Scanner data and multilateral price index methods

UN GWG on Big Data for Official Statistics

Workshop on Scanner Data and Official Statistics

Kigali, Rwanda, 29 April – 1 May 2019

Delivering insight through data for a better Canada

Outline

- Three classes of multilateral index methods:
  - GEKS method
  - Geary-Khamis method
  - Time Product Dummy (or fixed effects) method
- Length of index estimation window
- Extension methods
- Monitoring and quality control
- Conclusion

Classes of multilateral index methods

- Methods traditionally used in the spatial comparison of price levels
- Comparison should be independent of the choice of base country/region:
  - methods are transitive
- Recently adapted to temporal comparison of price levels
- Use weights at product level
- Are free of chain drift
- Multilateral methods and their applications:

Multilateral method	Expenditure data needed?	Known application
GEKS-Törnqvist	Yes	Australia: Grocery data New Zealand: Electronics
GEKS-Jevons	No	Does not take advantage of available sales data!
Geary-Khamis (GK)	Yes	Netherlands: Almost all scanner data including supermarkets data
Time Product Dummy (TPD)	Yes/No, both versions possible	New Zealand: Rental prices
Time Dummy Hedonic (TDH)	• Yes/No, both versions possible • Needs detailed attribute data	Usually considered for consumer electronics

GEKS method

- Gini (1931); Eltetö and Köves (1964) and Szulc (1964)
- Estimation window $[0, T]$. For *t* in [0, T]:

$$P^{0,t} = \prod_{z=0}^{T} \left(\frac{P^{0,z}}{P^{t,z}} \right)^{\frac{1}{T+1}}$$

- T+1 bilateral price indexes $P^{0,z}$, $z = 0,1,\ldots, T$
- T+1 bilateral price indexes $P^{t,z}$, $z = 0,1,\ldots, T$
  - $P^{0,t}$ is calculated through T+1 paths: $P^{0,z} \times P^{z,t}$
  - None of these paths should be preferred to the others
  - Geometric average of these T+1 results

GEKS method

- Bilateral index formula:
  - Needs to satisfy the time reversal test
  - Fisher index
  - Törnqvist index
  - Jevons index (not so relevant in the context of scanner data!)

- If the dataset has limited/no characteristics but we have expenditure information, we can use a superlative bilateral index formula (e.g. Törnqvist, Fisher)

- If the dataset has no expenditure information, we can use an unweighted bilateral formula (e.g. Jevons)

Geary-Khamis method

- Geary (1958) and Khamis (1972)
- For an homogeneous product, in a given time period, price equals unit value:
  - Unit value = (total sales value) / (total quantity sold)
- $p_i^t q_i^t = \left(\frac{p_i^t}{v_i} \right) \left(v_i q_i^t \right)$ for a product *i* available in period *t*
- v_i is a quality adjustment factor for product *i*.
- $\left(\frac{p_i^t}{v_i} \right)$: Quality adjusted prices; $\left(v_i q_i^t \right)$: Adjusted quantities

- Adding up quantities of dissimilar goods to form the unit value index isn't necessarily meaningful
- Use standardized or quality-adjusted quantities
- Apply quality adjustment factors to the various item quantities to express them in terms of a "base" product, and then simply add them up

Geary-Khamis method

- Quality adjusted unit value:

$$\bar{p}^t = \frac{\sum_{i \in G^t} \left(\frac{p_i^t}{v_i} \right) \left(v_i q_i^t \right)}{\sum_{i \in G^t} v_i q_i^t} = \frac{\sum_{i \in G^t} p_i^t q_i^t}{\sum_{i \in G^t} v_i q_i^t}$$

→ "Quality adjusted prices" and "adjusted quantities" world

- GK price index between 0 and *t*:

$$P^{0,t} = \frac{\bar{p}^t}{\bar{p}^0}$$

$$P^{0,t} = \frac{\left(\sum_{i \in G^t} p_i^t q_i^t \right) / \left(\sum_{i \in G^t} v_i q_i^t \right)}{\left(\sum_{i \in G^0} p_i^0 q_i^0 \right) / \left(\sum_{i \in G^0} v_i q_i^0 \right)}$$

- (1) $$P^{0,t} = \frac{\left(\sum_{i \in G^t} p_i^t q_i^t \right) / \left(\sum_{i \in G^0} p_i^0 q_i^0 \right)}{\left(\sum_{i \in G^t} v_i q_i^t \right) / \left(\sum_{i \in G^0} v_i q_i^0 \right)}$$

"Change in total sales from 0 to *t*", "Weighted quantity index"

- (2) $$v_i = \frac{\sum_{z=0}^{T} \left(q_i^z p_i^z \right) / P^{0,z}}{\sum_{z=0}^{T} q_i^z}$$

"Weighted deflated prices": reference prices

- Need to solve (1) and (2) simultaneously; iterative algorithms typically used

Time Product Dummy method

- Country Product Dummy method in the spatial price comparison
- Product prices in month t follows a stochastic model:

$$\ln p_i^t = \alpha + \delta^t + \gamma_i + \varepsilon_i^t$$

γ_i:	Product fixed effects
δ^t:	Time fixed effects
α:	Intercept
ε_i^t:	Error terms, with a normal distribution
i:	an individual product (UPC/SKU)

