Testing unit value data price indices

Li-Chun Zhang[1,2], ***Ingvild Johansen***[2], and ***Ragnhild Nygaard*** [2]

[1] ***University of Southampton (L.Zhang@soton.ac.uk)***

[2] ***Statistics Norway***

Three points to be covered in this presentation:

[1] overriding issues of ***unit-value (UV)*** price indices

[2] ***5 tests*** for dynamic item universe

[3] practical ***segmented UV (SUV)*** price indices

Unit-value (UV) price data

One has 'everything' at *each given time period*:

- ***items*** distinguishable from each other by `(outlet, GTIN)`

- ***unit-value price & quantum*** for each item over whole period

Traditional ***matched-model (MM)*** index approach

- observed BigData item universe **not constant** over time: problem moved from **observation deficiency** to **formula deficiency**

- MM approach requires identification of ***persistent items***:

  BigData = BigTrouble if item-matching pursued rigorously

Terms of Reference (TOR)

Two overriding requirements of UV price index method:

1. Accommodate *all* items in a dynamic universe

2. Keep the cost of item-matching sustainable

Should cover several often-mentioned desirable features, incl. e.g.

- incorporate quantity data of product offers
- generic and applicable across different consumer groups
- capture the dynamic product universe
- handles substitution: include in-coming items immediately
- handles practical challenges: avoid manual interference

Terms of Reference (TOR)

In addition, would like to maintain both cost-of-living (***COLI***) and cost-of-goods (***COGI***) perspectives, e.g.

- harmonised with other NSOs and consistent with HICP
- transparent and easy to communicate to users

Do not expect ideal index formula, but methods that as much as possible fulfil the TOR.

Future research: developing shared explicit *empirical criteria* of well-behaving indices

5 tests for dynamic universe, COLI & COGI

Identity test (T1) If $U_0 = U_t$ and $p_i^0 \equiv p_i^t$ for any $i \in U_0$, then $P^{0,t} = 1$.

Fixed basket test (T2) If $U_0 = U_t$ and $q_i^0 \equiv q_i^t$ for any $i \in U_0$, then $P^{0,t} = V^{0,t} = V^t/V^0$.

Upper bound test (T3) If $U_0 \subseteq U_t$, and $p_i^t \leq p_i^0$ for all $i \in U_0$, then $P^{0,t} \leq 1$.

- **Test t3** If $U_0 \subset U_t$, i.e. $U_{t\backslash 0} \neq \emptyset$, and $p_i^0 = p_i^t$ for all $i \in U_0$, then $P^{0,t} \leq 1$.

5 tests for dynamic universe, COLI & COGI

Lower bound test (T4) If $U_t \subseteq U_0$, and $p_i^t \geq p_i^0$ for all $i \in U_t$, then $P^{0,t} \geq 1$.

- **Test t4** If $U_t \subset U_0$, i.e. $U_{0\backslash t} \neq \emptyset$, and $p_i^0 = p_i^t$ for all $i \in U_0$, then $P^{0,t} \geq 1$.

Responsiveness test (T5) For $U_0 \neq U_t$, $P^{0,t}$ should *not always* reduce to $f(D_{0t})$, where $D_{0t} = D(U_{0t})$ and U_{0t} consists only of the persistent items between 0 and t.

NB. ***comparison universe*** of $P^{0,t}$: $\{U_0, U_t\}$; but one can choose ***reference universe*** of $P^{0,t}$: $R_B = \{U_0, U_t\}$, $R_M = \{U_0, U_1, ..., U_t\}$

Why no *transitivity* test? Some concerns...

Roughly, an index is transitive if $P^{0,t} = P^{0,r}P^{r,t}$ for any $r \neq 0, t$, provided all the three indices are *calculated in the same way.*

$\star$ $U_0 = U_r = U_t$, $0 < r < t$, $p_i^0 = p_i^t$ for $\forall i \in U$: By test T1, $P^{0,t} = 1 \Rightarrow P^{0,r} = 1/P^{r,t}$. If $P^{t,r} = 1/P^{r,t}$, then $P^{t,r} = P^{0,r}$. Then, the index needs to be invariant whether going from $q(U_0)$ to $q(U_r)$ or from $q(U_t)$ to $q(U_r)$, where $q(U_0) \neq q(U_t)$ in general. *But is this acceptable for a COLI, if utility is not just quantity?*

$\star$ Does transitivity prevent chain drifting? Suppose $U_0 \cap U_t = \emptyset$. Chained index between 0 and t is clearly still possible. *But what is the 'ideal' direct index between* 0 *and* t *to be compared with?*

Why no *transitivity* test? Some concerns...

