Using Online Prices for Measuring Real Consumption Across Countries

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International income comparisons such as the Penn World Tables (PWT) rely on data provided by the International Comparisons Program (ICP) at the World Bank, which collects prices from thousands of comparable goods and services all over the world to calculate purchasing power parities (PPPs). While ICP continually improves its methods, its reliance on traditional data collection through National Statistical Offices (NSOs) causes many problems, including the low frequency of data collection (every 6 years), long delays in publication (results for the 2011 round were published in 2014), issues affecting the comparability of products and methods across countries and time (see e.g. Deaton & Heston (2010), Inklaar and Rao (2017)), as well as the need to rely on the efforts of individual countries that can refuse to participate (e.g. Argentina for ICP 2011) or lack transparency regarding their data and methods (see Feenstra et al. (2013)).

The availability of new (big) data sources provides hope for improvements along several of these dimensions. In particular, we show that online prices can be used to construct quarterly PPPs published in real-time, with a closely-matched basket of goods and identical methodologies in a variety of developed and developing economies. At a more fundamental level, the ability to remotely collect online prices provides more control and transparency to the data and methodologies used to compute PPPs across countries.

Our data cover eleven countries in three major consumption categories, Food and Beverages, Fuel, and Electronics, from 2011 to 2017. In a validation exercise, we find that PPPs constructed with online prices are close to those reported by ICP in 2011. Next, we illustrate the potential of the new data to

provide real time estimates of real consumption across countries.

While promising, we also highlight many potential problems associated with the use of online prices for PPP calculations, including the missing variety problem, the lack of corresponding volumes and limited coverage of products and countries.

I. Data and Methodology

We use micro data available at the Billion Prices Project (BPP) at MIT, including daily web-scraped prices from 2010 to 2017 for all products sold by some of the largest multi-channel retailers in eleven countries: Argentina, Australia, Brazil, China, Canada, Netherlands, Germany, Japan, South Africa, the United Kingdom, and the United States.[1] These prices include taxes and exclude shipping costs.[2]

In constructing price comparisons across countries, one is confronted with the same problems that complicate CPI measurement, in particular the comparison of like-with-like. Product codes that are attached to the online goods cannot be used because they tend to be retailer or county-specific. Moreover, identical products are seldom available across countries, except for global branded products. The latter constitute a relatively minor share of expenditures. To ensure sufficient coverage (so-called "representativity") local goods have to be grouped before matching is feasible.

To construct PPPs, we therefore mimic the procedures as followed in ICP 2011, starting with the creation of our own list of "items" (narrowly-defined product categories) to which individual products will be matched.[3] Our item list consists of 267 narrow definitions that cover all subsectors of the UN's COICOP classification system for Food, Fuel and Electronics.[4] These items were chosen to strike a balance between comparability and representativeness. We have a mix of narrowly-defined global products (e.g. "Decaf Ground Illy Coffee") and broader item definitions for unbranded products or local brands (e.g. "Basmati Rice" or "Decaf Ground Coffee, all other brands"). Our item definitions

[1] The data were collected by PriceStats, a private company associated with the BPP, which also matched the products for 9 of the 11 countries in our sample. Alberto Cavallo is a co-founder of both the BPP and PriceStats..

[2] For countries where the sales tax is not included in prices shown to customers online, we add a standard sales or VAR tax to scraped prices as follows: US Food 0.952%, Electronics 5.08%. Japan Food and Electronics 5% before 3/2014 and 8% afterwards; Germany Food "7% and Electronics 19%; Canada Electronics, Chocolates and Sodas 12%. The Canadian average is computed from state-level rates bweighted by state population

[3] See World Bank (2014) for a description of ICP methodologies, and World Bank (2013) for an extensive motivation of why these methods are applied.

[4] See https://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=5. Our "Food and Beverages" sector corresponds to COICOP code 01, the "Fuel" sector is COICOP 07.2.2, and "Electronics" covers COICOP covdes 09.1.1 to 09.1.4.

tend to be more narrowly defined than those in ICP's 2011 list, particularly in electronics.[5]

The matching of individual products to each item definition is a complex process. The micro data contains detailed descriptions for millions of products. Searching this database, we find those products that best match the item descriptions in each country, and enter their package sizes so that we can calculate unit prices (e.g. price per gram).

A total of 99,028 individual products were matched, with a mean of 30 products per item in each country. Our coverage of expenditure improves considerably after 2012 because we concentrated our matching efforts in recent years, when the micro data becomes more abundant (see Appendix Figure 1).

