

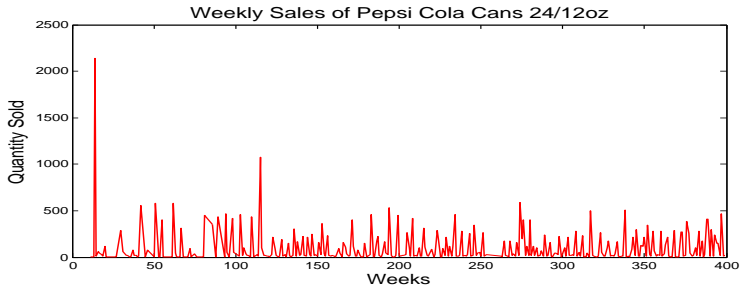
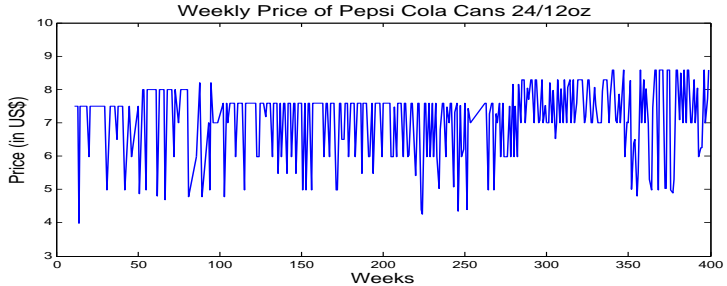
# Price Discounts and the Measurement of Inflation

Kevin J. Fox and Iqbal A. Syed

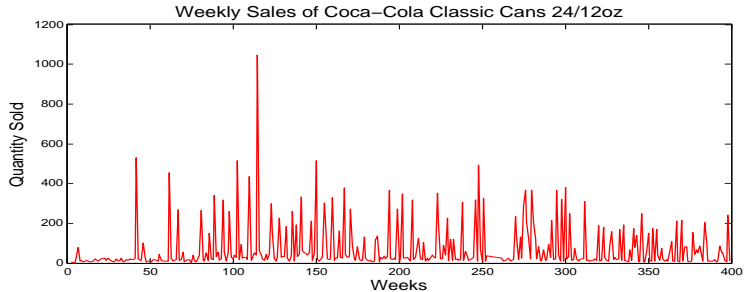
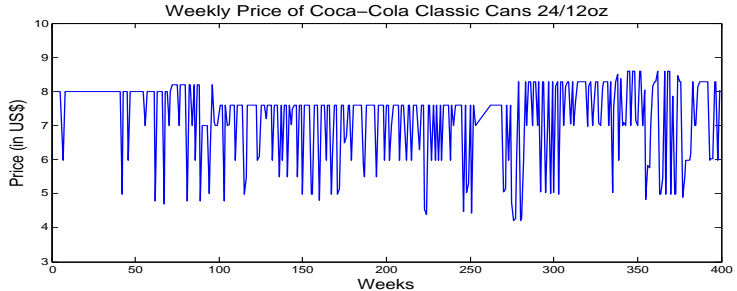
UNSW Australia

Ottawa Group Meeting, Japan  
20–22 May 2014

# Volatility in Prices and Volumes Sold



# Volatility in Prices and Volumes Sold



Regarding a brand of detergent in The Netherlands:

*“The quantity shifts associated with sales are dramatic. Consumers react instantaneously to discounts and purchase large quantities of the good—as a matter of fact, they hardly buy the good when it is not on sale. In this respect it is inappropriate to speak of a regular price during non-sale weeks.”*

de Haan and van der Grient, *Journal of Econometrics*, 2011.

## Overview

- ▶ Consumers are responsive to sales, yet statistical agency practice tends to under-weight sale prices in the CPI.
- ▶ Impact on representativeness of prices in the CPI and on estimates of inflation?
- ▶ Use scanner data from US supermarkets, 2001-2011 (IRI Academic Data), for six major cities.
- ▶ Exclusion of sales prices introduces a systematic upward bias.
- ▶ If sales are included but under-weighted, then inflation is not significantly impacted if the under-weighting remains fairly stable.
- ▶ Using only data from different weeks, we have found that a Rolling Year GEKS-type index can correct for directional bias.