⋆ What about GEKS (Ivancic et al., 2011)?

- spatial extension: undirected and limited; temporal extension: directional and unlimited, round-table analogy is unnatural
- in reality, the disseminated GEKS over time is *not* transitive
- built only on *2-step* breakdowns, i.e. $P^{0,r}$ and $P^{r,t}$ for $0 \leq r \leq t$; but why not, say, all *3-step* breakdowns, i.e. $P^{0,r}$, $P^{r,s}$ and $P^{s,t}$ for $0 \leq r \neq s \leq t$? is there a unique construction?

Transitivity seems not a necessity of COLI, generally undefined for a dynamic universe, requiring *ad hoc* imposition on index formulae.

Some test results

	Identity	Fixed-basket	Upper-bound	Lower-bound	Responsiveness
MGK	Yes if R_B No if R_M	Yes	Yes	Yes	Not in Setting of t3 or t4
RQ	Yes	Yes if R_B No if R_M	Possibly for T3 No for t3	Possibly for T4 No for t4	Yes
RQP	Yes if R_B No, if R_M	Yes if R_B No if R_M	Possibly for T3 No for t3	Possibly for T4 No for t4	Yes
WGM	Yes if R_B No if R_M	No	Generally No for T3	Generally No for T4	Not in Setting of t3 or t4
GEKS	No	No	No	No	Not if (U_0, U_1)

MGK: modified Geary-Khamis; dropping the constant price adjustment/Lehr

RQ: price comparison based on fixed reference quantities of *all* items

RQP $= \left(\text{RQ}\right)^{\alpha}\left(\text{MGK}\right)^{1-\alpha}$, analogous to Fisher index e.g. if $\alpha = 0.5$

WGM: weighted geometric means, e.g. de Haan and Krsinich (2014), Iklé (1972)

Remarks

⋆ **No index satisfies all the 5 tests**

⋆ No general recommendation at this stage, since it is possible for an index to compensate for a shortcoming in one respect with better properties in others

⋆ need to compromise between t3, t4 and T5 in practice

⋆ as shown in the paper: in the presence of a clear price trend, one can expect the bilateral MGK index to be *less volatile* than its *persistent-universe counterpart*

⋆ to reiterate: important to develop empirical criteria

On exchangeability and ideal segmentation

1. Exchangeability (to allow for substitution) is a local property, i.e. among a *limited* group of items

2. Exchangeability is more fundamental than observable traits. [Ideal item-matching based on exchangeability, not tangible or directly observable characteristics.]

3. Exchangeability is discrete: necessary and sufficient with *package-exchangeability* and not over a continuum

NB. refer to ***utility*** as what enables exchangeability, which can thus be a function of item UV-price, say, $u_i = f(p_i)$

On exchangeability and ideal segmentation

Over a suitable set of items, assume utility as a discrete, positive function of the UV-price, which is increasing in the latter in segments.

[$f(p)$ is increasing in segments, if $\forall p > 0$, $\exists\ [p_L, p_U] \ni p$, such that $f(p') < f(p)$ for any $p' < p_L$, and $f(p') > f(p)$ for any $p' > p_U$]

Ideal segmentation Provided $\{u_1, .., u_G\}$ for $\{U_0, U_t\}$, an *ideal segmentation* method is such that, for any $i \in U_0$ and $j \in U_t$, they are assigned to the same segment g, for $g = 1, ..., G$, whenever $f_0(p_i^0) = f_t(p_j^t) = u_g$.