Once the individual products are matched, we average all unit-price observations (across products and time) for each item, country, and quarter. This implicitly assigns more weight to those products that are available to consumers for a longer time. Average item prices are then aggregated to the level of a so-called "basic heading", such as 'Rice' or 'Coffee, Tea, and Cocoa'. Not all items within each basic heading are priced in every country, so we follow ICP and run a Country Product Dummy (CPD) regression for every quarter and basic heading. We then use the expenditure data from ICP 2011 to obtain country-level PPPs using a multilateral GEKS methodology.[6] To facilitate the comparison across countries and samples, we compute price level indices (PLIs), dividing the PPPs by the country's nominal exchange rate with the US dollar. PLIs are unit-free and reflect whether prices are higher (> 1) or lower (< 1) relative to the reference country.

II. Comparison to ICP

We compare our PLIs with those of ICP for 2011, the last year for which there is ICP data.

In principle, there are many reasons to expect differences. First, our prices are collected online for large branded retailers selling in mostly urban locations, while ICP data is collected in physical stores in many kinds of retailers and geographical locations. Second, online prices are collected every day, while ICP prices are obtained once (or a few times) per year. Temporal aggregation obscures the comparison because PPPs can vary significantly within a year (particularly in high inflation countries). Third, there are methodological details in ICP that we cannot

[5] See Table A2 in the Appendix for more examples and some item counts by basic heading.

[6] As Argentina did not participate in ICP 2011, we use the expenditure information from ICP 2005. Expenditure information at this detailed level (for example on 'potatoes' or on 'beef and veal') is not readily available for all countries in published national accounts, so we assume a constant expenditure composition within our period.

replicate. This includes the use of an "importance" weight for each item in the CPD regression, as quantity weights are not available at a detailed item level but only at the basic heading level.

Despite these differences, Figure 1 shows that PLIs computed with online data align well with those calculated from ICP data (US = 1). These are results for grouped items within Food, Fuel and Electronics, using basic heading expenditure weights (see Appendix Figure 1 for comparisons at basic heading level). The PLIs are closest for fuel, where the item definitions are identical across ICP and BPP. In Food and Electronics there is more dispersion but no evidence of PLIs being consistently higher or lower with online data.

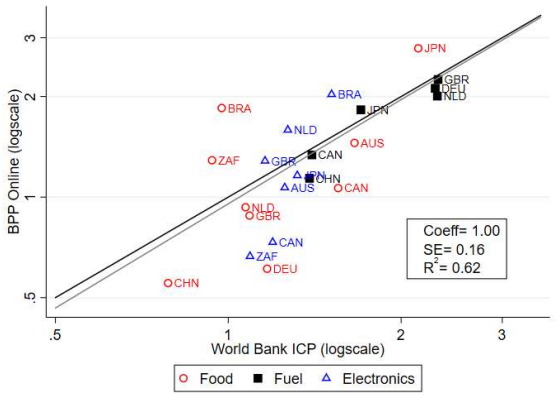

FIGURE 1. BPP VS ICP PRICE LEVEL INDEXES - 2011

Note: Comparison of the ICP 2011 and BPP bilateral Fisher indices at the sector level for each country. 45-degree line in black, linear fit line in gray. All axes on log scale.

Multi-lateral PLIs for each country are compared in Table 1. On average, online and ICP PLIs for 2011 differ by 15% in absolute value across the eleven countries. In some cases, such as Australia, the results are nearly identical, while in others, such as Japan, the difference is as high as 28%. On average, the differences are much smaller in 2014, when our coverage of basic headings with online prices is nearly complete. This comparison is possible because some OECD countries publish PPPs every three years.

TABLE 1- MULTILATERAL PRICE LEVEL INDEX (PLI=PPP/E), USA=1

	2011		2014	
	ICP FFE	BPP FFE	OECD FFE	BPP FFE
Argentina	n.a.	0.79	n.a.	1.05
Australia	1.53	1.52	1.36	1.24
Brazil	1.20	1.44	n.a.	1.17
Canada	1.30	1.08	1.29	1.15
China	0.93	0.71	n.a.	0.97
Germany	1.30	1.12	1.35	1.20
Japan	2.01	2.57	1.42	1.58
Netherlands	1.29	1.21	1.27	1.22
South Africa	0.96	1.11	n.a.	0.91
United Kingdom	1.25	1.14	1.37	1.26
United States	1.00	1.00	1.00	1.00
Mean Abs. Difference				
All		15%		
OECD		17%		9%

Notes: Multi-lateral GEKS PLIs covering all basic headings available in Food, Fuel, and Electronics. BPP numbers are yearly averages (from quarterly PLIs). Argentina refused to participate in ICP 2011 (See Cavallo (2013) for a discussion Argentina's official price data during this period).