- Estimation method:
  - Weighted least squares regression
  - Expenditure shares s_i^t as weights

- Let $v_i = \exp\left(\hat{\gamma}_i\right)$. It can be shown that for a set of products G^t,

$$P^t = \prod_{i \in G^t} \left(\frac{p_i^t}{v_i} \right)^{s_i^t}$$

→ Quality adjusted price

Time Product Dummy method

- Time Product Dummy index between 0 and *t*:

$$P^{0,t} = \frac{\bar{p}^t}{\bar{p}^0} = \frac{\prod_{i \in G^t} \left(\frac{p_i^t}{v_i} \right)^{s_i^t}}{\prod_{i \in G^0} \left(\frac{p_i^0}{v_i} \right)^{s_i^0}}$$

Ratio of quality adjusted prices

$$v_i = \prod_{z=0}^{T} \left(\frac{p_i^z}{P^{0,z}} \right)^{w_i^z}; \qquad w_i^z = \frac{s_i^z}{\sum_{k=0}^{T} s_i^k}$$

Quality adjustment factors

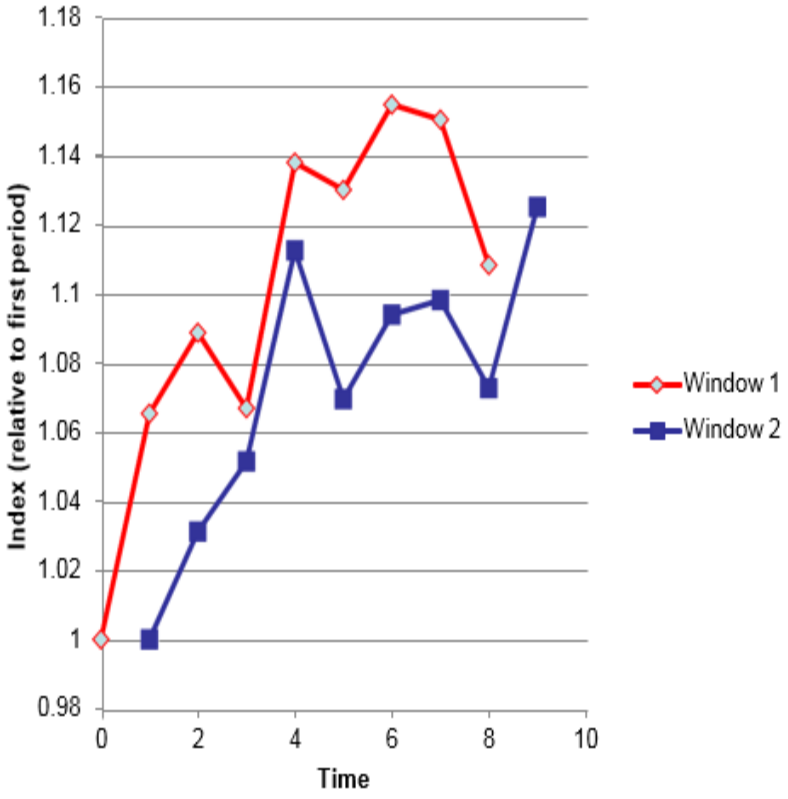
- Close similarities with GK method
- Indexes can be calculated using the regression framework or an iterative algorithm as for GK

Length of index estimation window

- Estimation windows shorter than a year:
  - Problematic with seasonal products
- Estimation windows larger than a year:
  - Differences with respect to 13-month window estimation are generally small for published classes level
  - Bilateral indexes between all pairs of months of the window are used:
    - A very large window may lead to a loss of characteristicity
    - The estimated price change does not actually pertains only to the two periods under comparison
- A 13-month window is typically used
  - ABS chose a window of 5 quarters for their quarterly CPI

Extension methods

- Why index series extension?
- Index estimation based on a fixed window [0, T]
- Data from new period T+1 can alter comparisons between earlier periods
- CPI is non revised
- How do we form a multilateral “window” incorporating the current period?
- How do we splice the results onto previous index levels?



Extension methods

Three period TPD

Fixed Effect Estimates	
🍐	0.00
🍌	-0.68
🍎	-0.30
A	0.00
B	0.30
C	0.46

$$I_{TPD}^{A,B} = \frac{\exp(\delta^B)}{\exp(\delta^A)} = 1.35$$

Four period TPD

Fixed Effect Estimates	
🍐	0.00
🍌	-0.61
🍎	-0.37
A	0.00
B	0.37
C	0.50
D	0.62

$$I_{TPD}^{A,B} = \frac{\exp(\delta^B)}{\exp(\delta^A)} = 1.45$$

Extension methods

- Rolling or expanding window approaches

Rolling window							
time	0	1	2	…	t	t+1	t+2
	|	-	-	-	|		
		|	-	-	-	|	
			|	-	-	-	|