# Background

- ▶ With scanner data sets, significant attention to price dynamics in recent years.
- ▶ Focus mainly on whether temporary price changes should be included in “sticky price” models in macroeconomics.
  - ▶ e.g. *Bils and Klenow 2004; Kehoe and Midrigan 2008; Klenow and Kryvtsov 2008; Nakamura and Steinsson 2008, 2013; Eichenbaum, Jaimovich and Rebelo 2011; Bils, Klenow and Malin 2012; Dhyne et al. 2006*
- ▶ Impact of treatment of sales on inflation has been relatively overlooked.

# Background

- ▶ With scanner data sets, significant attention to price dynamics in recent years.
- ▶ Focus mainly on whether temporary price changes should be included in “sticky price” models in macroeconomics.
  - ▶ e.g. *Bils and Klenow 2004; Kehoe and Midrigan 2008; Klenow and Kryvtsov 2008; Nakamura and Steinsson 2008, 2013; Eichenbaum, Jaimovich and Rebelo 2011; Bils, Klenow and Malin 2012; Dhyne et al. 2006*
- ▶ Impact of treatment of sales on inflation has been relatively overlooked.

# Background

- ▶ Sales are discounts on regular prices  $\Rightarrow$  expected that over the long run the movement of sale and regular prices would be similar.
- ▶ But can be changes in relationship. For example:
  - ▶ The average price dips and the spread around the average price dips could change over time.
  - ▶ There could be a systematic movement away from purchasing at regular prices to sale prices, perhaps due to macroeconomic conditions.



# Background

- ▶ Sales are discounts on regular prices  $\Rightarrow$  expected that over the long run the movement of sale and regular prices would be similar.
- ▶ But can be changes in relationship. **For example:**
  - ▶ The average price dips and the spread around the average price dips could change over time.
  - ▶ There could be a systematic movement away from purchasing at regular prices to sale prices, perhaps due to macroeconomic conditions.

## Background

If sale prices are in general under-sampled, there will be a tendency for over-estimating the cost of living.

*“The average of weekly and monthly prices, unweighted by quantities, will overstate the cost of buying a good, especially for those consumers who “stock up” during sales. This in turn implies that if the frequency of sales differs over time and between locations, the true costs to the consumer can differ dramatically, even if the unweighted average price is the same. Hence, inflation measures based on unweighted averages can over- or understate the actual change in prices.”*

Hosken and Reiffen (2004; p. 143)

# Background

Also:

- ▶ Because regular prices are more prevalent, there is a tendency in the statistical agency procedures to select regular prices.
- ▶ Even if the item-store is properly chosen according to expenditure shares, the selected price prevailing at the time of price collector's visit to the store, which is either a sale or a regular price, may not be representative of the corresponding expenditure share.
- ▶ Difficult to rectify through weighting of price relatives, even if the weights correspond to expenditure shares.

# Background

Also:

- ▶ Because regular prices are more prevalent, there is a tendency in the statistical agency procedures to select regular prices.
- ▶ Even if the item-store is properly chosen according to expenditure shares, the selected price prevailing at the time of price collector's visit to the store, which is either a sale or a regular price, may not be representative of the corresponding expenditure share.
- ▶ Difficult to rectify through weighting of price relatives, even if the weights correspond to expenditure shares.

# Background

Also:

- ▶ Because regular prices are more prevalent, there is a tendency in the statistical agency procedures to select regular prices.
- ▶ Even if the item-store is properly chosen according to expenditure shares, the selected price prevailing at the time of price collector's visit to the store, which is either a sale or a regular price, may not be representative of the corresponding expenditure share.
- ▶ Difficult to rectify through weighting of price relatives, even if the weights correspond to expenditure shares.

