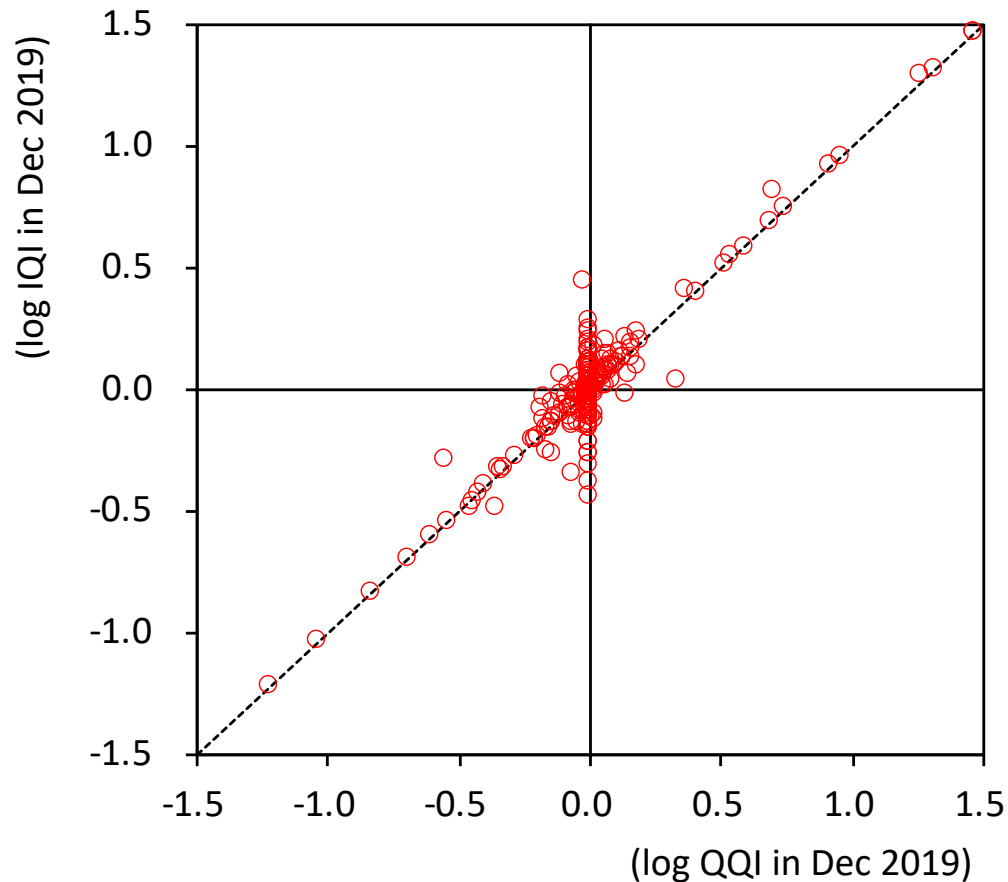
$$\begin{aligned} \frac{QAL_{i,t}}{QAL_{i,t-1}} &= \frac{RPS_{i,t}/RPS_{i,0}}{CPI_{i,t}} \bigg/ \frac{RPS_{i,t-1}/RPS_{i,0}}{CPI_{i,t-1}} \\ &= \frac{RPS_{i,t}}{RPS_{i,t-1}} \times \frac{CPI_{i,t-1}}{CPI_{i,t}} \end{aligned}$$

Price Substitution Simulation

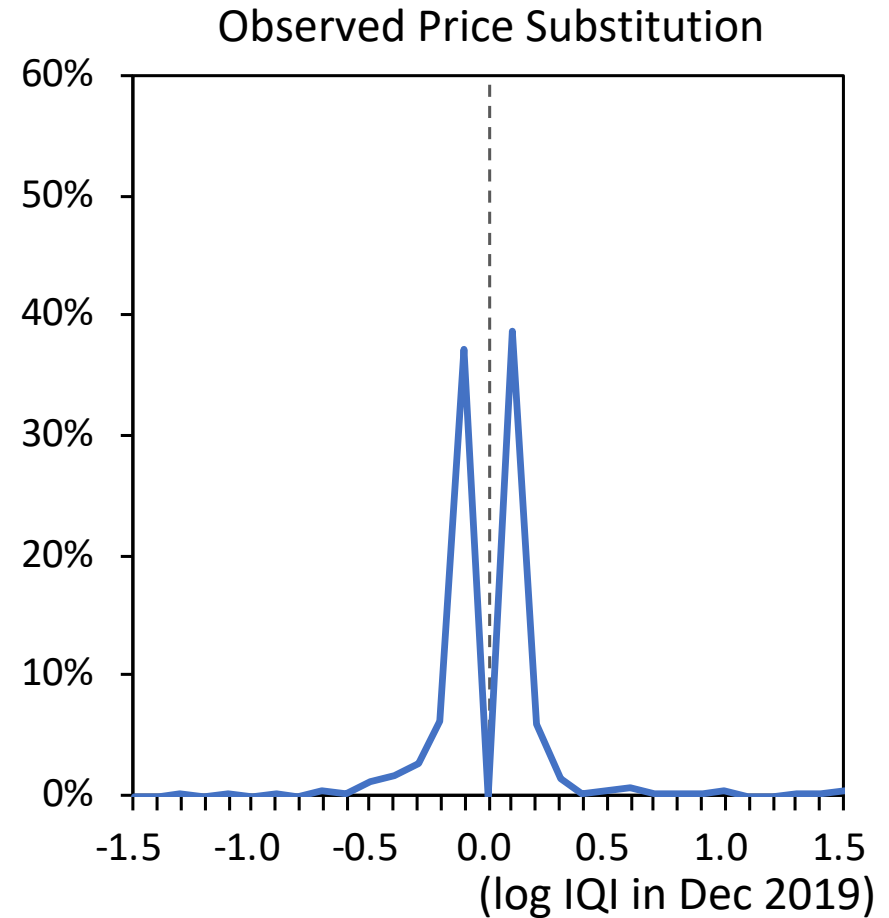
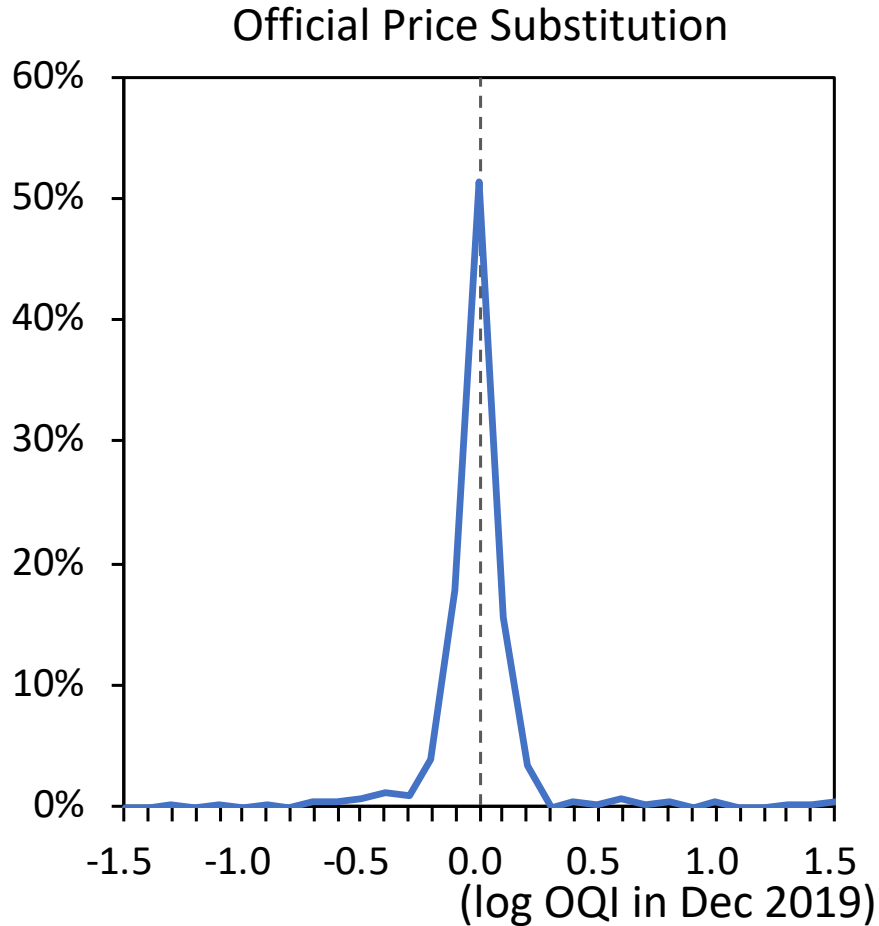
- Observed Price Substitutions:
 - Adjusting prices surveyed to exactly follow CPI as defined in the Implied Quality Index
- Official Price Substitutions:
 - Adjusting prices surveyed just at the official announcement of specification change
- Differences:
 - Mainly reflecting price substitution at individual prices, not overall item

Price Substitution

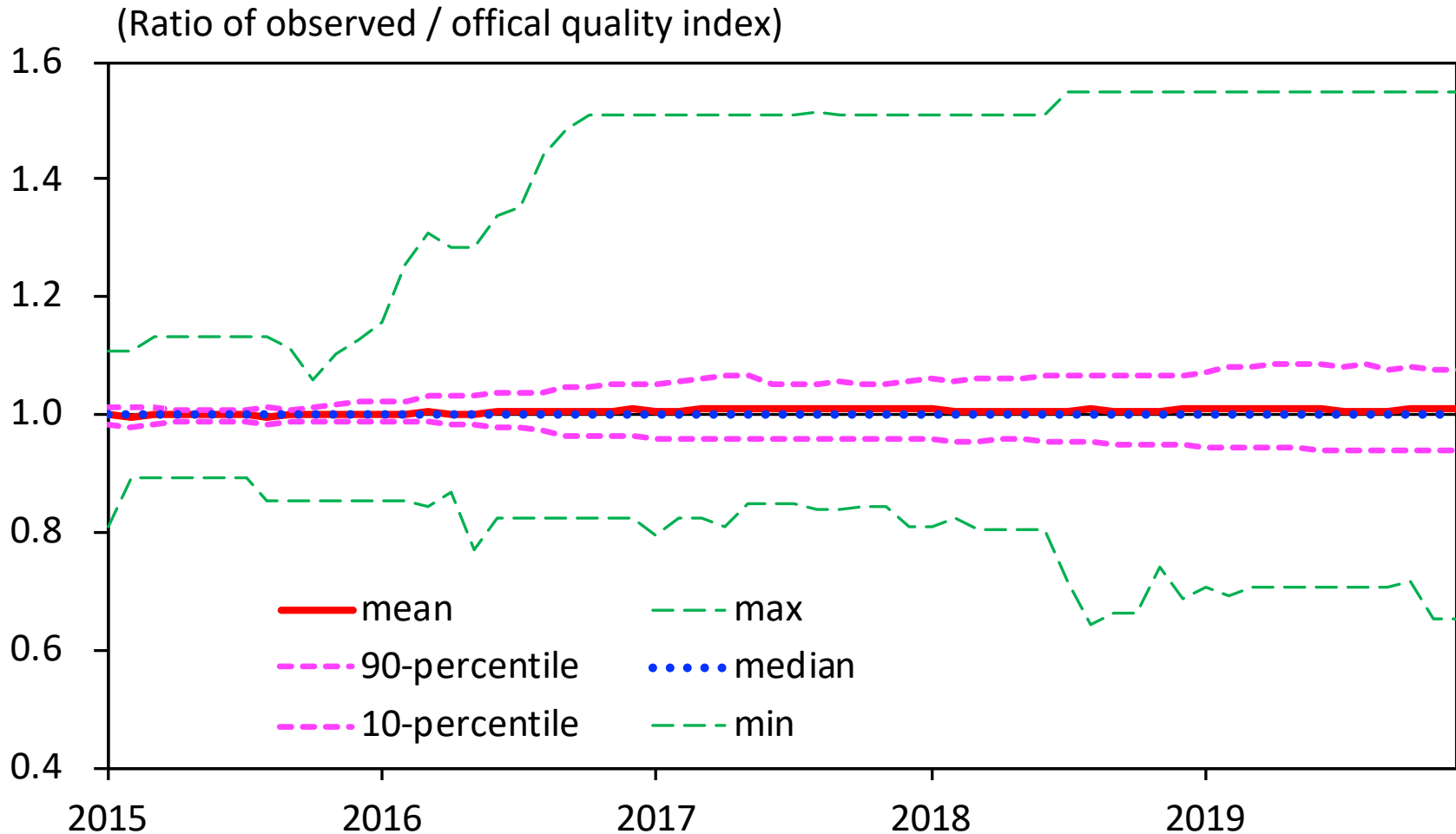
Cumulative Effects of Official and Observed Substitution of Prices Surveyed



