

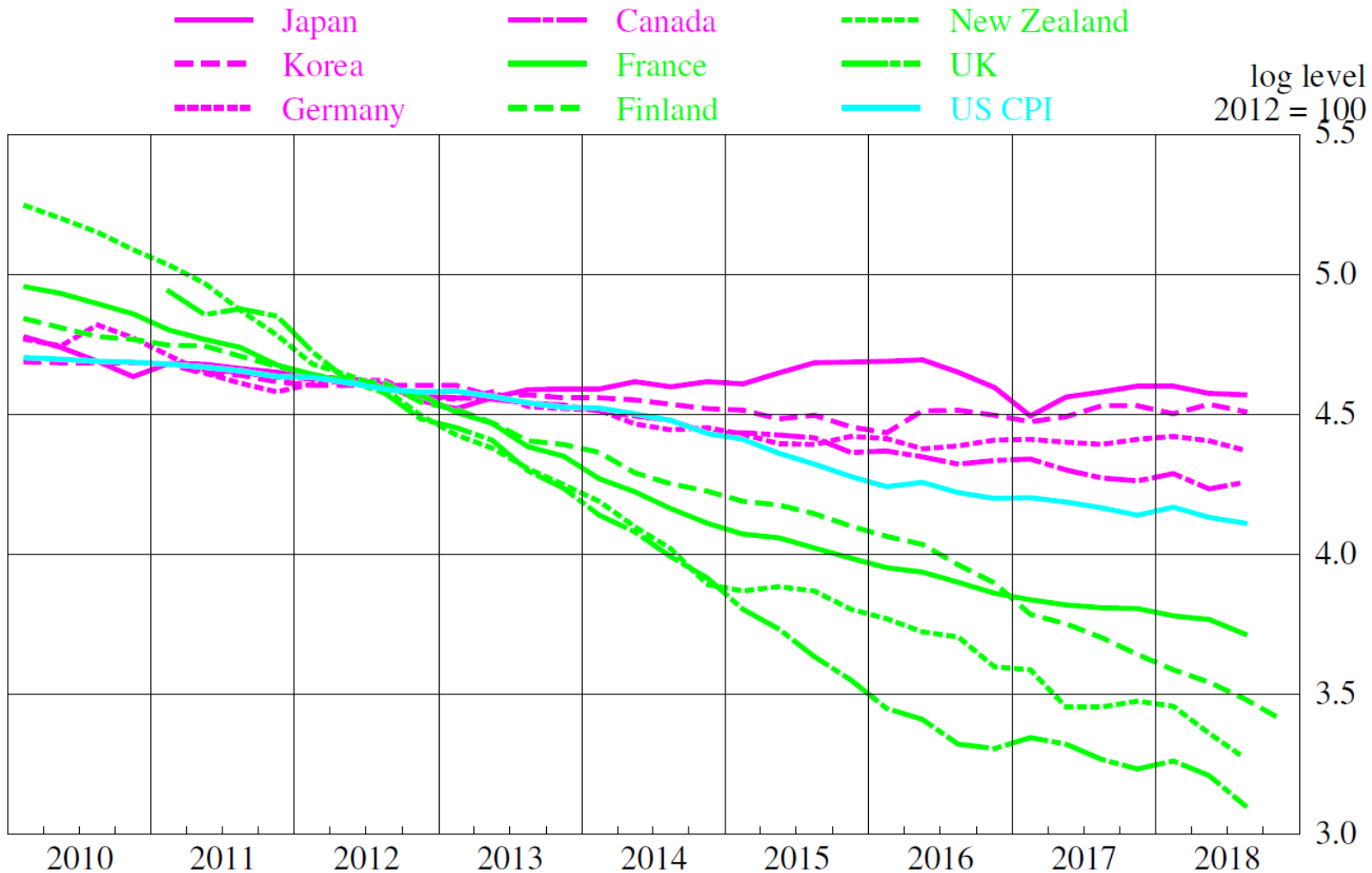
New Price Indexes for Smartphones

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Prepared for 2019 ESCoE Conference on Economic Measurement, based on “Getting Smart about Phones,” NBER working paper 25645.

The views in this work are not necessarily those of the Federal Reserve or other organizations with which the authors are affiliated.