## Unit Values and Price Relatives

Monthly unit values,  $p_i^t$ , for each item  $i = 1, \dots, N$  aggregated over sale and regular prices for each period  $t = 1, \dots, T$ . The price relative of item  $i$ :

$$\frac{p_i^1}{p_i^0} = \frac{p_{r,i}^1 w_{r,i}^1 + p_{s,i}^1 w_{s,i}^1}{p_{r,i}^0 w_{r,i}^0 + p_{s,i}^0 w_{s,i}^0}$$

$w_{r,i}^t$  and  $w_{s,i}^t$  are the share of item  $i$ 's quantity sold at regular ( $p_{r,i}^t$ ) and sale ( $p_{s,i}^t$ ) prices to the total quantity sold, respectively.

## Unit Values and Price Relatives

Monthly unit values,  $p_i^t$ , for each item  $i = 1, \dots, N$  aggregated over sale and regular prices for each period  $t = 1, \dots, T$ . The price relative of item  $i$ :

$$\frac{p_i^1}{p_i^0} = \frac{p_{r,i}^1 w_{r,i}^1 + p_{s,i}^1 w_{s,i}^1}{p_{r,i}^0 w_{r,i}^0 + p_{s,i}^0 w_{s,i}^0}$$

$w_{r,i}^t$  and  $w_{s,i}^t$  are the share of item  $i$ 's quantity sold at regular ( $p_{r,i}^t$ ) and sale ( $p_{s,i}^t$ ) prices to the total quantity sold, respectively.

## Unit Values and Price Relatives

Monthly unit values,  $p_i^t$ , for each item  $i = 1, \dots, N$  aggregated over sale and regular prices for each period  $t = 1, \dots, T$ . The price relative of item  $i$ :

$$\frac{p_i^1}{p_i^0} = \frac{p_{r,i}^1 w_{r,i}^1 + p_{s,i}^1 w_{s,i}^1}{p_{r,i}^0 w_{r,i}^0 + p_{s,i}^0 w_{s,i}^0}$$

$w_{r,i}^t$  and  $w_{s,i}^t$  are the share of item  $i$ 's quantity sold at regular ( $p_{r,i}^t$ ) and sale ( $p_{s,i}^t$ ) prices to the total quantity sold, respectively.



# Unit Values and Price Relatives

- ▶ The inclusion of sale prices in the calculation of unit values will clearly lower the unit values in each period.
- ▶ But the important question is whether the inclusion of sale prices systematically affects the price relatives,  $p_i^1/p_i^0$ , the average price change for item  $i = 1, \dots, N$ .
- ▶ Sale prices will affect the price relatives if
  1. the sale price movements differ from the regular price movements, and
  2. the quantity share during sales changes between periods.

## Unit Values and Price Relatives

- ▶ The inclusion of sale prices in the calculation of unit values will clearly lower the unit values in each period.
- ▶ But the important question is whether the inclusion of sale prices systematically affects the price relatives,  $p_i^1/p_i^0$ , the average price change for item  $i = 1, \dots, N$ .
- ▶ Sale prices will affect the price relatives if
  1. the sale price movements differ from the regular price movements, and
  2. the quantity share during sales changes between periods.

## Unit Values and Price Relatives

- ▶ The inclusion of sale prices in the calculation of unit values will clearly lower the unit values in each period.
- ▶ But the important question is whether the inclusion of sale prices systematically affects the price relatives,  $p_i^1/p_i^0$ , the average price change for item  $i = 1, \dots, N$ .
- ▶ Sale prices will affect the price relatives if
  1. the sale price movements differ from the regular price movements, and
  2. the quantity share during sales changes between periods.

# Unit Values and Price Relatives

We construct three different sets of price relatives:

1. unit values are calculated using the share of quantity sold at each price (the preferred approach);
2. only regular prices are used; and
3. the percentage of sample periods a price prevailed in the market is used as the weight for the price in the construction of the unit value  $\Rightarrow$  “frequency” weighting. Closest to standard statistical agency practice.