Price Substitution (Cont'd)



Differences over Time



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Aggregation Formula

Carli
formula

$$I_C = \frac{1}{n} \sum_{i=1}^n \left(\frac{p_{i,t}}{p_{i,0}} \right)$$

Japanese CPI

Dutot
formula

$$I_D = \left[\frac{1}{n} \sum_{i=1}^n p_{i,t} \right] / \left[\frac{1}{n} \sum_{i=1}^n p_{i,0} \right] = \sum_{i=1}^n p_{i,t} / \sum_{i=1}^n p_{i,0}$$

Jevons
formula

$$I_J = \prod_{i=1}^n \left(\frac{p_{i,t}}{p_{i,0}} \right)^{\frac{1}{n}} = \prod_{i=1}^n (p_{i,t})^{\frac{1}{n}} / \prod_{i=1}^n (p_{i,0})^{\frac{1}{n}}$$

Elasticity of Substitution

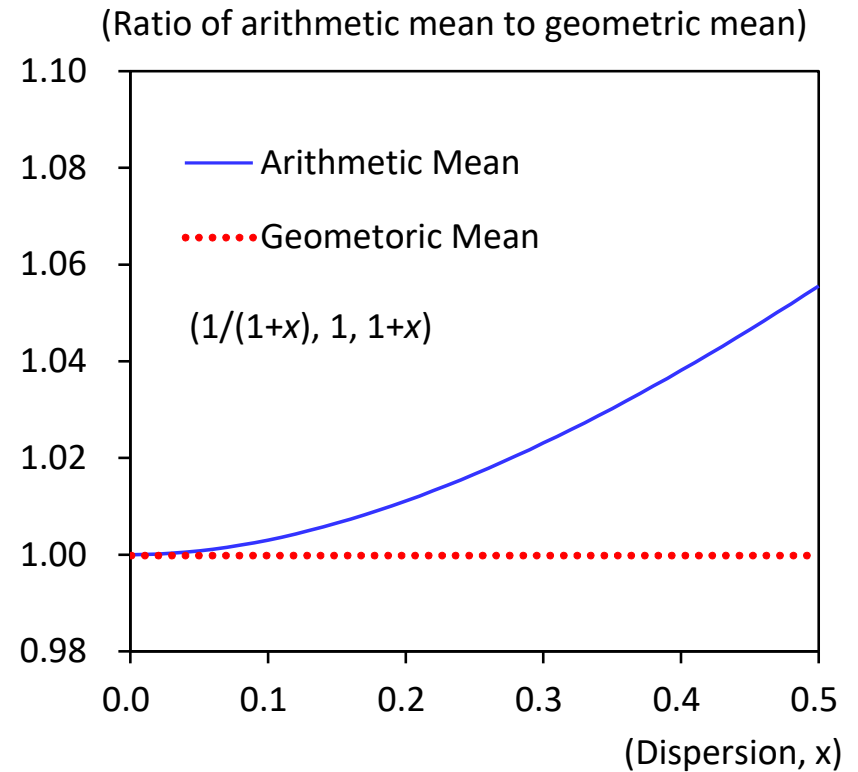
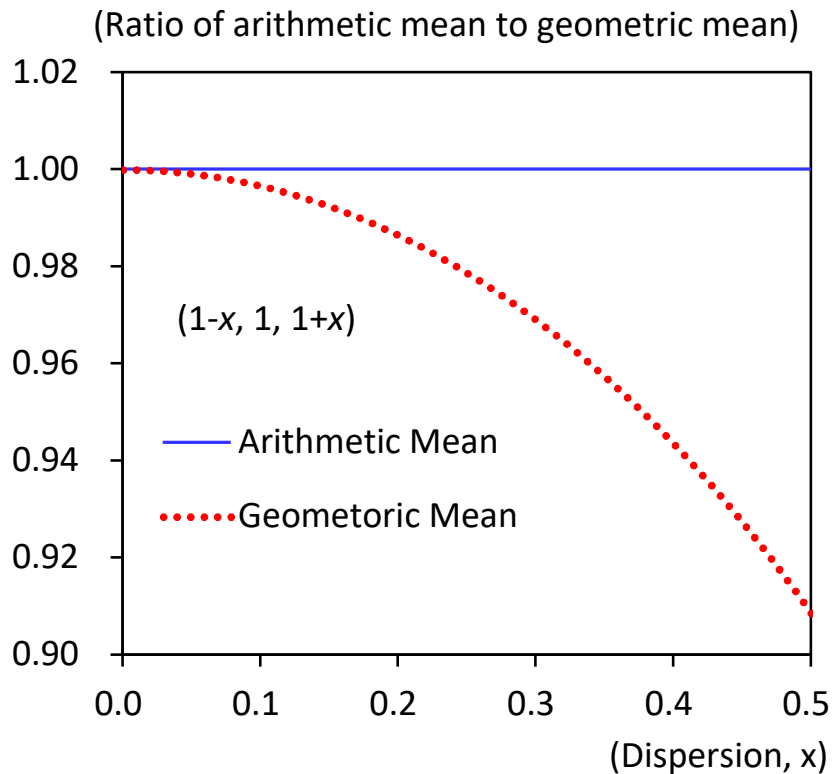
0 → Arithmetic mean
 ^
 Elasticity of Substitution
 ^
 1 → Geometric mean

Somewhere
b/w 0 and 1

$$I_{CES} = \left[\sum_{i=1}^n \left(\frac{p_{i,t}}{p_{i,0}} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

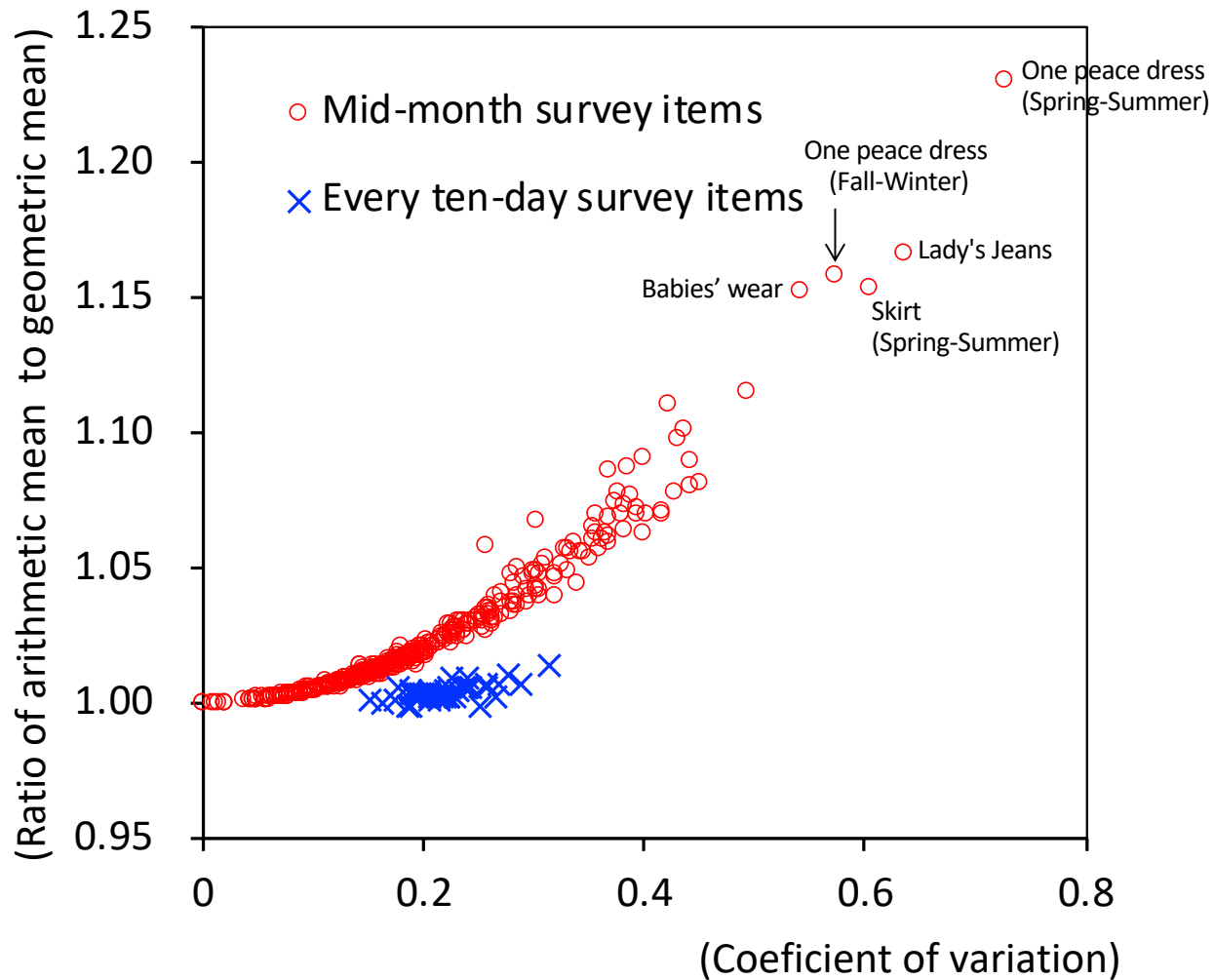
Proposed in Shiratsuka (1999)

Arithmetic vs. Geometric Means



Note: Mean-preserving spreads exercise using data for $(1-x, 1, 1+x)$ and $(1/(1+x), 1, 1+x)$, respectively .