'Cell Phone' CPIs, Various Countries



Note: the scope of some NSI indexes shown is broader than cell phones.

Cell phone price indexes differ wildly...

Today's goal: A Quality-Adjusted CPI for Cell Phones

1. Data source
2. Matched-model indexes
3. Matched-model or hedonic?
4. Hedonic Approach
5. Results
6. Conclusions

Work in the underlying paper also covers how phones are counted in the U.S. national accounts, a topic left for another day...

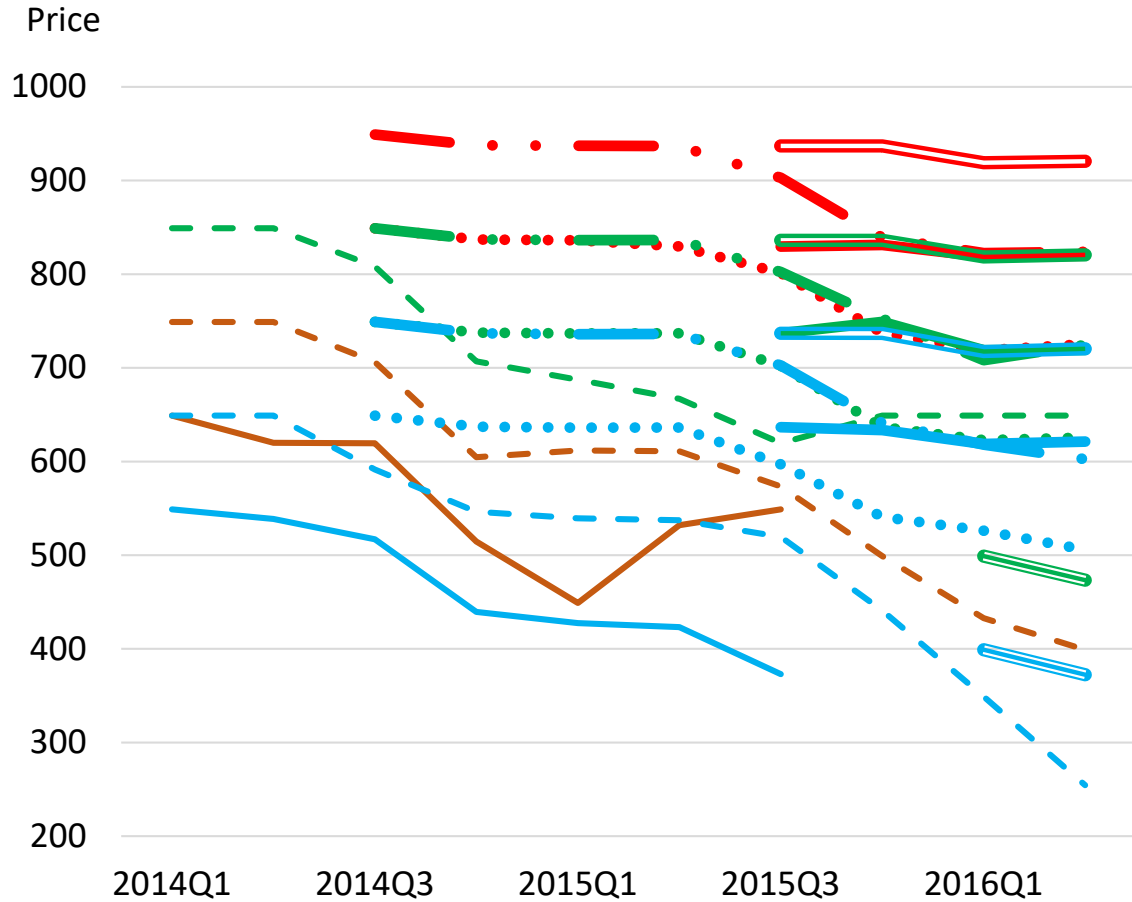
Data Source

- *Worldwide Quarterly Mobile Phone Tracker*, International Data Corporation.
- U.S. Quarterly prices and unit retail sales for 2010-2017.
- Data for exhaustive list of 1,294 smartphones.
- Detailed technical characteristics by model.
- Price: average selling price *with no contract**
 - Excludes: point-of-sale taxes
 - Includes: freight, insurance, shipping, tariffs.
 - Not list price (e.g. Apple)
- Model definition:
 - IDC “model”, e.g. iPhone 4s
 - Storage, e.g. 8 GB
 - Generation, e.g. 3G
 - Operating system version, e.g. Android Jelly Bean 4.1

* Contract-free prices for all phones reported directly by telecom service providers.