One of the main advantages of using online PPPs is the opportunity to provide timely estimates of real consumption across countries. The first column in Table 2 provides a cross-country comparison of real household

consumption of food, fuel and electronics for 2017Q4 using our online PPPs.

TABLE 2 – REAL HOUSEHOLD CONSUMPTION PER CAPITA OF FOOD, FUEL AND ELECTRONICS BASED ON BPP PRICE DATA FOR 2017Q4 (USA=1)

	Actual	Extrapolated
Argentina	0.41	0.70
Australia	0.76	0.74
Brazil	0.20	0.22
Canada	0.61	0.89
China	0.11	0.18
Germany	0.60	0.76
Japan	0.45	0.40
Netherlands	0.57	0.70
South Africa	0.18	0.20
United Kingdom	0.72	0.76
United States	1.00	1.00

Sources: Total household consumption expenditure in local currency units, total population, the consumer price index and the exchange relative to the US dollar is taken from the *OECD Main Economic Outlook*, no. 102 (November 2017). For China, household consumption expenditure is from the UN National Accounts Official Country Data for 2015, extrapolated to 2017 using the growth of GDP at constant prices and the consumer inflation rate for 2016 and 2017 from the IMF World Economic Outlook of October 2017. The share of food, fuel and electronics in total household consumption is from ICP 2011.
Notes: 'Extrapolated' figures are based on the 2011 BPP price level index, extrapolated to 2017Q4 using the difference in (overall) consumer price inflation from 2011 to 2017Q4 between each country and the United States minus the change in the exchange rate. Estimates of for Argentina, Brazil, China and South Africa are for 2017 as a whole, rather than the fourth quarter of 2017. The 'Actual' figures are based on the BPP prices for 2017Q4.

Our approach has a major advantage above standard nowcasting procedures that rely on extrapolation of benchmark PPPs with relative CPI movements. The latter are prone to biases that distort the PLIs. In fact, one of the potential advantages to more frequent PPP online data is the ability to avoid extrapolation "surprises" in countries where CPI data and methods do not match well with the ICP comparisons framework. Comparing column 2 (based on extrapolated 2011 PPPs) with column 1 reveals that these surprises can be large and occasionally more than 50 percent (as for China, Argentina and Canada).

III. Limitations

While helpful, online data has many limitations. First, given that prices are mostly from large retailers with an online presence, the resulting PPPs may not be representative for national averages, especially in countries with a fragmented retail sector. Furthermore, the prices in websites of these retailers can be different from the prices found in their physical stores, where most retail transactions take place (at least for now). Cavallo (2017) shows these differences are small on average, but they can still affect relative price-level comparisons.[7]

Second, most retailers that sell online tend to have a single price for all locations within a country. This seems at odds with existing ICP data that shows significant regional price dispersion (such as urban areas having higher prices of food, especially in poorer countries).[8] This lack of spatial price differences can be

[7] To control for persistent online-offline differences, ICP can periodically estimate an average difference and adjust local prices accordingly. See Cavallo (2017) for a discussion.

[8] Some of this price dispersion could be explained by data collected from different retailers, as there is growing evidence that firms use uniform-pricing policies within countries. See DellaVigna & Gentzkow (2017) for the US, and Cavallo (2017) for some other countries.

resolved by scraping more localized retailers, whose online presence is improving over time.

Third, online data do not have expenditure weights for individual products, so it is hard to know which products are more important for the comparison. In ICP this is decided upon by the NSO data collectors, who arguably have better information to make the choice (although there is often little transparency on how this is done). While scanner or other expenditure data sources could potentially be used as a complement, the question of which matched individual products are more representative of actual consumption remains.[9]

Fourth, online data only cover a limited number of product categories. The three sectors included in this paper represent between 13% and 23% of the share of household consumption in these countries. While more categories with online prices can be potentially added, there are hard-to-compare areas of consumption that will remain a challenge such as housing, personal services or health services. Indeed, the challenges for cross-country price comparisons in these areas are at least as big as for over-time CPI measurement. While progress is being made, as more services are offered online, it is clear that online prices still need to be complemented with other data sources when making comparisons of GDP across countries.

Lastly, online data is currently available in a small number of countries. We have matched data in only 11 countries out of approximately 60 for which the BPP has some data. While this can improve, our approach is not yet viable in many developing countries where there is little price data online.

IV. Conclusions

We have shown that online prices can be used to enhance ICP data, dramatically improving the speed and transparency of PPPs compared with traditional data collection methods. We have also identified many challenges and limitations of online data.