Arithmetic vs. Geometric Means



Panel Regression

$$AGR_{i,t} = Const + \alpha CV_{i,t} + \beta CV_{i,t}^2 + \epsilon_{i,t}$$

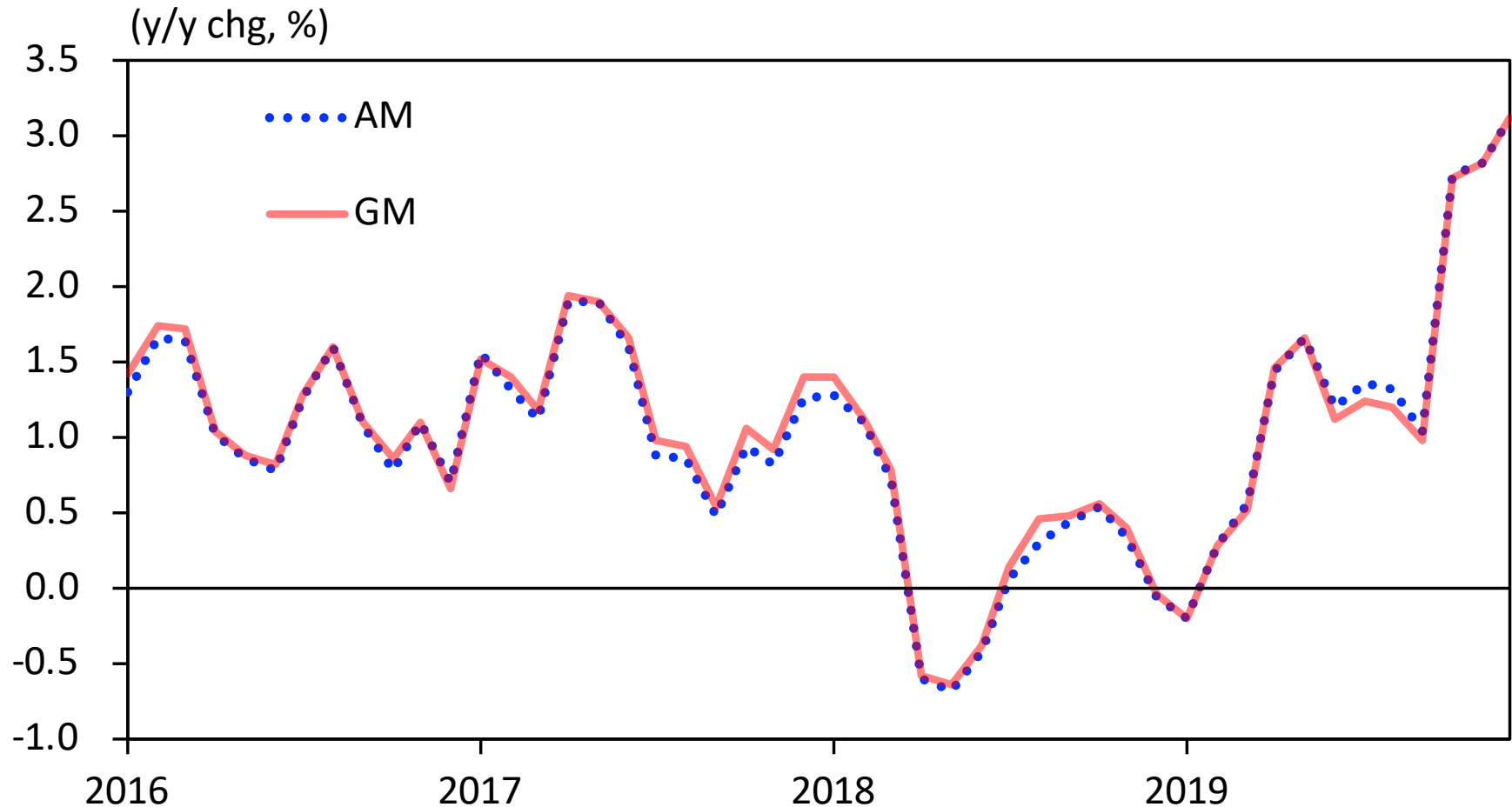
- Importance of Between Variation:
 - Pooled vs. Fixed-effect: Not quite similar
 - Pooled vs. Between: Quite similar

	Pooled		Fixed-effect		Between	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
CV	0.030	0.002 **	0.022	0.009 *	0.035	0.010 **
CV ²	0.406	0.006 **	0.427	0.023 **	0.394	0.024 **
Const.	0.998	0.000 **	0.998	0.001 **	0.997	0.001 **
# Obs.	23,825		23,825		418	
# Groups	---		418		---	
R-squared	0.961		0.960		0.978	

Notes: ** and * indicates statistical significance at 99 and 95 percent level. Standard errors are heteroscedasticity robust estimates.

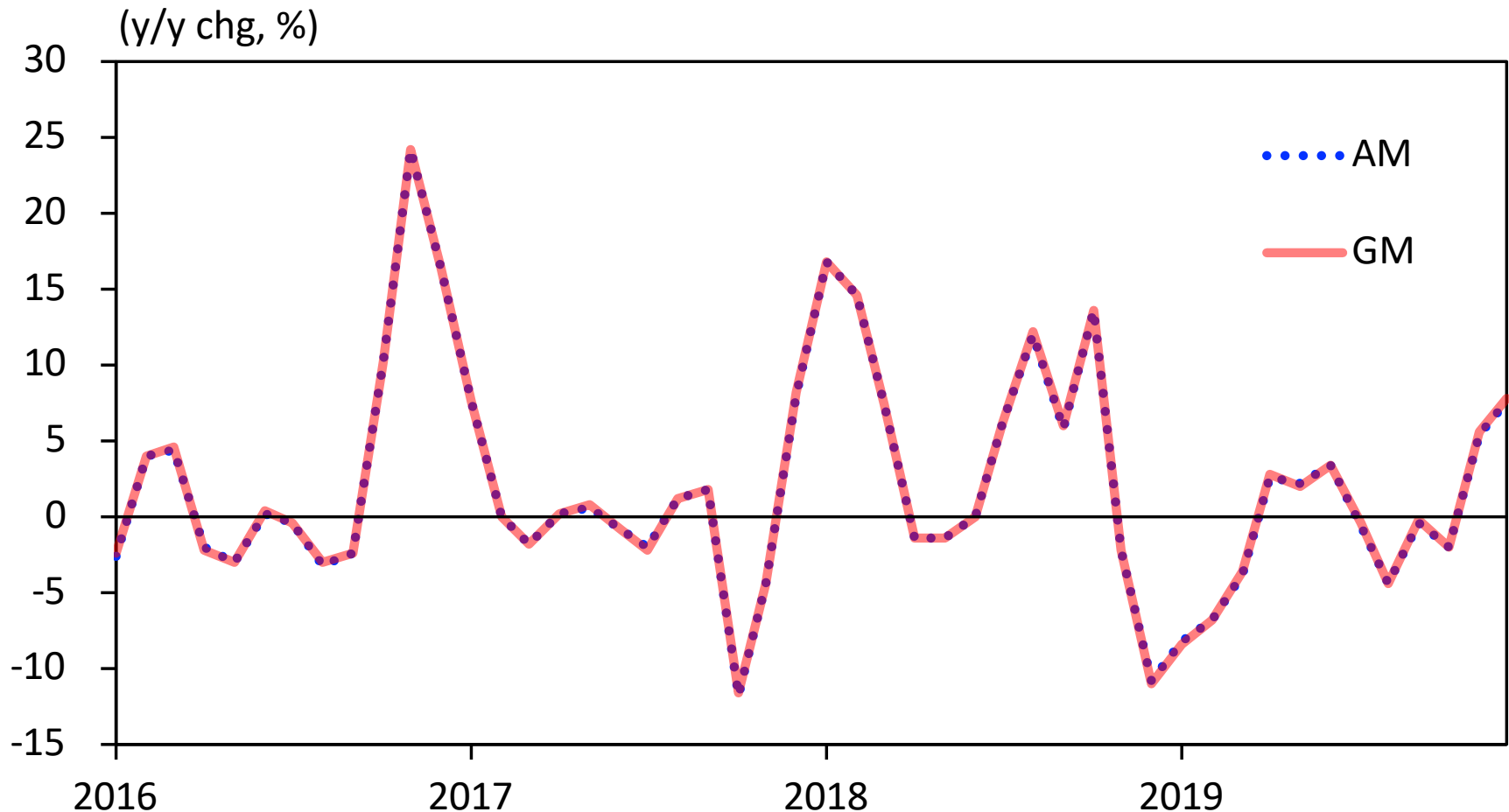
Difference in Annual Inflation Rates

Mid-month Survey Items

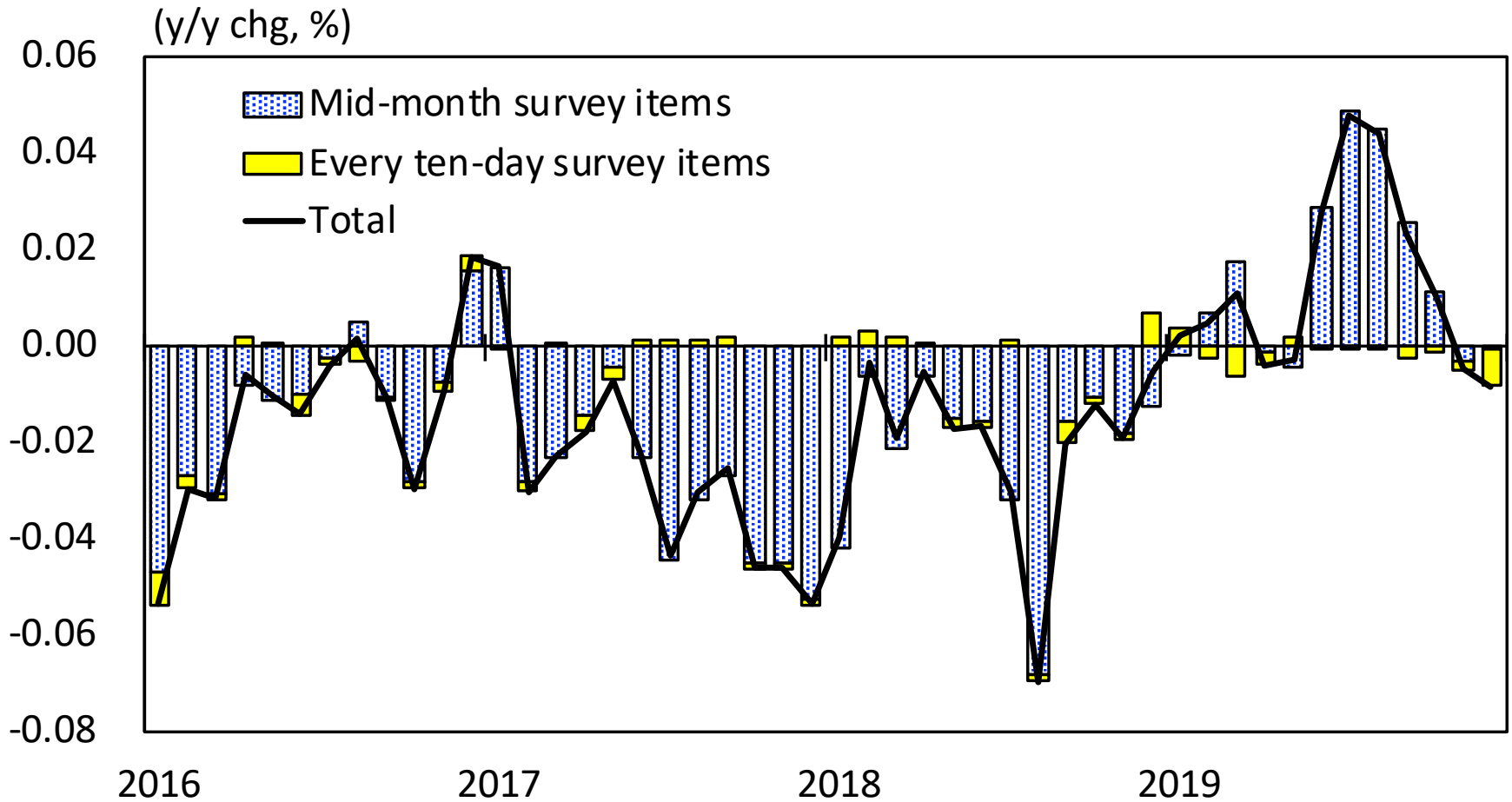


Difference in Annual Inflation Rates

Every Ten-day Survey Items



Impacts on Overall CPI Inflation



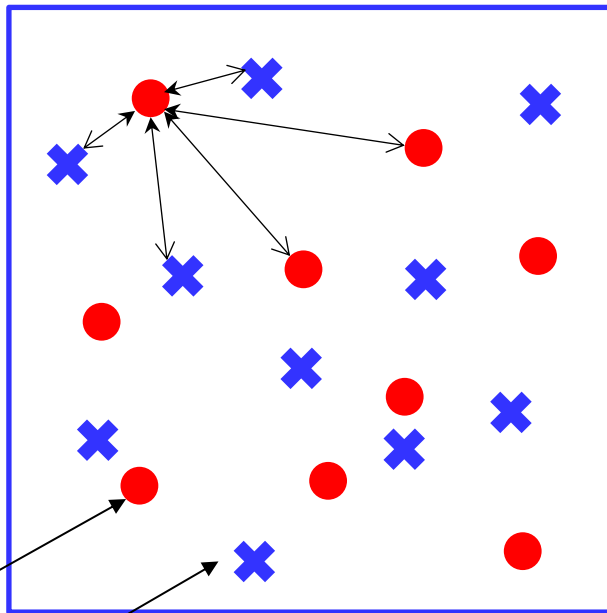
Note: Figures are contribution of difference in year-on-year CPI inflation of arithmetic mean and geometric mean to overall CPI Inflation.