Price and Quantity Data Illustration

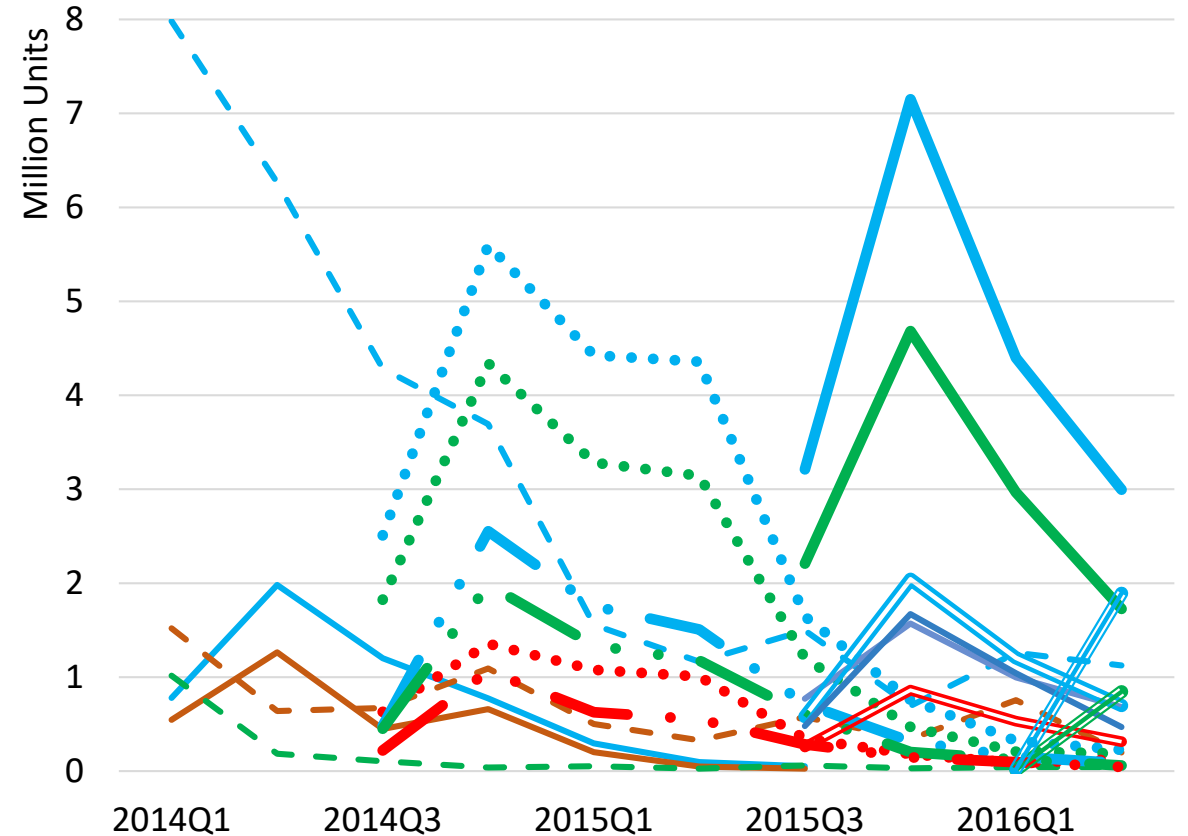
Model Prices, Manufacturer A



Source. International Data Corporation.

Notes. Line pattern indicates mobile phone generation. Line color indicates amount of storage.