# Unit Values and Price Relatives

We construct three different sets of price relatives:

1. unit values are calculated using the share of quantity sold at each price (the preferred approach);
2. only regular prices are used; and
3. the percentage of sample periods a price prevailed in the market is used as the weight for the price in the construction of the unit value  $\Rightarrow$  “frequency” weighting. Closest to standard statistical agency practice.

# Unit Values and Price Relatives

We construct three different sets of price relatives:

1. unit values are calculated using the share of quantity sold at each price (the preferred approach);
2. only regular prices are used; and
3. the percentage of sample periods a price prevailed in the market is used as the weight for the price in the construction of the unit value  $\Rightarrow$  “frequency” weighting. Closest to standard statistical agency practice.

# Unit Values and Price Relatives

We construct three different sets of price relatives:

1. unit values are calculated using the share of quantity sold at each price (the preferred approach);
2. only regular prices are used; and
3. the percentage of sample periods a price prevailed in the market is used as the weight for the price in the construction of the unit value  $\Rightarrow$  “frequency” weighting. **Closest to standard statistical agency practice.**

## Three Stages of Aggregation

- ▶ *First Stage:* Construct chained Jevons, Törnqvist and RYCCD indexes at the elementary level, for each of the three unit values  $\Rightarrow$  nine elementary indexes for each product-city pair.
- ▶ *Second Stage:* Aggregate the elementary indexes across cities using expenditure share weights to obtain chained indexes for each product category.
- ▶ *Third Stage:* Aggregate product category indexes to obtain overall chained indexes for all our products and categories.



## Three Stages of Aggregation

- ▶ *First Stage*: Construct chained Jevons, Törnqvist and RYCCD indexes at the elementary level, for each of the three unit values  $\Rightarrow$  nine elementary indexes for each product-city pair.
- ▶ *Second Stage*: Aggregate the elementary indexes across cities using expenditure share weights to obtain chained indexes for each product category.
- ▶ *Third Stage*: Aggregate product category indexes to obtain overall chained indexes for all our products and categories.

## Three Stages of Aggregation

- ▶ *First Stage*: Construct chained Jevons, Törnqvist and RYCCD indexes at the elementary level, for each of the three unit values  $\Rightarrow$  nine elementary indexes for each product-city pair.
- ▶ *Second Stage*: Aggregate the elementary indexes across cities using expenditure share weights to obtain chained indexes for each product category.
- ▶ *Third Stage*: Aggregate product category indexes to obtain overall chained indexes for all our products and categories.

## Aggregation of Price Relatives: Index Formulae

$$\text{Jevons: } P_J^{0,1} = \prod_{i=1}^N \left( \frac{p_i^1}{p_i^0} \right)^{1/N},$$

$$\text{Törnqvist: } P_T^{0,1} = \prod_{i=1}^N \left( \frac{p_i^1}{p_i^0} \right)^{0.5(S_i^0 + S_i^1)},$$

where  $S_i^t$  is the expenditure share of item  $i$  in period  $t = 0, 1$ .

$$\text{RYCCD: } P_{RYCCD}^{0,T} \equiv \prod_{t=0}^{12} \left[ P_T^{0,t} \times P_T^{t,12} \right]^{1/13} \prod_{t=13}^T \prod_{T-12}^T \left[ P_T^{T-1,t} \times P_T^{t,T} \right]^{1/13}$$

# Data

- ▶ IRI Academic Data Set for the period 2001-2011.
- ▶ Weekly prices and quantities for each item sold separately in each store (Bronnenberg, Kruger and Mela, 2008).
- ▶ Use data for six large U.S. cities: Chicago, Houston, Los Angeles, New York, Philadelphia and Washington D.C.
- ▶ Ten products selected. Many of these products match closely with the item definition used by BLS price collectors at stores during sample collection for the CPI (BLS, 2007).