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More Fundamental Problem

Random Sampling

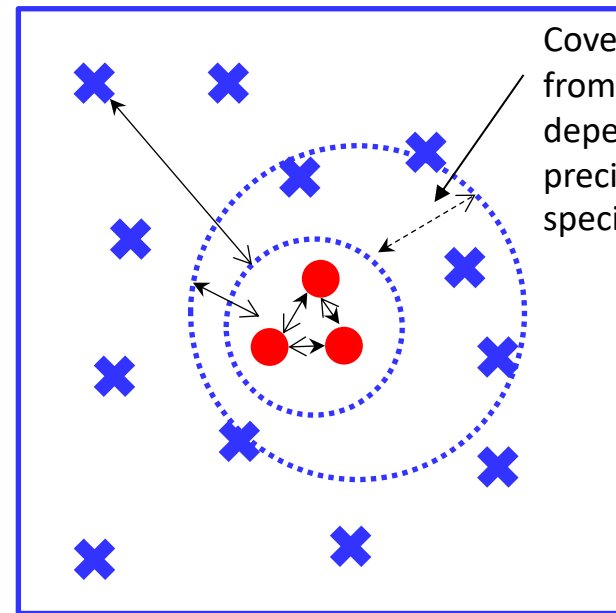


Prices surveyed

Prices Not surveyed

Elementary
Aggregation
Formula

One-specification for One-item



Coverage differs from item to item, depending on the preciseness of specification

Price
Representativeness

Heterogeneous Prices

- Some Items w/ Loosely Defined Specification:
 - Highly heterogeneous prices surveyed
 - Implicit high weight for high-priced products
 - Vulnerable to temporary survey failures
- Possible solution: Trimmed mean formula

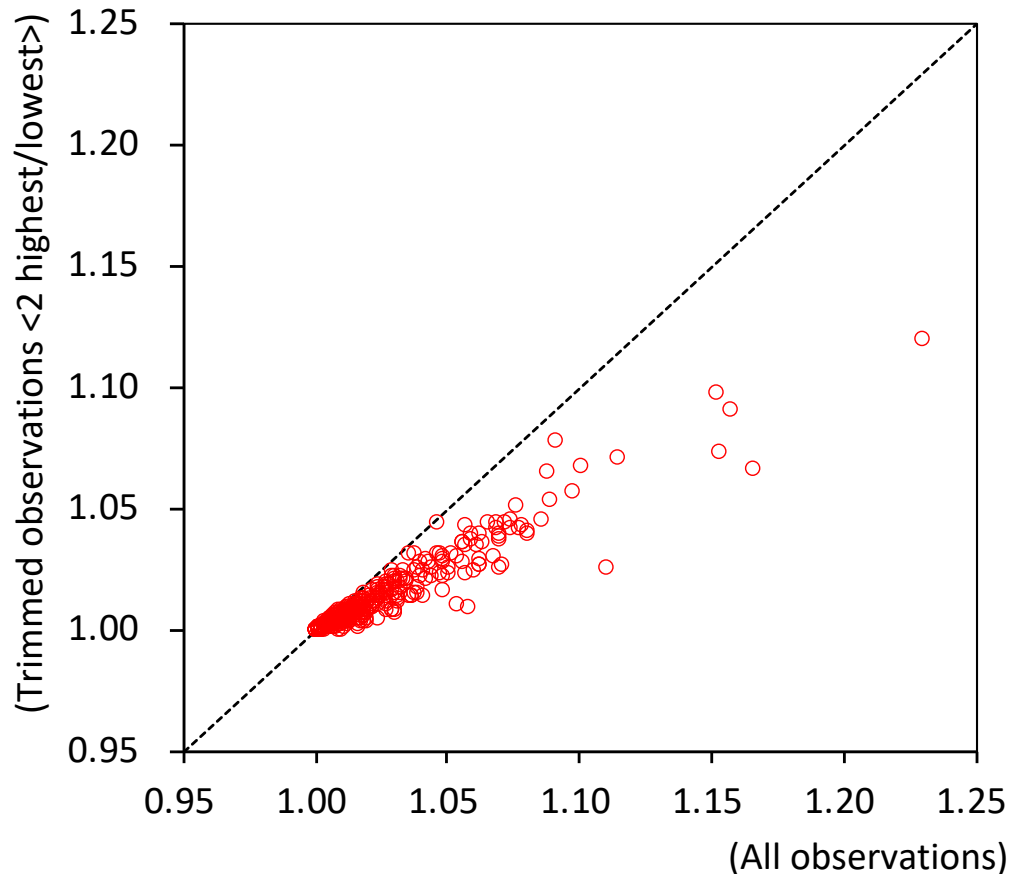
$$TRA(k)_t = \frac{1}{n-2k} \sum_{i=1+k}^{n-k} p_{i,t}, TRG(k)_t = \prod_{i=1+k}^{n-k} (p_{i,t})^{\left(\frac{1}{n-2k}\right)},$$

where p_i is ordered from low to high price.

$$n = 42 \rightarrow k = 3, n = 21 \rightarrow k = 2$$

Arithmetic vs. Geometric Means

Arithmetic / Geometric Mean Ratio

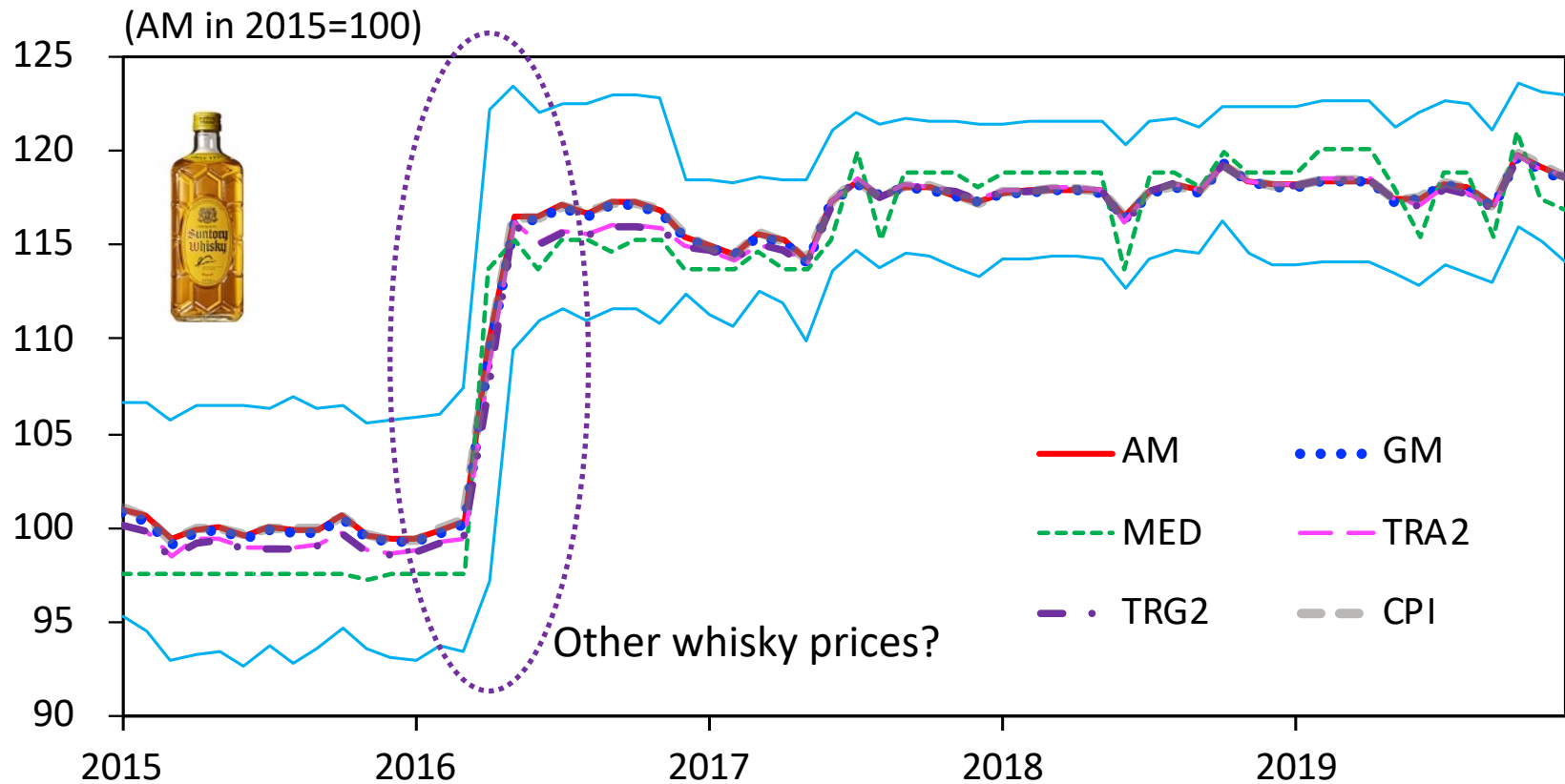


Mid-Month Survey Items

	Items	Specification	
1	Whisky	Detailed	Suntory Kau Bin
2	Soy Sauce		Kikkoman or Yamasa (1-little bottle)
3	Washing Machine		Specific brand and product (undisclosed)
4	Butter	Loose	200-gram box (excluding unsalted butter)
5	Gasoline		Regular gasoline (1 little, excluding self-service station)
6	Cap		Standard product with logo (chemical fiber)
7	Women's Jeans		Blue jeans, denim, standard product
8	Pan		Saucepan (standard product, stainless steel, 18cm, 2.0-2.5 little)
9	Battery		AA alkaline battery (packed 4 batteries)