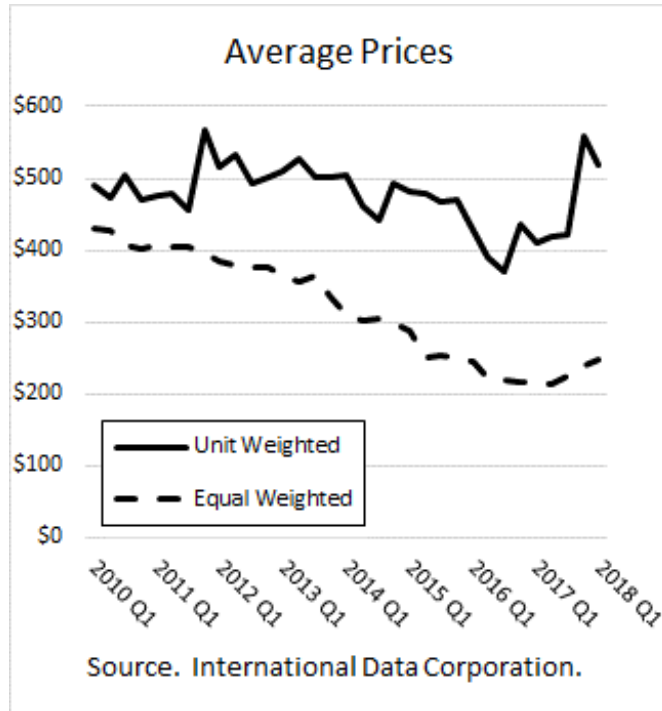
Model Units, Manufacturer A



Source. International Data Corporation.

Notes. Line pattern indicates mobile phone generation. Line color indicates amount of storage.

Matched-Model Indexes



- Average smartphone price moves roughly sideways
- But the individual prices fall

Matched-Model Index

$$\frac{I_t}{I_{t-1}} = \prod_{i \in \Omega_t} \left(\frac{p_t^i}{p_{t-1}^i} \right)^{w_t^i}$$

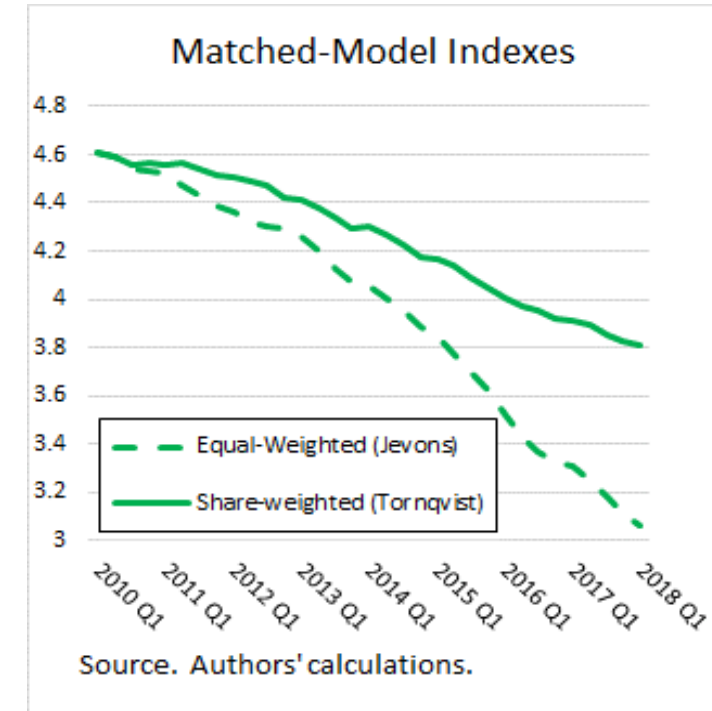
$$\Omega_t = \{i: \exists p_t^i\} \cap \{i: \exists p_{t-1}^i\}$$

Tornqvist Weights

$$w_t^i = \frac{1}{2} \left[\frac{p_t^i q_i^i}{\sum_{j \in \Omega_t} p_t^j q_t^j} + \frac{p_{t-1}^i q_i^i}{\sum_{j \in \Omega_{t-1}} p_{t-1}^j q_{t-1}^j} \right]$$

Jevons Weights

$$w_t^i = \frac{1}{n_t}$$



- Tornqvist index falls 10% per year on average.
- Weights matter a lot.

Matched-Model or Hedonic?

- Matched-model works well when:
 - Market is competitive.
 - “Model” quality is stable.
 - Data is high frequency OR
 - Weights on new models are very small when they appear
- Those conditions are not present
 - Apple, e.g., has market power.
 - Derived demand for features affects “quality”
 - Quarterly may be too infrequent.
 - Weights on entry can be big.