On exchangeability and ideal segmentation

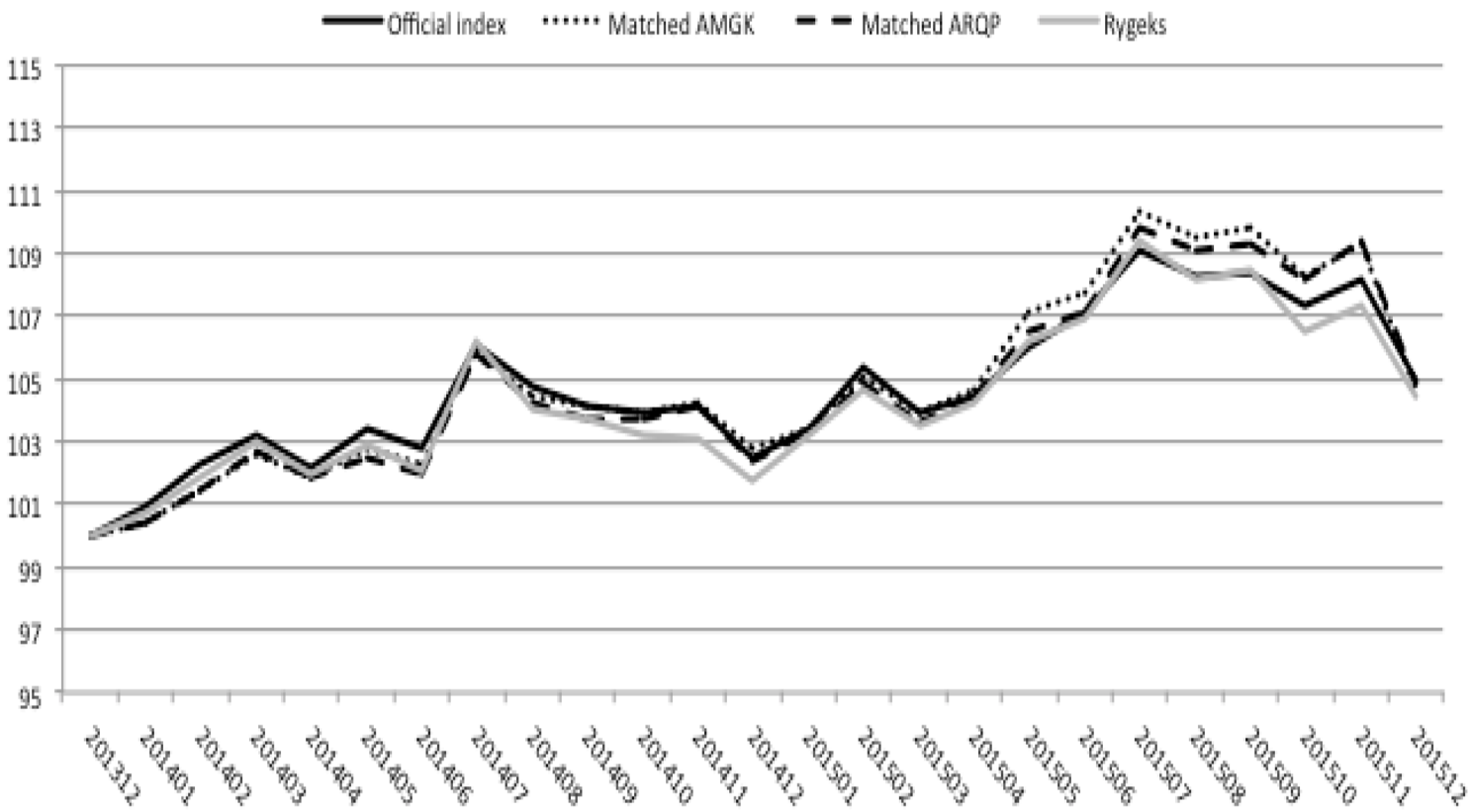
NB. When $U_0 = U_t$, correct matching of the persistent items yields an ideal segmentation method. However, the approach is inadequate for a dynamic universe, due to the existence of $U_{t\setminus 0}$ and $U_{0\setminus t}$.

Other segmentation methods are necessary in a dynamic universe. In particular, two simple methods:

- *(Dynamic) segments*: form G segments based on $\{p_{is}; i \in U_t\}$, separately for each t, where p_{is} is a chosen 'normal' price
- *Fixed segments*: assign detected persistent items to the same segment; assign the rest according to fixed segment boundaries