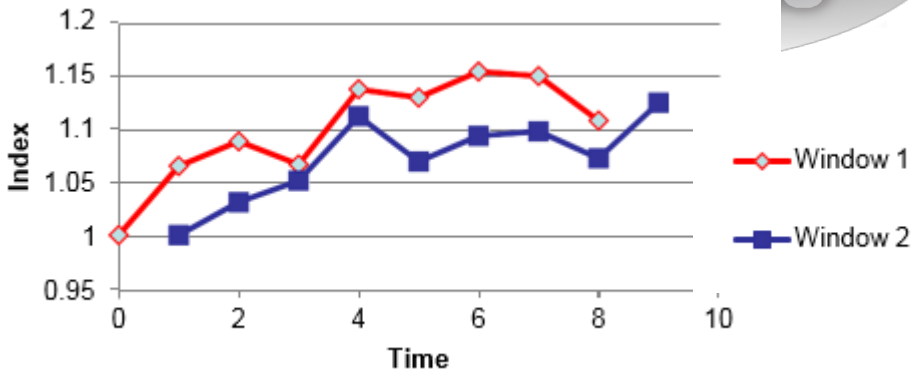
- Fixed length
- Variable start point

Expanding window								
time	0	1	2	…	t-1	t	t+1	t+2
	|	|						
	|	-	|					
	|	-	-	-	|			
	|	-	-	-	-	|		
						|	|	
						|	-	|

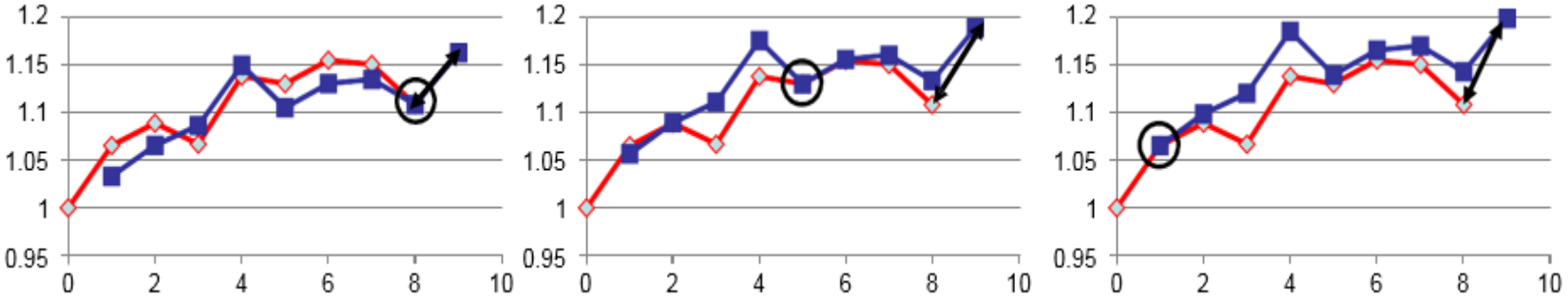
- Variable length
- Fixed start point (can be updated from time to time)

Extension methods

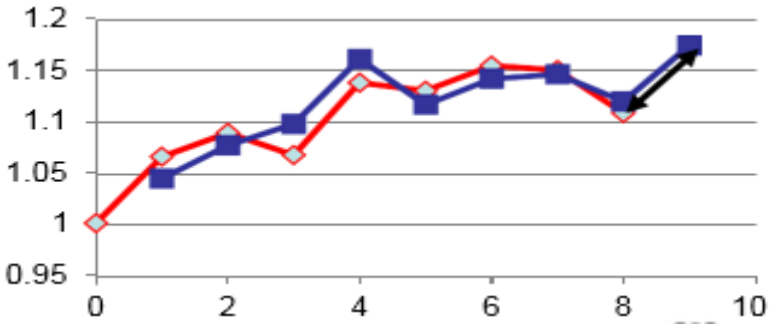
- How could we link together indexes from successive windows?



- Link in one period (which one?)



- Take the geomean over all links



Monitoring and quality control

- Important to have clearly defined checks and analyses on the data:
  - So large that any manual verification will not work

- Quality control before index calculation:

  - Has each new file been read correctly?
  - Plot time series of sample sizes
  - Plot time series of the number of unique products classified to each CPI lowest level class
  - Plot time series of the total sales of all products classified to each CPI lowest level class

Monitoring and quality control

- Quality control after index calculation
  - Decide on which elementary aggregates/published classes need to be reviewed after index calculation
  - Develop tools to identify CPI aggregates with unusual month over month price changes or unusual twelve-month price changes
    - Investigate on the main drivers of the identified ‘outliers’ and decide on their treatment
  - Develop decomposition tools that help with explaining price movements

Conclusion

- Multilateral index methods:
  - use sales and quantity data
  - give transitive index formula
  - are free of chain drift

- Product definition should be determined before using a multilateral index method

- All three method classes generally give similar price index results, but not exactly the same index values!

Conclusion

- Development of multilateral index methods has benefited from the availability of big and rich scanner data

- Do participants countries' statistical agencies already have access to retail scanner data?

  - How important are the consumer purchases made from retailers equipped with scanner registers in the different countries?

  - Are retailers not willing to cooperate in sharing their scanner data?

  - Any other issues?

Questions?

Thank you!