Hedonic Approach

- Hedonic function: attribute price variation to variation in product characteristics, X .
- Time dummies: coefficient on time dummy, D_t , provides (log of) the relative price for time t .
- Adjacent-period regressions allows characteristic effects to vary over time.
- Alternative hedonic approaches
 - Hybrid: Impute pre-entry and post-exit shadow prices with cross-sectional hedonic. Use observed prices, when present.
 - Full imputation: substitute $X_i\beta_t$ for $P_{i,t}$.
 - Explicit quality adjustment: apportion premium/discount for new products to quality and inflation using hedonic function.

Hedonic Function

$$\ln(P_{i,t}) = \alpha + \sum_k \beta_k X_{k,i,t} + \varepsilon_{i,t}$$

Adjacent-Period Time Dummy Approach

$$\ln(P_{i,2}) = \alpha_2 + \sum_k \beta_{k,2} X_{k,i} + \delta_2 D + \varepsilon_{i,2}$$

⋮

$$\ln(P_{i,T}) = \alpha_T + \sum_k \beta_{k,T} X_{k,i} + \delta_T D + \varepsilon_{i,T}$$

Index

$$\frac{I_t}{I_{t-1}} = \exp\{\delta_t\}$$

Hedonic Approach: Control Variables

- Manufacturer dummies
- Performance measures
 - Storage
 - Screen size
 - Camera resolution
 - Processor speed
- Operating system *version*
 - e.g. Android KitKat 4.4
- Generation: 2G/2.5G/3G
- Input method: touch/QWERTY
- Introduction period dummy
 - Early adopters may pay
 - More to be a hipster
 - Less, to offset burden of implicit beta testing
 - Some producers systematically introduce new models late in the quarter
 - Disequilibrium – law of one (constant quality) price not holding
 - Used in early hedonic studies

Results: Hedonic Coefficients

Control Variable	Ave. Coefficient	# Significant of 32 Regressions
Storage $\ln(GB)$	0.12	31
Screen $\ln(in^2)$	1.04	25
Camera $\ln(MPixels)$	0.36	31
Processor $\ln(MHz)$	1.00	23
Intro. Period	-0.06	19

All significant coefficients for storage, screen, camera, and processor are positive. 14 of 19 significant coefficients for the entry-quarter dummy are positive.

Dummy Group	# Regressions w/ Any Significant Dummy Coefficients	Ave. # of Significant Dummy Coefficients
Manufacturers (out of 43)	30	6.7
Operating System Versions (out of 58)	28	5.4

Adjusted R^2 average across quarterly regressions: 0.91.
Minimum R^2 among quarterly regressions: 0.85.

Observations average across quarterly regressions: 417.
Minimum observations among quarterly regressions: 145.

Significance measured at the 10 percent level.

Results: Alternative Cell Phone Price Indexes

Index Description	Ann. Ave. Rate of Change 2010 Q1 – 2018 Q1
Preferred hedonic <u>smartphone</u> index: Adjacent-quarter hedonic	-15.5
Alternative hedonic <u>smartphone</u> indexes: Time-invariant coefficients Manufacturer specific regressions	-19.6 -16.0
Tornqvist <u>smartphone</u> matched-model	-10.0
Tornqvist <u>feature phone</u> (not smart) matched model	-18.5
<u>All cell phone</u> index: Aggregate of smartphone hedonic and feature matched-model	-16.6
Byrne-Corrado (used price) <u>all cell phone</u> matched-model (Currently used in national accounts)	-22.1
U.S. BLS CPI for “telephone hardware, calculators, and other consumer information items” (<u>NOT just cell phones!</u>)	-6.7

Conclusions

- Constant-quality prices for cell phones have fallen rapidly since 2010.
- Results depend substantially on
 - Approach to weighting
 - Matched-model v. hedonic approach
 - Time-varying coefficients on control variables.
- Comparison to official U.S. CPI not possible with current product structure
- Implications for national accounts / PCE / GDP?
 - The new price index falls 6 ppt SLOWER than the one currently used
 - But this effect is largely offset by a reduction in imports