We further note that the process of selecting ("matching') products across countries remains a challenge, even with "Big Data". Online prices can enlarge the universe of products from which comparable goods are chosen, and potentially improve the transparency and similarity in methods used across countries, but selecting individual goods continues to be a labor-intensive task that cannot be easily performed by machine-learning algorithms or other automated procedures.

[9] See Antoniades (2017).

Future work should address these issues, as well as explore other potential uses of online prices in the context of PPP measurement, such as the computations of standard errors for national average prices, the use of retailer dummies and other product characteristics in CPD regressions, and ways to address the problem of product varieties that are country-specific.

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ONLINE APPENDIX

I - Details on PPP methodology

To deal with the unbalanced nature of the panel, we follow ICP and run a Country Product Dummy (CPD) regression in every quarter and for every basic heading k:

$$\log p_{ij}^{k} = \eta_{i}^{k} + \eta_{j}^{k} + \epsilon_{ij}^{k} \quad (1)$$

The price of item i in country j is 'explained' using item dummies η_i and country dummies η_j. The item dummies capture the international price of the item, while the exponent of each country dummy is the estimated PPP for that particular basic heading, $P_{kj} = \exp(\eta_j^k)$. The country dummy for the reference country (in our case the United States) is omitted, so $P_{kUSA} = 1$.

We use the expenditure data from ICP 2011 for further aggregation using a multilateral GEKS methodology.[10] Let s_{kj} be the expenditure share of basic heading k in total consumption, then we can define the Laspeyres index $P_{jb}^{L} = \sum_k s_{kb} P_{kj}/P_{kb}$ using expenditure shares in the reference country b, the Paasche index $P_{jb}^{P} = \left(\sum_k s_{kj}\, P_{kb}/P_{kj}\right)^{-1}$ using country j expenditure shares, and the Fisher index as the geometric mean: $P_{jb}^{F} = \left(P_{jb}^{L} \times P_{jb}^{P}\right)^{\frac{1}{2}}$. The Fisher index can be computed using any reference country and results differ depending on the choice of reference country, so the final step is to compute the reference-country independent GEKS PPP for all M countries:

$$P_{j}^{GEKS} = \left(\prod\nolimits_{b}^{M} P_{1b}^{F} P_{bj}^{F}\right)^{\frac{1}{M}}$$

PPPs are expressed as national currency per unit of the base country (in our case the US dollar). To ease interpretation across countries and samples, we also compute price level indices (PLIs), dividing the PPPs by the country's nominal exchange rate with the US dollar. PLIs are unit-free and reflect whether prices are higher (PLI > 1) or lower (PLI < 1) in each country relative to the reference country.

[10] As Argentina did not participate in ICP 2011, we use the expenditure information from ICP 2005. Expenditure information at this detailed level, so expenditure on 'potatoes' or on 'beef and veal' is not readily available for all countries in published national accounts, so we assume a constant expenditure composition within our period.

APPENDIX FIGURES AND TABLES

TABLE A1 —DATA SOURCE COMPARISON

For Food, Fuel, and Electronics*	BPP (2017)	ICP (2011)
Data collection	Daily	Few times a year
Publication frequency	Quarterly	~6 years (3 years for OECD)
Number of items	267	238
Products per item-country (mean)	30	10-15 homogeneous** 70-100 heterogeneous
Type of coverage	Goods	Goods & Services
Locations	Urban	Urban & Rural
Countries	11	199

Notes: *COICOP codes for Food and Beverages (01), Fuel (07.2.2), and Electronics (From 09.1.1 to 09.1.4) **Estimates in World Bank (2013).

Source: Authors' calculations based on World Bank (2013)