# Data

- ▶ IRI Academic Data Set for the period 2001-2011.
- ▶ Weekly prices and quantities for each item sold separately in each store (Bronnenberg, Kruger and Mela, 2008).
- ▶ Use data for six large U.S. cities: Chicago, Houston, Los Angeles, New York, Philadelphia and Washington D.C.
- ▶ Ten products selected. Many of these products match closely with the item definition used by BLS price collectors at stores during sample collection for the CPI (BLS, 2007).

# Data

- ▶ IRI Academic Data Set for the period 2001-2011.
- ▶ Weekly prices and quantities for each item sold separately in each store (Bronnenberg, Kruger and Mela, 2008).
- ▶ Use data for six large U.S. cities: Chicago, Houston, Los Angeles, New York, Philadelphia and Washington D.C.
- ▶ Ten products selected. Many of these products match closely with the item definition used by BLS price collectors at stores during sample collection for the CPI (BLS, 2007).

# Identifying Sales

Sales not flagged in the data set.

- ▶ Use new “sales spotter” algorithm (Syed 2015), calibrated against Dominick’s Finer Foods dataset (Kilts Center for Marketing, U. of Chicago Booth School of Business).
- ▶ Whether the spotter attributes the price change to sale price depends on whether the price change adheres to certain rules reflecting the basic features of sale prices.

# Identifying Sales

Sales not flagged in the data set.

- ▶ Use new “sales spotter” algorithm (Syed 2015), calibrated against Dominick’s Finer Foods dataset (Kilts Center for Marketing, U. of Chicago Booth School of Business).
- ▶ Whether the spotter attributes the price change to sale price depends on whether the price change adheres to certain rules reflecting the basic features of sale prices.



**Table:** Data description and some facts on Sales

Products <sup>†</sup>	No. of Obser. <sup>‡</sup> (ml.)	Exp. Share by Prods (%)	Exp. Share at Sales (%)	Average Sales Price Dip* (%)	Average Sales Duration (weeks)
Beer & Ale	17.77	16.07	32.99	12.40	2.92
Carb. Bever.	42.96	26.81	46.38	21.60	2.29
Coffee	16.71	6.23	33.10	21.66	2.78
Cold Cereal	30.78	15.82	33.57	28.38	2.43
FZ Din. & Ent.	40.41	12.30	40.71	27.42	2.54
House. Clean.	10.33	2.24	23.09	21.04	2.52
Laundry Deter.	13.54	8.17	38.52	25.79	2.52
Marg. & Butter	7.36	2.76	24.62	21.92	2.35
Peanut Butter	5.48	1.94	25.34	19.47	2.68
Soup	34.46	7.67	28.47	28.05	2.60
All Items**	219.79	100.00	37.13	22.71	2.53

**Table:** Frequency and size of Sales, volume sold during Sales and their changes during 2001–2011

Products <sup>†</sup>	Sale Weeks and Volume Sold		Changes in the Magnit. of Sales		Ratio of Sale Freq. to Quant. Share	
	Sale	Quant.	Growth	Std.	Growth	Std.
	Freq. <sup>‡</sup> (%)	Share <sup>‡</sup> (%)	Rate* (%/yr)	Error	Rate* (%/yr)	Error
Beer & Ale	15.36	23.07	-1.80**	0.92	3.50**	1.20
Carb. Bever.	26.79	45.53	-0.21	1.32	1.69	1.28
Coffee	20.73	37.17	-0.70	1.13	2.81	1.93
Cold Cereal	19.42	43.20	0.05	1.10	1.77	1.35
FZ Din. & Ent.	30.10	48.22	-2.32**	1.02	1.29	1.40
House. Clean.	17.29	28.07	2.12	1.72	-0.30	1.79
Laundry Deter.	21.95	44.90	0.12	0.99	2.28	1.39
Marg. & Butter	18.83	30.57	2.21	1.75	3.44**	1.52
Peanut Butter	16.99	33.07	0.04	2.09	1.85	1.72
Soup	17.47	32.70	0.08	1.56	3.49**	1.47
All Items <sup>§</sup>	22.08	39.32	-0.54	1.20	2.21	1.39