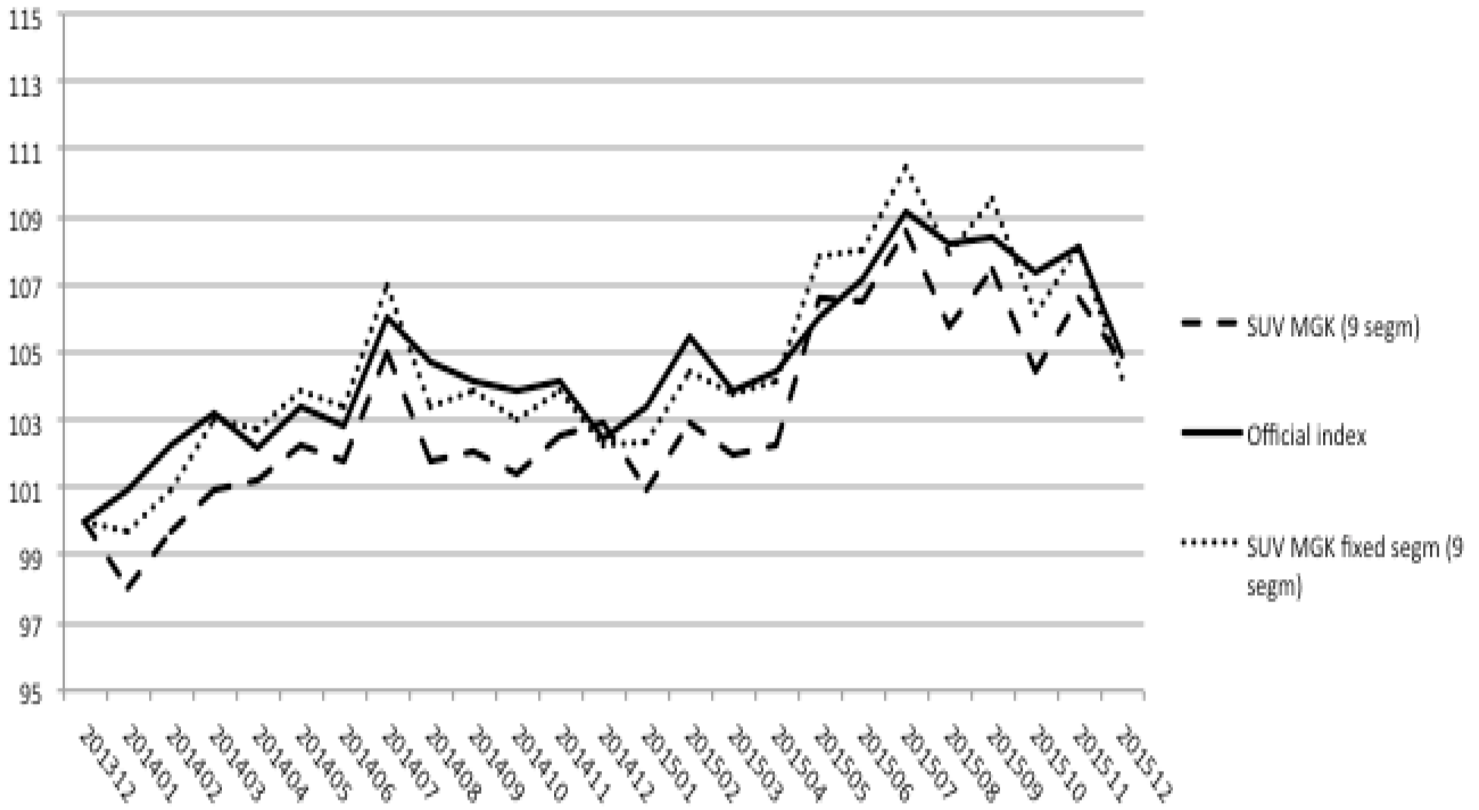
NB. Automatic detection by `(outlet, GTIN)`; use of metadata; segmentation by expenditure value share; segmentation by ANOVA