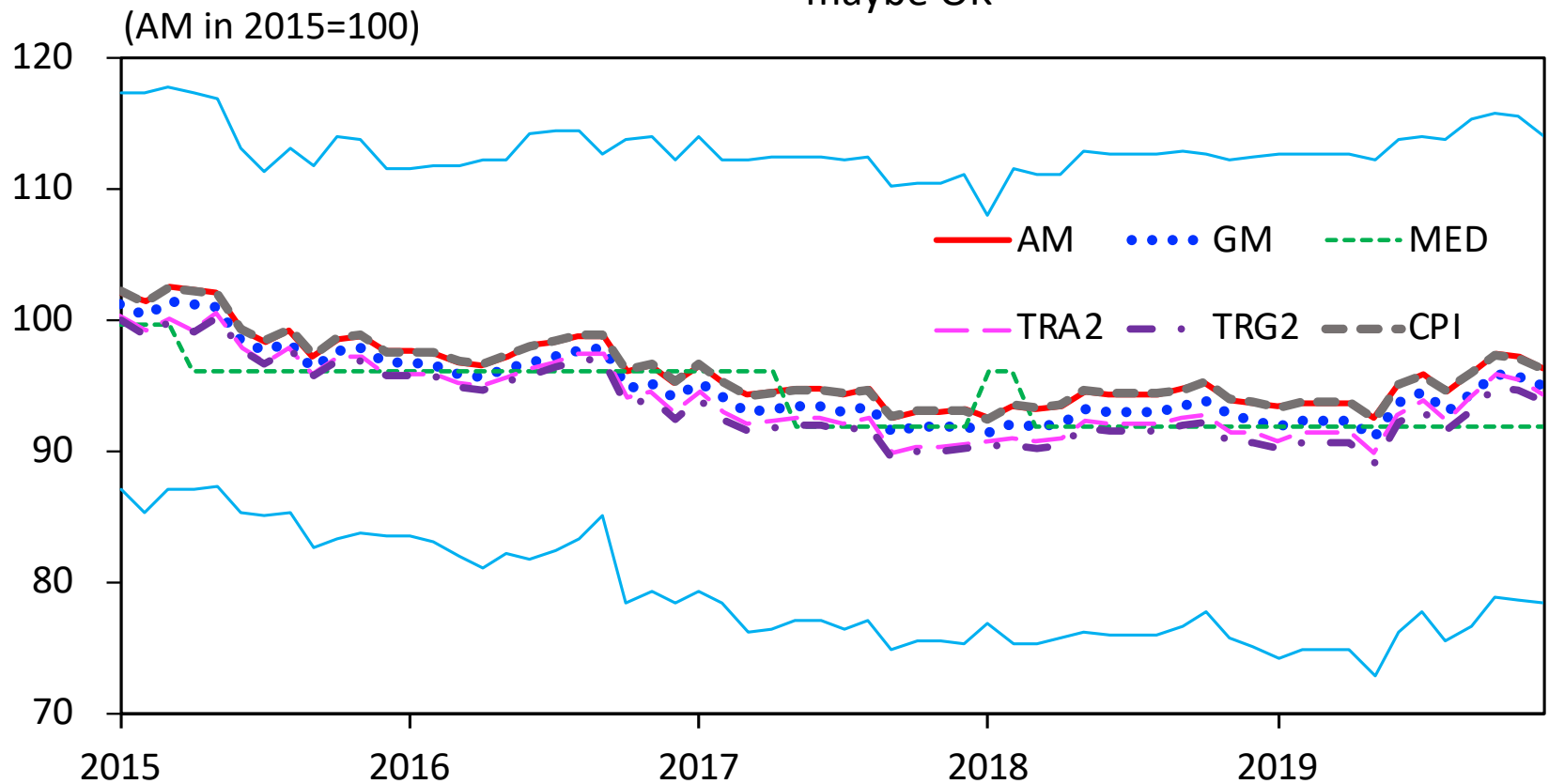
Example 1: Whisky

High accuracy in elementary aggregation,
but price representativeness?



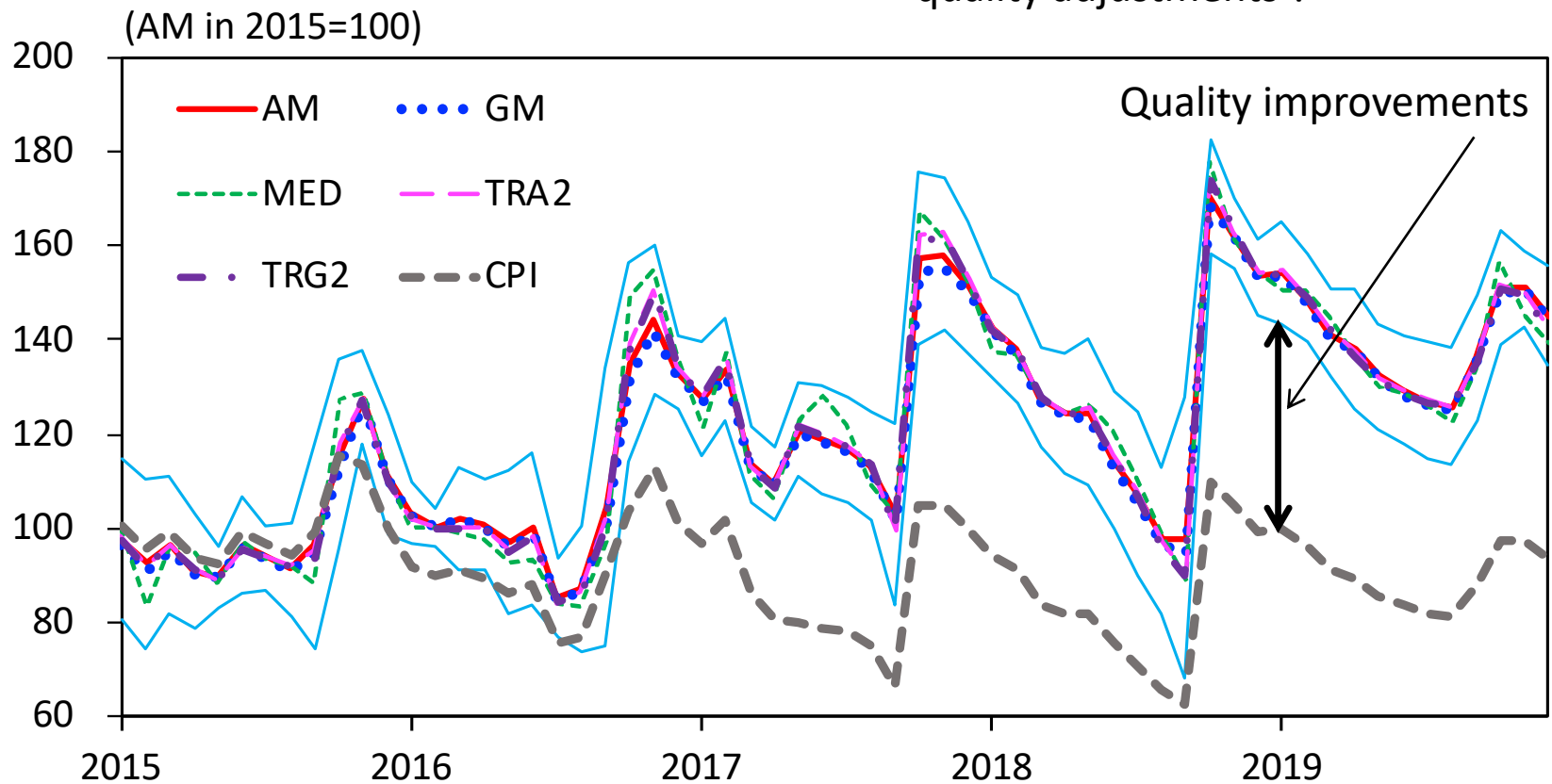
Example 2: Soy Sauce

Relatively high accuracy in elementary aggregation, and price representativeness maybe OK



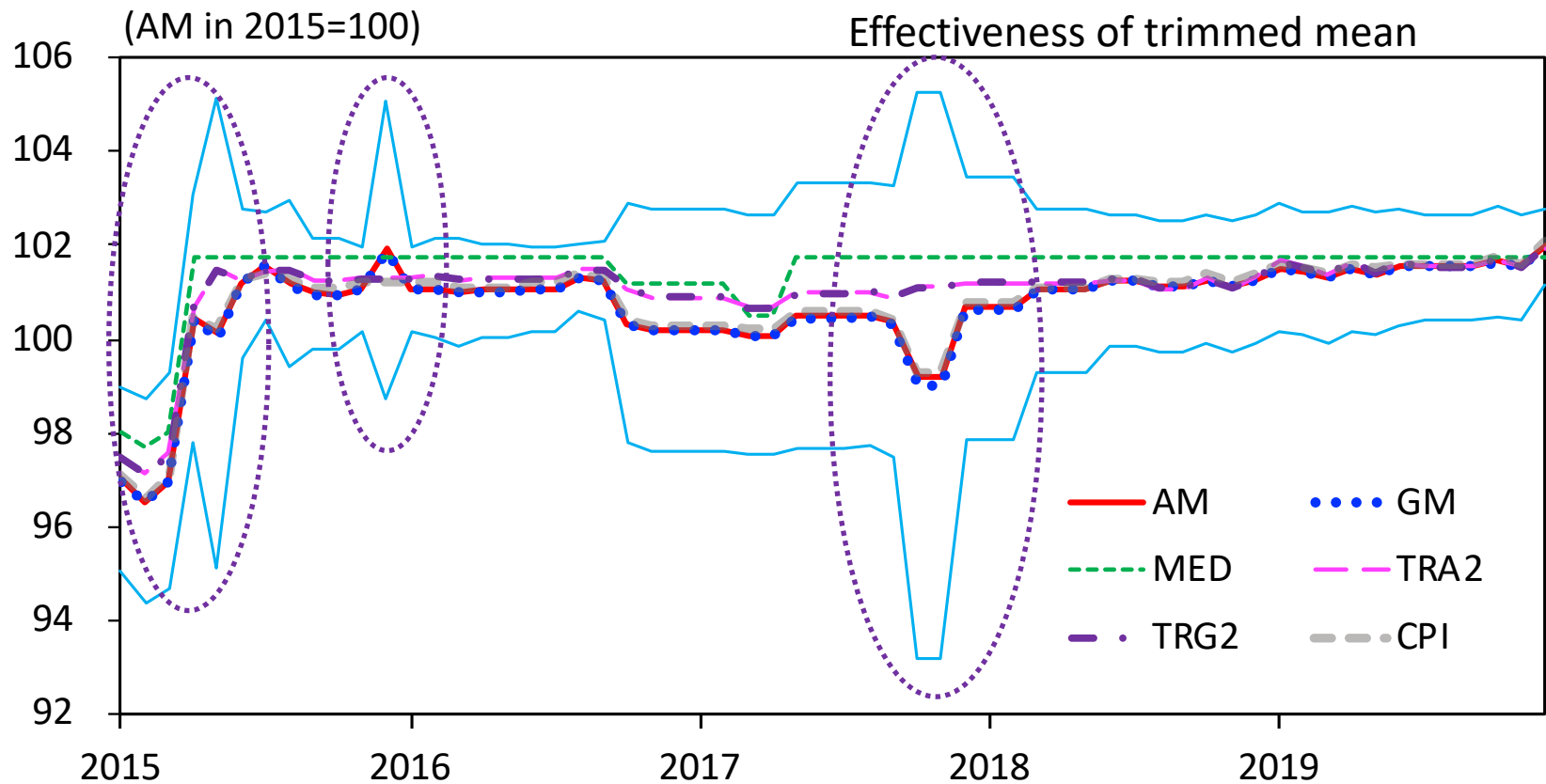
Example 3: Washing Machine

Accuracy in elementary aggregation,
price representativeness, and
quality adjustments ?