**Table:** Average annual deviation of the regular price index and sale frequency weighted index from the quantity share weighted index for 2001–2011 (in percentage points)

Products <sup>†</sup>	Jevons Index		Törnqvist Index		RYCCD Index	
	Regular Price Deviation*	Frequency Weight Deviation**	Regular Price Deviation	Frequency Weight Deviation	Regular Price Deviation	Frequency Weight Deviation
Beer & Ale	1.78	0.01	-0.24	-0.04	0.23	-0.04
Carb. Bever.	4.46	-0.13	-1.14	0.09	0.71	0.25
Coffee	6.19	0.08	2.28	0.12	1.08	0.36
Cold Cereal	5.67	-0.21	1.55	-0.31	0.66	0.08
FZ Din. & Ent.	6.43	-0.14	1.13	-0.28	0.25	-0.27
House. Clean.	5.00	0.07	2.64	0.29	0.89	0.17
Laundry Deter.	7.64	-0.11	2.55	-0.18	1.00	0.06
Marg. & Butter	3.29	-0.09	1.13	-0.05	0.40	0.01
Peanut Butter	3.22	-0.06	0.85	-0.02	0.09	-0.12
Soup	5.22	0.07	0.80	-0.29	0.86	-0.01
All Items <sup>‡</sup>	4.84	-0.08	0.56	-0.09	0.61	0.07

## Summary of Results So Far

1. There is a systematic under-weighting of sale prices through the use of sale frequencies rather than quantities shares. The unit values in each period are therefore overestimated.
2. The extent to which they are biased remains approximately the same between the comparison periods.
3. Regular and sale prices move at different rates (though not in any particular direction)  $\Rightarrow$  if sale prices are excluded from price indexes, the measurement of inflation will be biased.
4. However, if the sale prices are included even though they are under-weighted, as long as the degree by which this under-weighting takes place remains the same, the measured inflation will be close to the true price change.

## Summary of Results So Far

1. There is a systematic under-weighting of sale prices through the use of sale frequencies rather than quantities shares. The unit values in each period are therefore overestimated.
2. The extent to which they are biased remains approximately the same between the comparison periods.
3. Regular and sale prices move at different rates (though not in any particular direction)  $\Rightarrow$  if sale prices are excluded from price indexes, the measurement of inflation will be biased.
4. However, if the sale prices are included even though they are under-weighted, as long as the degree by which this under-weighting takes place remains the same, the measured inflation will be close to the true price change.

## Summary of Results So Far

1. There is a systematic under-weighting of sale prices through the use of sale frequencies rather than quantities shares. The unit values in each period are therefore overestimated.
2. The extent to which they are biased remains approximately the same between the comparison periods.
3. Regular and sale prices move at different rates (though not in any particular direction)  $\Rightarrow$  if sale prices are excluded from price indexes, the measurement of inflation will be biased.
4. However, if the sale prices are included even though they are under-weighted, as long as the degree by which this under-weighting takes place remains the same, the measured inflation will be close to the true price change.

## Summary of Results So Far

1. There is a systematic under-weighting of sale prices through the use of sale frequencies rather than quantities shares. The unit values in each period are therefore overestimated.
2. The extent to which they are biased remains approximately the same between the comparison periods.
3. Regular and sale prices move at different rates (though not in any particular direction)  $\Rightarrow$  if sale prices are excluded from price indexes, the measurement of inflation will be biased.
4. However, if the sale prices are included even though they are under-weighted, as long as the degree by which this under-weighting takes place remains the same, the measured inflation will be close to the true price change.