Some results: Grocery market 2014-2015, Norway



Using automatically matched persistent items *and* quantity data

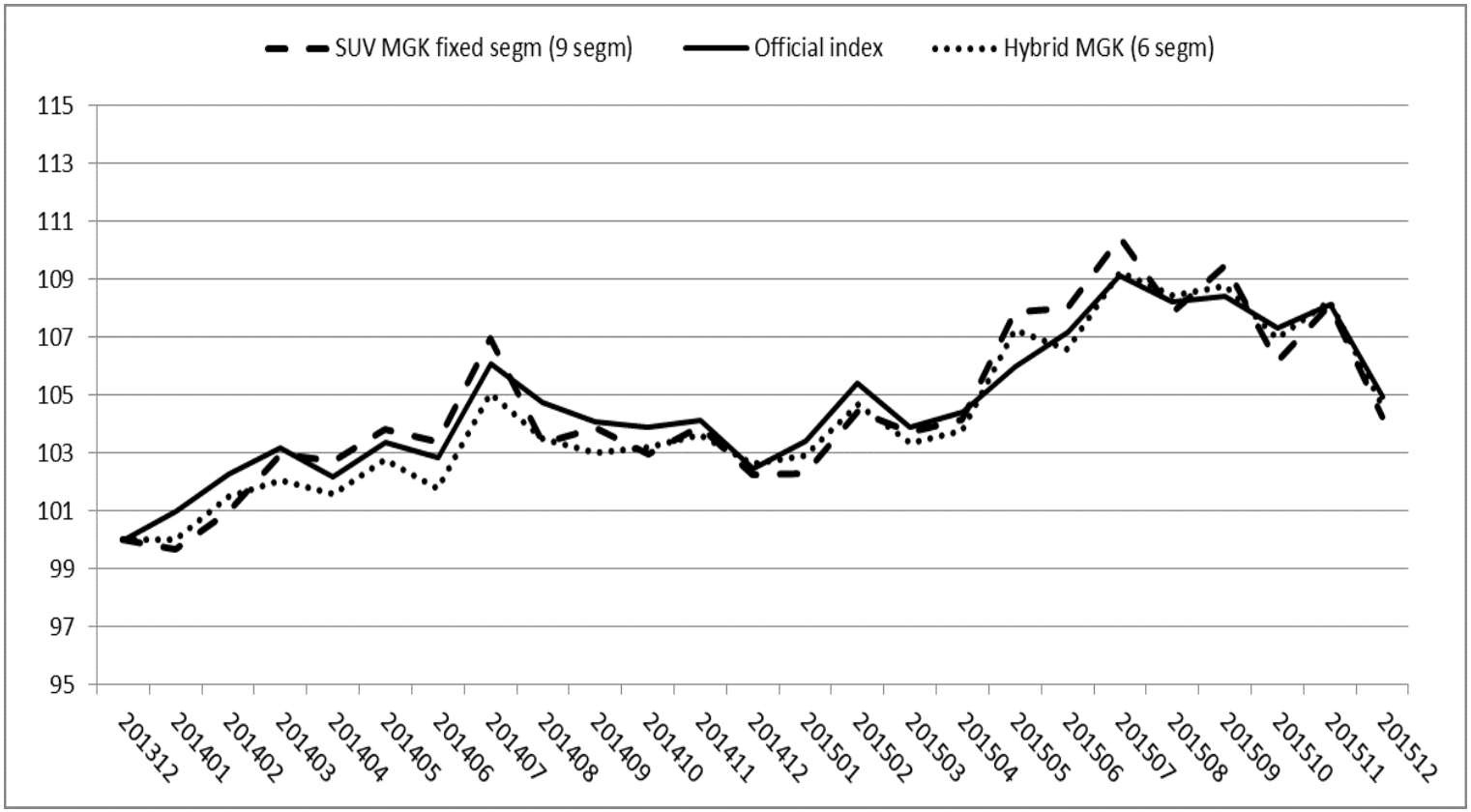
Some results: Grocery market 2014-2015, Norway



NB. minimum processing effort in order to be fully responsive

NB. 9 segments, not "homogeneous products" (Chessa, 2016)