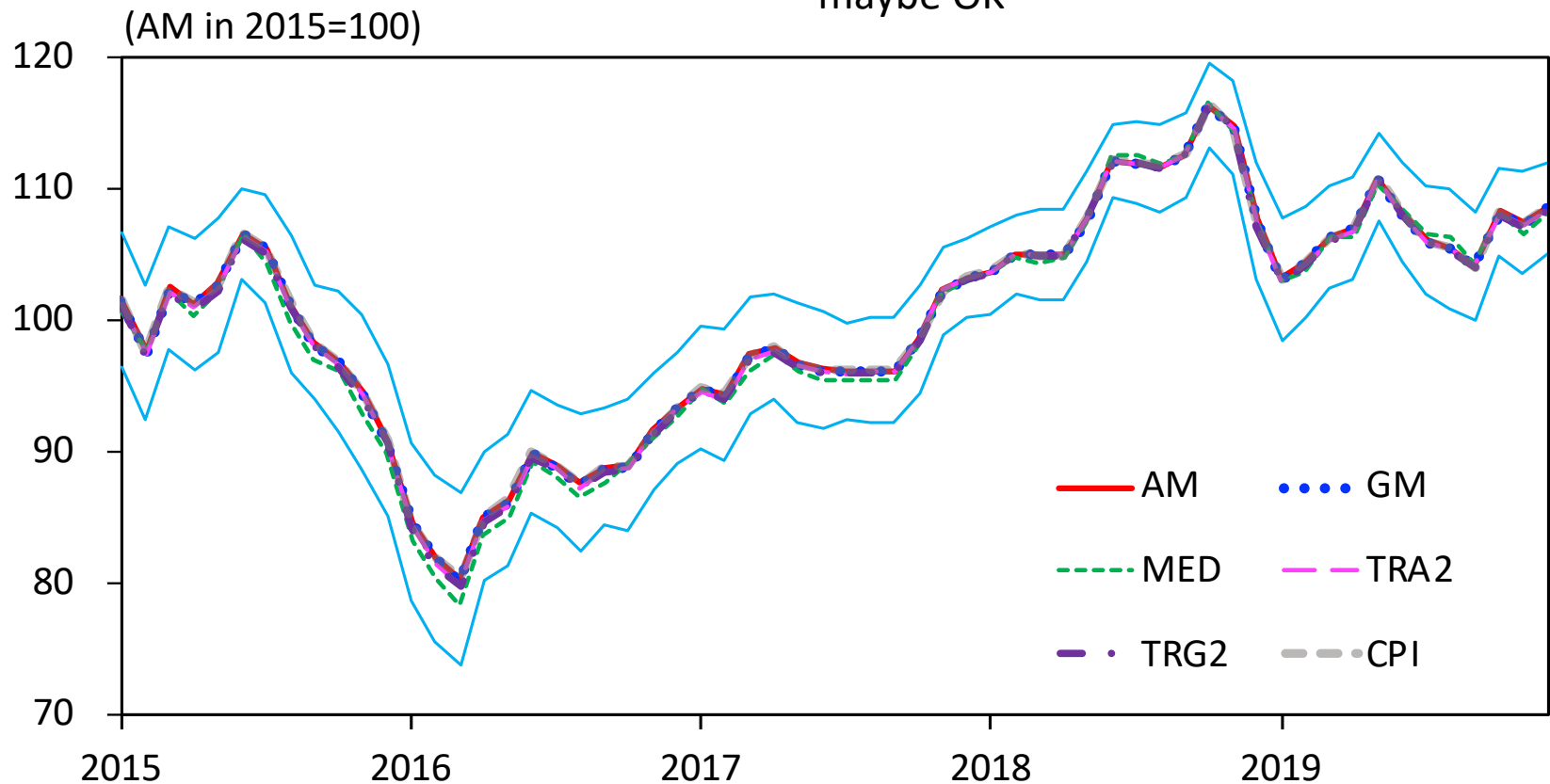
Example 4: Butter

Relatively high accuracy in elementary aggregation, and price representativeness maybe OK? But price survey failure. → Effectiveness of trimmed mean



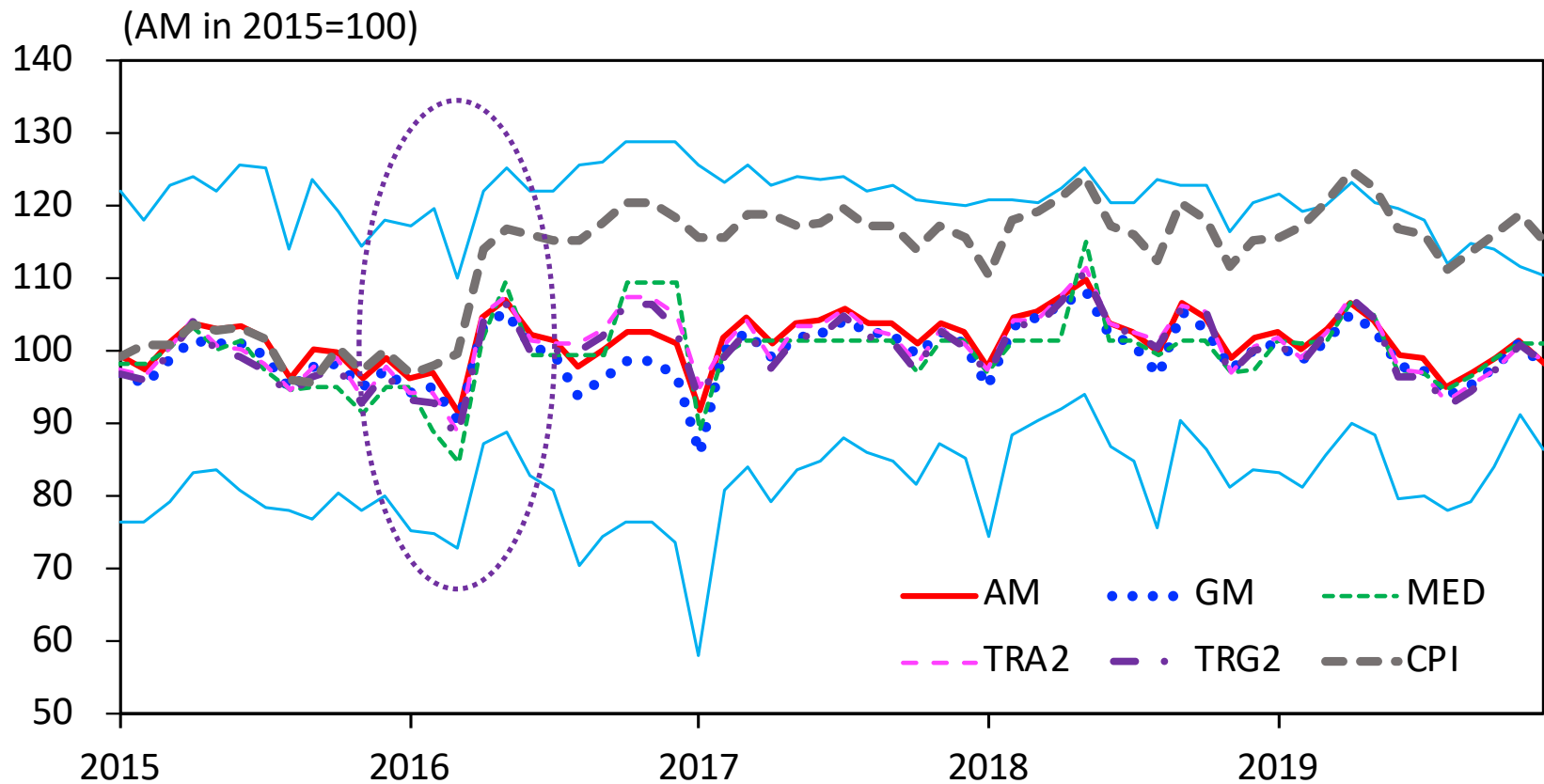
Example 5: Gasoline

Relatively high accuracy in elementary aggregation, and price representativeness maybe OK



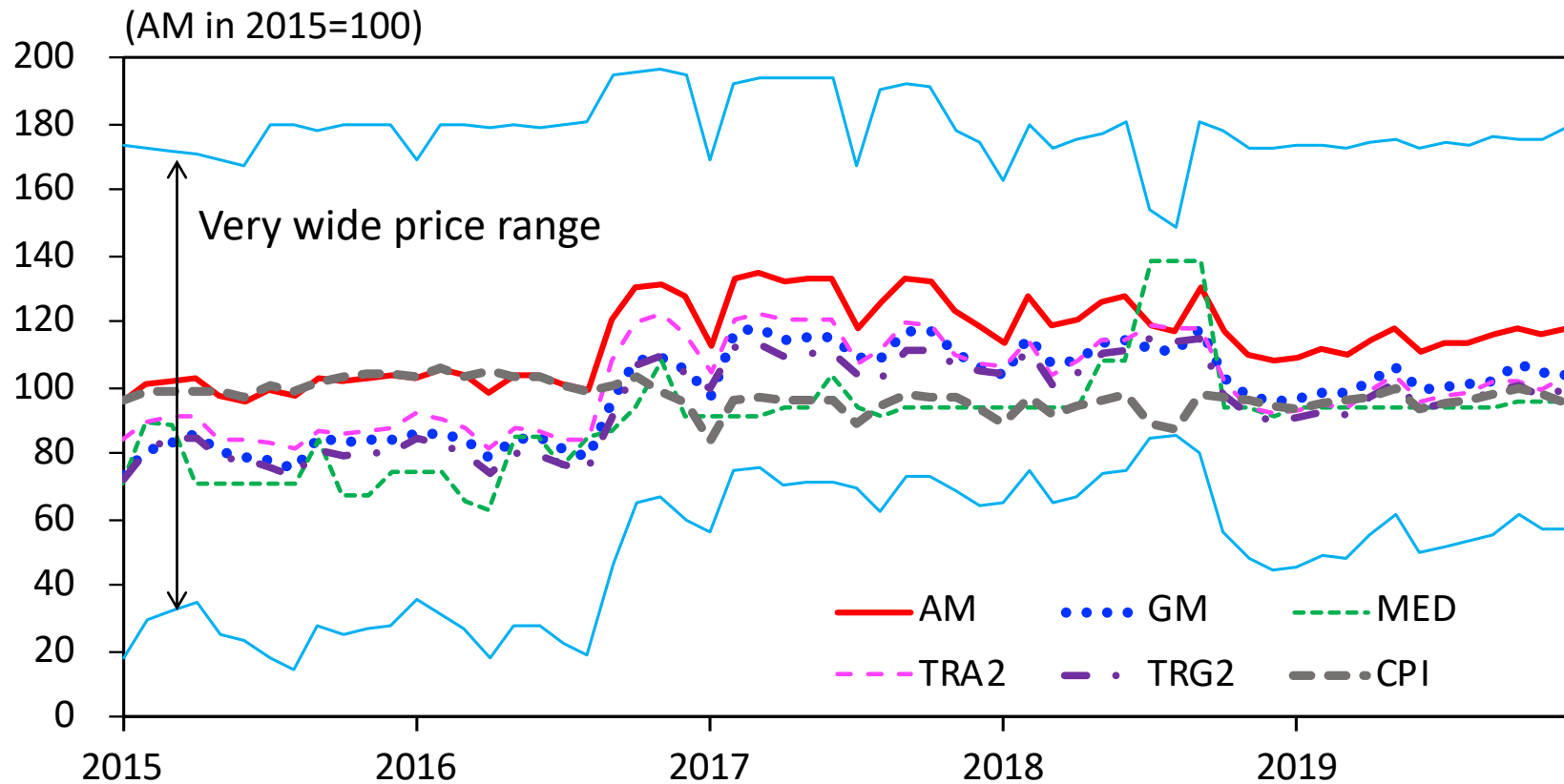
Example 6: Cap

Quality adjustment? Price survey failure?