**Table:** Average annual deviation between Jevons index, and Törnqvist and RYCCD indexes for 2001–2011 (in percentage points)

Products	Jevons vs. Törnqvist Index <sup>†</sup>			Jevons vs. RYCCD Index		
	Reg. Prices: Freq. Share Weights	All Prices: Freq. Share Weights	All Prices: Quant. Share Weights	Reg. Prices: Freq. Share Weights	All Prices: Freq. Share Weights	All Prices: Quant. Share Weights
Beer & Ale	0.74	-1.23	-1.28	0.89	-0.61	-0.66
Carb. Bever.	5.71	-0.10	0.12	4.13	0.02	0.39
Coffee	2.16	-1.79	-1.74	1.79	-3.61	-3.32
Cold Cereal	2.47	-1.55	-1.65	3.60	-1.70	-1.41
FZ Din. & Ent.	3.31	-1.86	-2.00	3.74	-2.31	-2.44
House. Clean.	1.06	-1.53	-1.31	1.29	-2.92	-2.82
Laundry Deter.	4.19	-0.84	-0.91	4.30	-2.50	-2.34
Marg. & Butter	1.16	-1.05	-1.00	0.89	-2.10	-2.01
Peanut Butter	1.49	-0.92	-0.88	1.10	-1.97	-2.03
Soup	2.51	-1.55	-1.91	1.81	-2.47	-2.55
All Items <sup>‡</sup>	3.20	-1.08	-1.09	2.96	-1.43	-1.27



Figure 1: Tornqvist indexes constructed from different unit values, 2001–2011

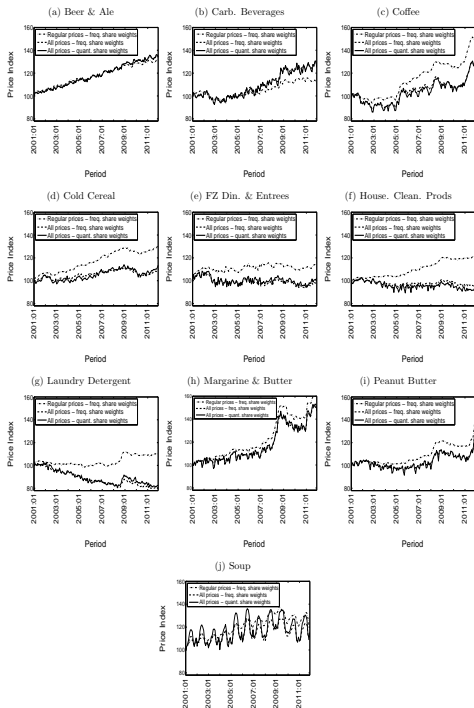


Figure 2: Aggregate indexes across all 6 cities and 10 products, 2001-2011

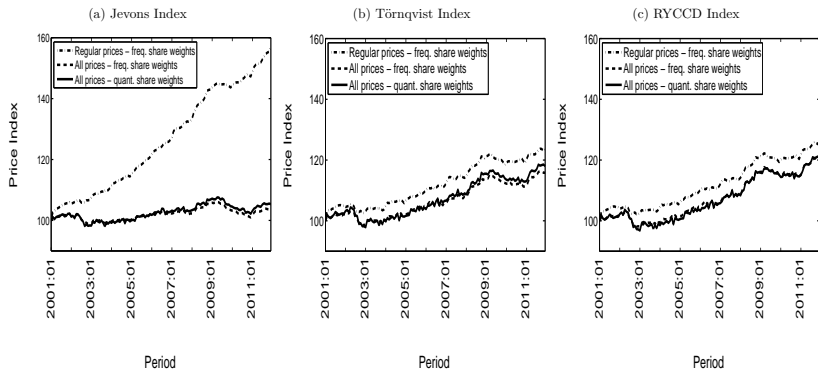
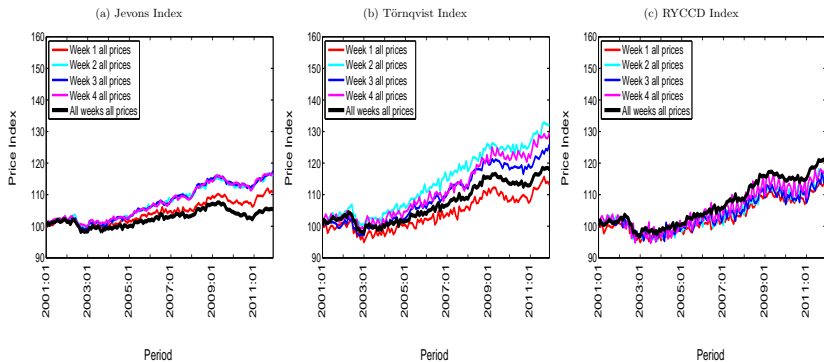