Some results: Grocery market 2014-2015, Norway

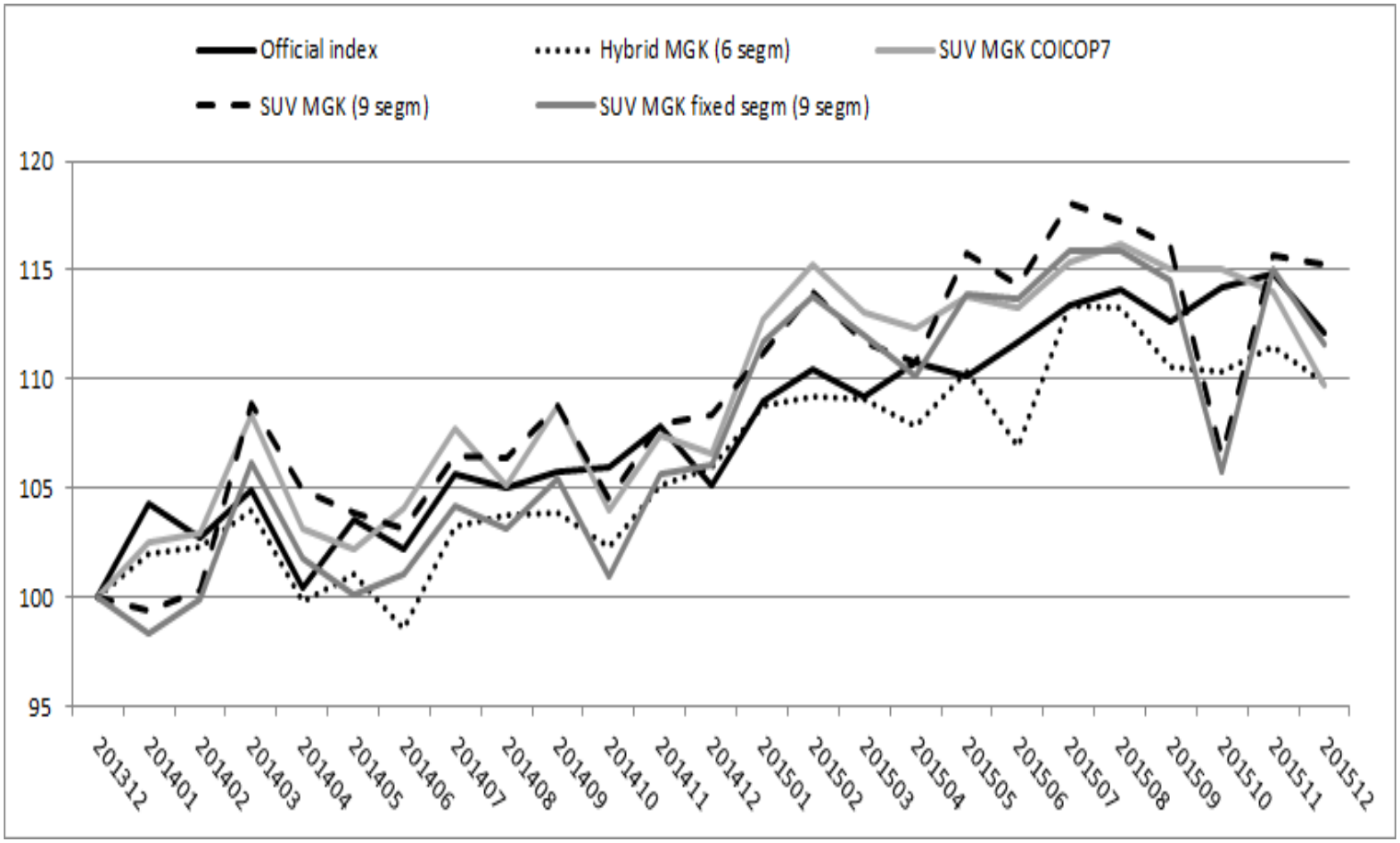


NB. hybrid: segmentation of only items not automatically matched

NB. small segments aside the matched items: exchangeability?

NB. somewhat messy & unstable to maintain over time

Metadata segmentation for soft drinks



NB. lower COICOP6-level; increasing volatility vs. Official index

To reiterate: empirical criteria for evaluation?

⋆ use available metadata for segmentation if possible?

⋆ audit sampling to check mis-segmentation rate?

⋆ how to disentangle volatility due to mis-segmentation vs. enhanced responsiveness to dynamic universe?

⋆ hybrid index combining automatically matched persistent-item index with all-inclusive direct SUV-index?

⋆ bilateral vs. multilateral index: comparisons differ with respect to short-term or long-term index movement?

⋆ adopting relative volatility bounds and movement bounds, e.g. w.r.t. a chosen persistent-item index?

[1] Chessa, A. G. (2016). A new methodology for processing scanner data in the Dutch CPI. *Eurostat review of National Accounts and Macroeconomic Indicators*, **1**, 49-69.

[2] de Haan, J. and F. Krsinich (2014). Scanner Data and the Treatment of Quality Change in Nonrevisable Price Indexes. *Journal of Business & Economic Statistics*, **32**, 341-358.

[3] Iklé, D.M. (1972). A New Approach to the Index Number Problem. *Quarterly Journal of Economics*, **86**, 188-211.

[4] Ivancic, L., Fox, K. J. and Diewert, E. W. (2011). Scanner data, time aggregation and the construction of price indexes. *Journal of Econometrics*, **161**, 24-35.