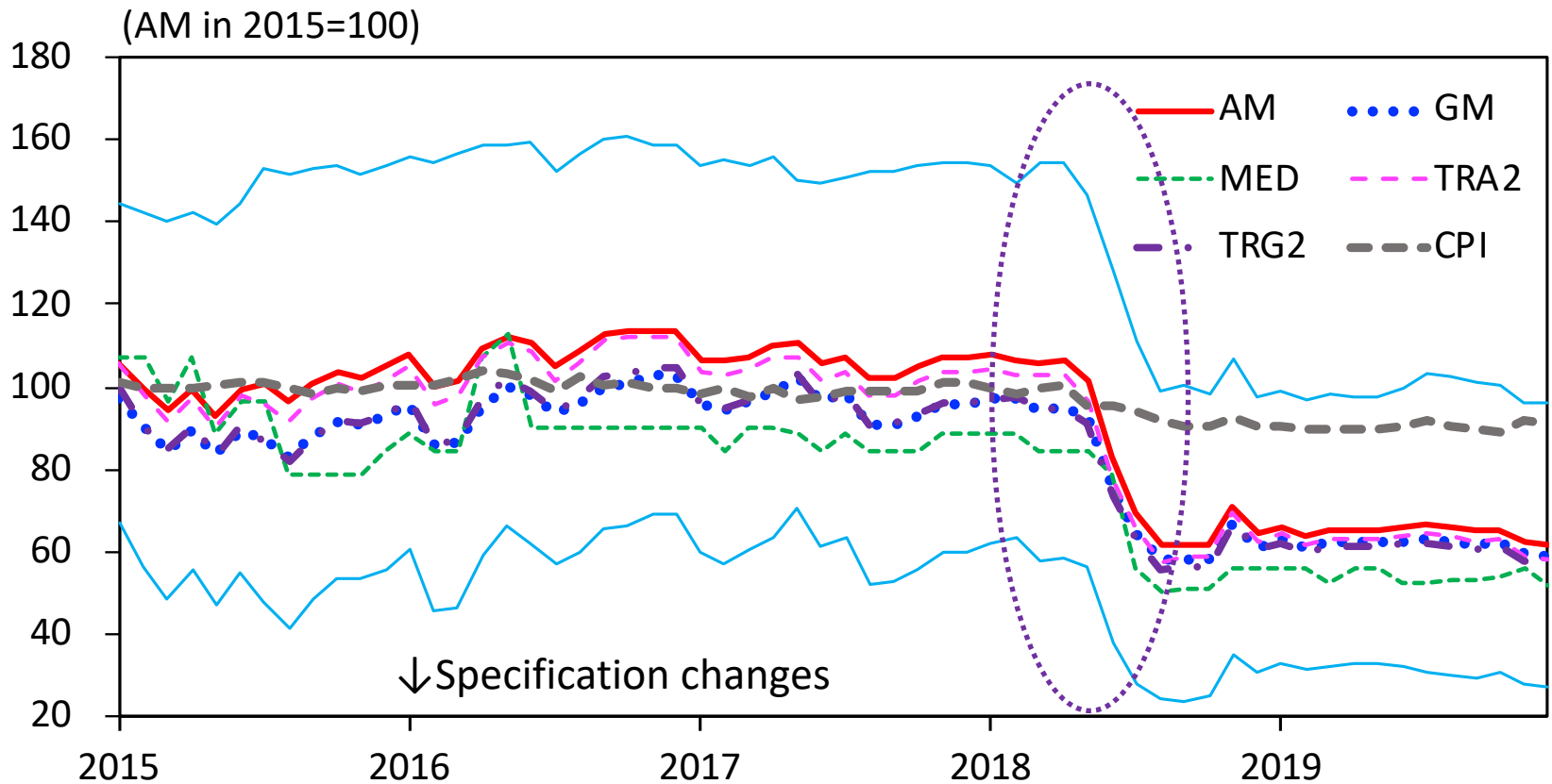
Example 7: Women's Jeans

Unstable price samples
Unintended overvaluation of high-priced products



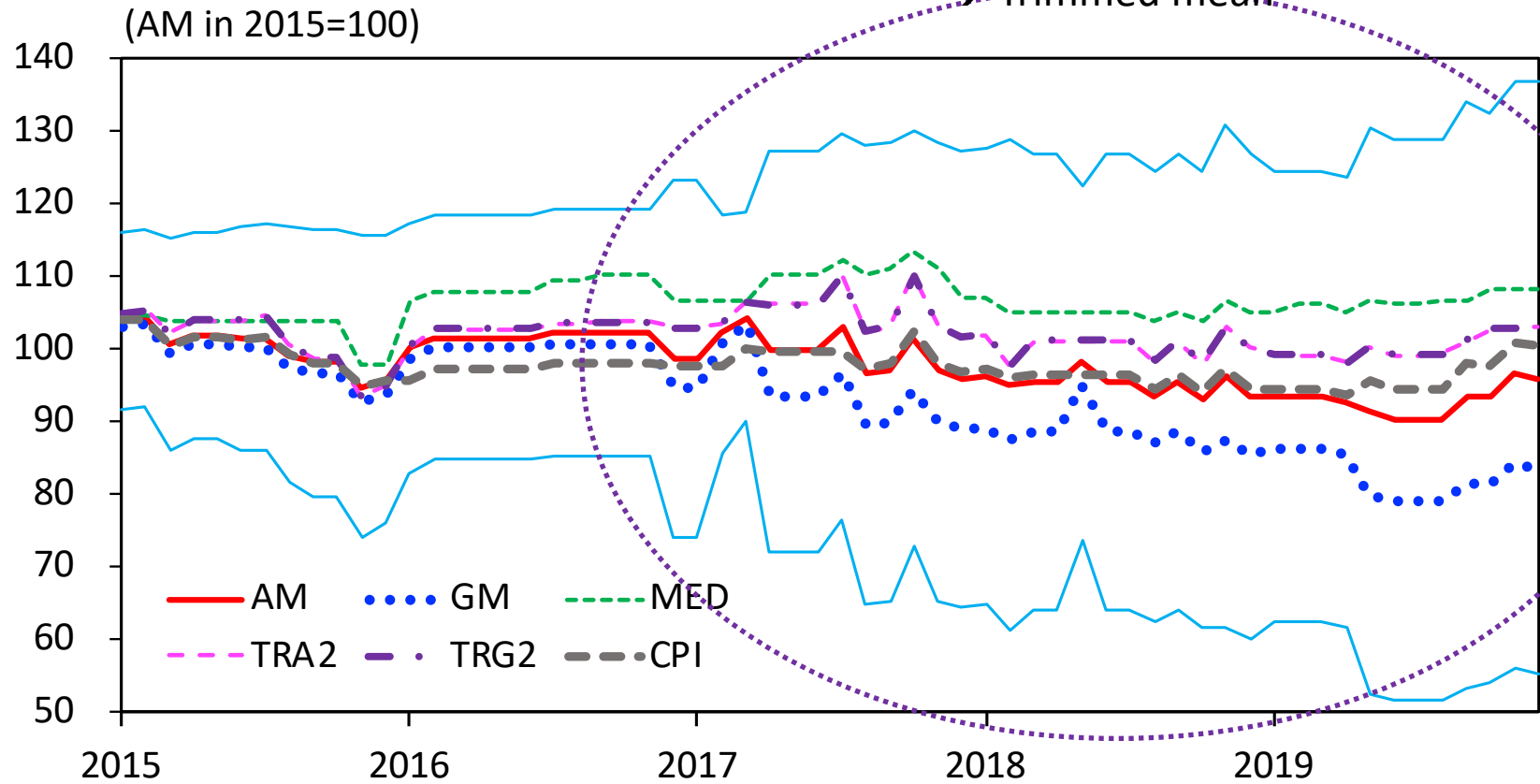
Example 8: Pan

Unstable price samples
Quality adjustments?



Example 9: Battery

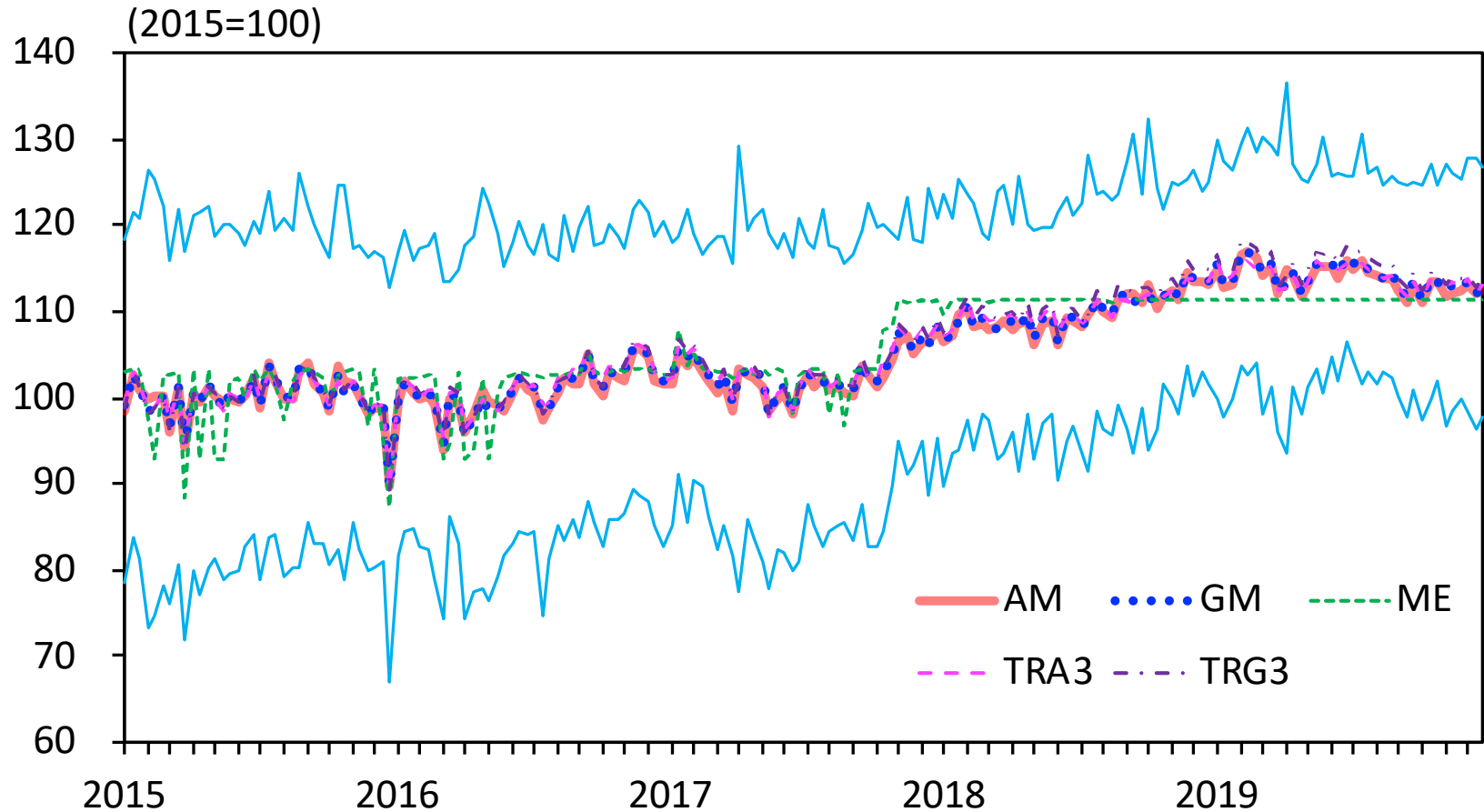
Unstable price samples
Private brands? Outlets?
→ Trimmed mean