Figure 3: Aggregate monthly indexes constructed using different and all weeks of data across all 6 cities and 10 products, 2001-2011



# Conclusions

- ▶ We found little systematic difference between the use of frequency weights and the preferred quantity share weights.
- ▶ This is a perhaps somewhat surprising, yet reassuring result for the accuracy of inflation measures.
- ▶ Effectively, we have found that if the sale prices are included even though they are under-weighted, as long as the degree by which this under-weighting takes place remains the same, the measured inflation will be close to the true price change.
- ▶ Using data from different weeks, we have found that the RYCCD index can correct for directional bias that's found in Jevons or Törnqvist indexes.
  - ▶ Of relevance if data from a particular week is (mostly) used.
  - ▶ Implications for constructing real time indexes using incomplete data.

# Conclusions

- ▶ We found little systematic difference between the use of frequency weights and the preferred quantity share weights.
- ▶ This is a perhaps somewhat surprising, yet reassuring result for the accuracy of inflation measures.
- ▶ Effectively, we have found that if the sale prices are included even though they are under-weighted, as long as the degree by which this under-weighting takes place remains the same, the measured inflation will be close to the true price change.
- ▶ Using data from different weeks, we have found that the RYCCD index can correct for directional bias that's found in Jevons or Törnqvist indexes.
  - ▶ Of relevance if data from a particular week is (mostly) used.
  - ▶ Implications for constructing real time indexes using incomplete data.

# Conclusions

- ▶ We found little systematic difference between the use of frequency weights and the preferred quantity share weights.
- ▶ This is a perhaps somewhat surprising, yet reassuring result for the accuracy of inflation measures.
- ▶ Effectively, we have found that if the sale prices are included even though they are under-weighted, as long as the degree by which this under-weighting takes place remains the same, the measured inflation will be close to the true price change.
- ▶ Using data from different weeks, we have found that the RYCCD index can correct for directional bias that's found in Jevons or Törnqvist indexes.
  - ▶ Of relevance if data from a particular week is (mostly) used.
  - ▶ Implications for constructing real time indexes using incomplete data.

# Conclusions

- ▶ We found little systematic difference between the use of frequency weights and the preferred quantity share weights.
- ▶ This is a perhaps somewhat surprising, yet reassuring result for the accuracy of inflation measures.
- ▶ Effectively, we have found that if the sale prices are included even though they are under-weighted, as long as the degree by which this under-weighting takes place remains the same, the measured inflation will be close to the true price change.
- ▶ Using data from different weeks, we have found that the RYCCD index can correct for directional bias that's found in Jevons or Törnqvist indexes.
  - ▶ Of relevance if data from a particular week is (mostly) used.
  - ▶ Implications for constructing real time indexes using incomplete data.

# Conclusions

- ▶ We found little systematic difference between the use of frequency weights and the preferred quantity share weights.
- ▶ This is a perhaps somewhat surprising, yet reassuring result for the accuracy of inflation measures.
- ▶ Effectively, we have found that if the sale prices are included even though they are under-weighted, as long as the degree by which this under-weighting takes place remains the same, the measured inflation will be close to the true price change.
- ▶ Using data from different weeks, we have found that the RYCCD index can correct for directional bias that's found in Jevons or Törnqvist indexes.
  - ▶ Of relevance if data from a particular week is (mostly) used.
  - ▶ Implications for constructing real time indexes using incomplete data.