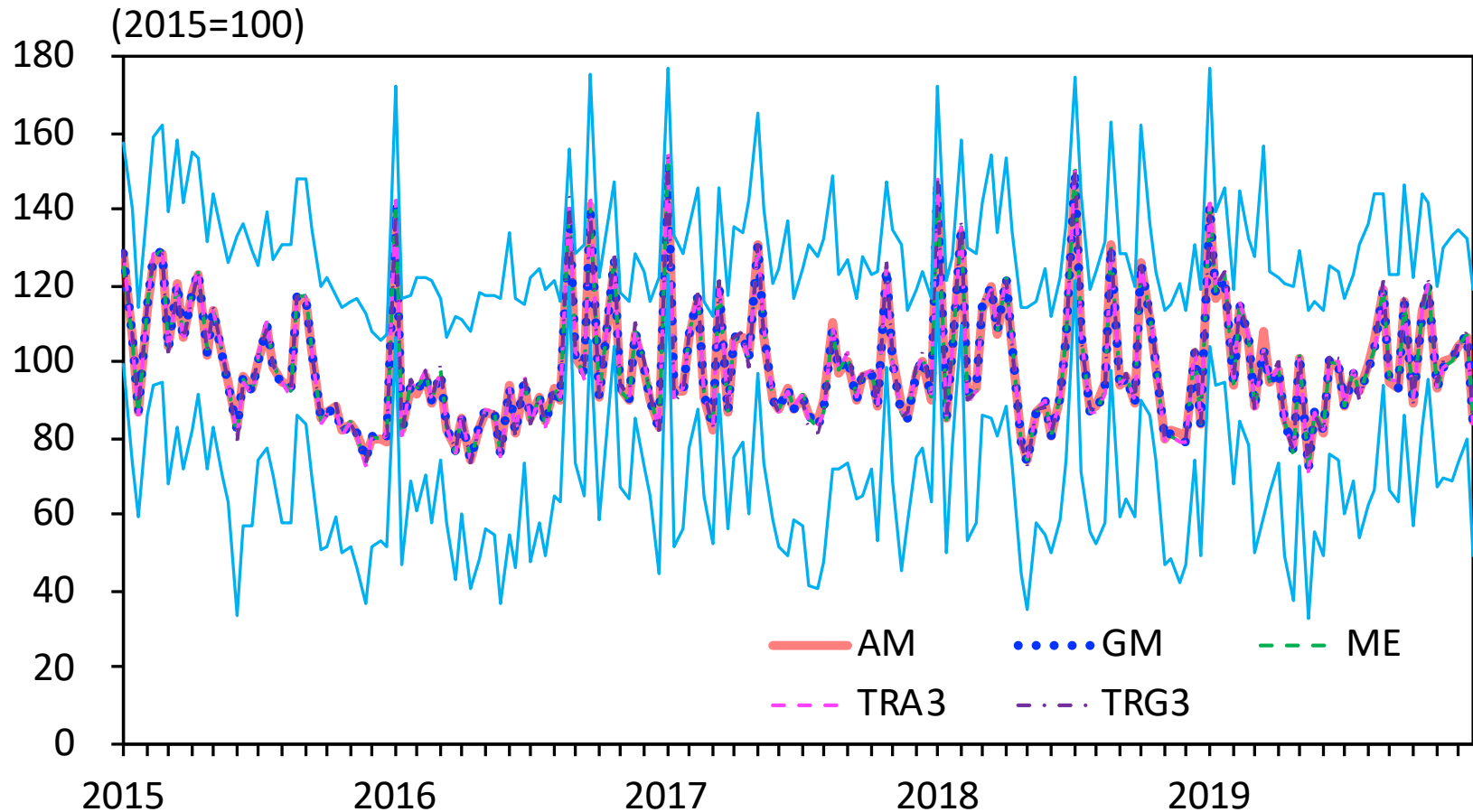
Every Ten-day Survey Items

	Item	Features
10	Sea Bream (<i>Tai</i>)	Low Price Volatility
11	Horse Mackerel (<i>Aji</i>)	High Price Volatility
12	Lettuce	

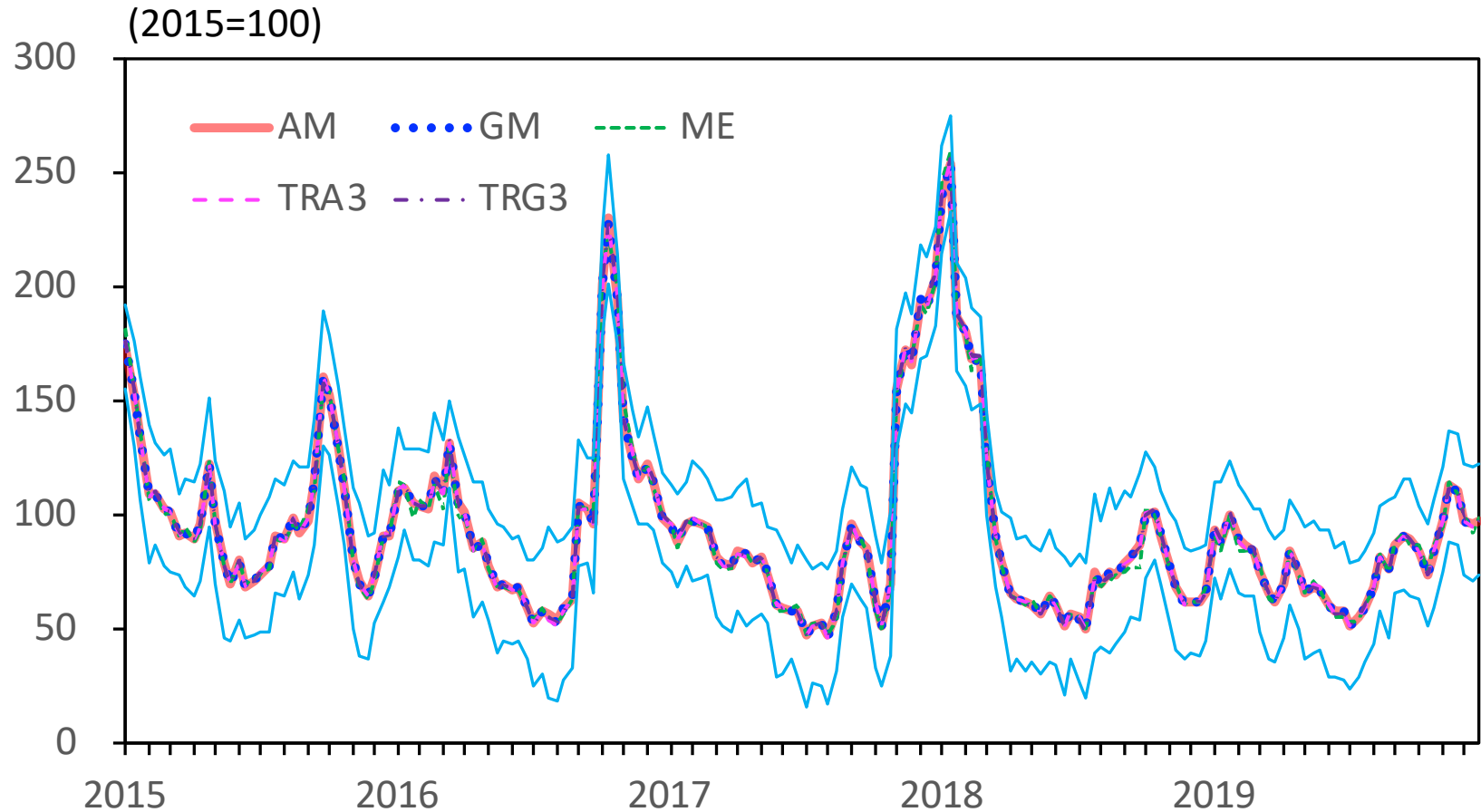
Example 10: Sea Bream



Example 11: Horse Mackerel



Example 12: Lettuce



Limit for RPS Micro Data

- Collection of Prices Surveyed in Each Month:
 - A lot of discontinuation in individual price series
 - No information on how to link discontinued prices
- Some Items w/ Loosely Defined Specification:
 - Highly heterogeneous prices surveyed
 - Implicit high weight for high-priced products
 - Vulnerable to temporary survey failures
 - Possible solution: Trimmed mean formula

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Tentative Assessment

- Lower-level Substitution Bias in Japanese CPI:
 - Not necessarily due to aggregation formula
 - Mostly due to price survey method
- One-Specification for One-Item Policy:
 - Impossibility of collecting homogeneous prices in some items
 - Not necessarily guarantee stable price survey + price representativeness

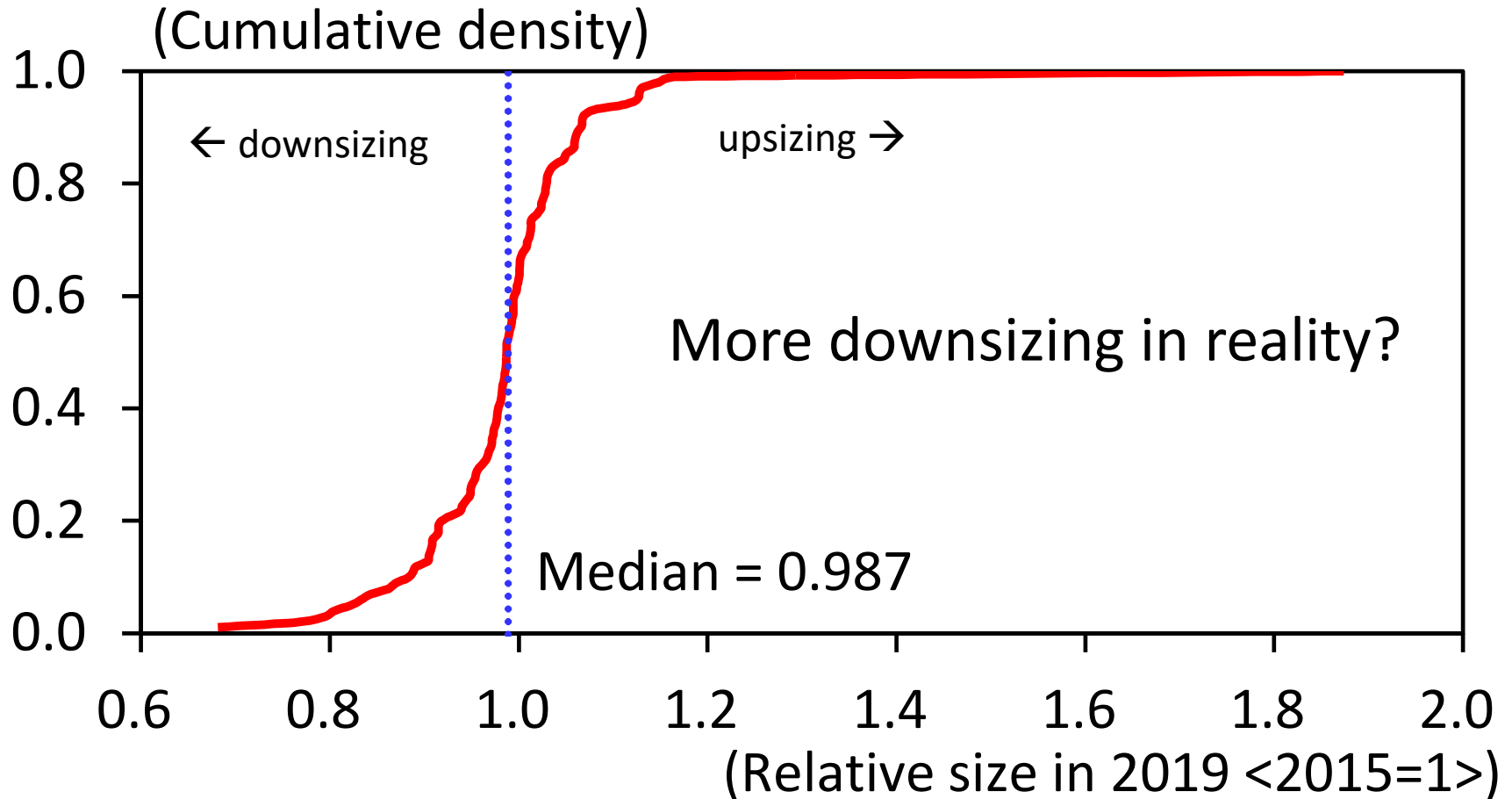
Possible Solution

- Item-by-item approach:
 - Importance of item-specific factors
 - How to balance elementary aggregation accuracy and price representativeness
- Heterogeneity in Products:
 - Alternative data sources: scanner, web-scraping
 - Alternative aggregation formula: CES aggregator?
- Possible Price Survey Errors:
 - Adjustment of outlier prices by trimmed mean

Open Questions

- Effectiveness of Alternative Data?
 - Application of scanner data to items with highly heterogeneous / differentiated prices
- Linked Individual Price Series?
 - Discontinuity in individual prices surveyed
 - Impossible to analyze price dynamics at an individual price level

Changes in Item Size over 2015-19



Note: Cumulative changes in unit size from 2015 to 19 for samples with information on unit size.