TABLE A2—ITEM LIST EXAMPLES

Basic Heading	Number of Items		Item Definition Examples	
	BPP	ICP	BPP	ICP
Rice	4	9	White Rice, All Brands, Basmati	Basmati Rice
			White Rice, All Brands, Long-grain	Long-grain rice – Family Pack
Other cereals, flour and other products	12	6	All-purpose Flour, All Brands, Wheat	Wheat flour, not self-rising
			All-purpose Flour, All Brands, All Other	Wheat flour, not self-rising
			Cereal for Breakfast, Kellogg's, All Other	Cornflakes (Kellogg's)
Pasta	7	6	Pasta, All Brands, Spaghetti	Spaghetti
			Pasta, Barilla, Penne (including whole grain)	Short Pasta
Beef and Veal	2	8	Beef, All Brands, Tenderloin roast or steak	Beef, fillet
			Beef, All Brands, Ground	100% Beef, minced
Poultry	1	6	Chicken, All Brands, Breasts	Chicken breast without skin
Fresh, chilled or frozen sea food	2	13	Shrimp, All Brands, Fresh Uncooked	Whole Shrimps
			Shrimp, All Brands, Frozen Uncooked	Shrimps
Preserved or processed fish and seafood	4	5	Canned Tuna, All Brands, In Oil	Canned Tuna without skin
			Canned Tuna, All Brands, In water	Canned Tuna without skin
			Canned Tuna, All Brands, All Other	Canned Tuna without skin
Cheese	7	6	Cream Cheese, Philadelphia, Regular	Cream Cheese
			Cream Cheese, Philadelphia, Fat free, low fat	Cream Cheese
			Cream Cheese, Philadelphia, All Other	Cream Cheese
Eggs and egg-based products	1	2	Eggs, All Brands, Chicken	Large Size Chicken Eggs
			Eggs, All Brands, Chicken	Medium Size Chicken Eggs
Butter and margarine	3	3	Butter, All Brands, Salted	Salted Butter
			Butter, All Brands, All Other	Butter, unsalted
Other edible oils and fats	6	6	Olive Oil, All Brands, Extra Virgin	Olive Oil
Fresh or chilled fruits	7	13	Apples, All Brands, Red	Apple, Red Delicious
Fresh or chilled vegetables	5	15	Onions, All Brands, White, Yellow or Brown	Onion
			Onions, All Brands, Red	Onion
Food Products	17	13	Ketchup, Heinz, Regular	Tomato Ketchup
			Ketchup, All Brands, Regular	Tomato Ketchup
			Ketchup, All Brands, All Other	Tomato Ketchup
			Ketchup, All Brands, Reduced Sodium/Sugar	Tomato Ketchup
Coffee, Tea and Cocoa	16	7	Chocolate Powder, Nesquick, Regular	Cocoa Powder, Tin
			Chocolate Powder, Nesquick, All Other	Cocoa Powder, Tin
			Coffee, All Brands, Ground (Excluding decaf.)	Coffee Roasted 100% Arabica
			Coffee, All Brands, Ground (Excluding decaf.)	Coffee Roasted 100% Robusta
			Coffee, Illy, Ground (including decaf)	Instant Coffee, Nescafe Classic
Mineral Waters, Soft drinks and vegetable Juices	35	6	Sodas, Coca Cola, Classic or Regular	Coca-Cola/Pepsi, Large
			Sodas, Pepsi, Classic or Regular	Coca-Cola/Pepsi, Large
			Mineral Water, All Brands, Still	Mineral Water
			Mineral Water, Evian	Mineral Water
			Mineral Water, Fiji	Mineral Water
Audio-visual, photographic and information processing equipment	82	27	Laptop, Apple, MacBook, 13 inch	Apple MacBook laptop computer
			Laptop, Acer, 14-16 inch	Acer Aspire One netbook
			Television, Phillips, LED 32"	Phillips 3000 series LCD TV 32"
			Television, Samsung, LED 32"	Samsung Series 5 LCD TV
			Television, All Brands, LED 32"	32 Inches LCD Television
			Television, LED, 40-43", LG	LG LD Series LCD TV 42"
			Camera Compact, Canon, 20-24mpx	Digital Compact Camera
			Camera Compact, Nikon, 20-24mpx	Digital Compact Camera
			Camera Compact, Sony, 20-24mpx	Digital Compact Camera
Fuels and lubricants for personal transport equipment	4	5	Petrol, All Brands, Low RON	Petrol
			Petrol, All Brands, Medium RON	Petrol, Super
			Petrol, All Brands, High RON	Petrol, Superplus
			Diesel	Diesel fuel

Notes: Full product list for BPP available with published data.

Source: Authors' calculations based on BPP and ICP data.

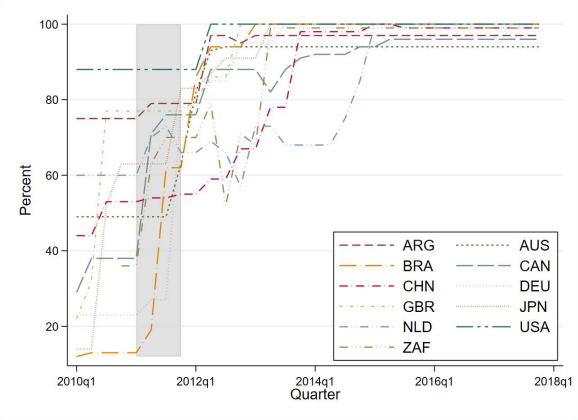
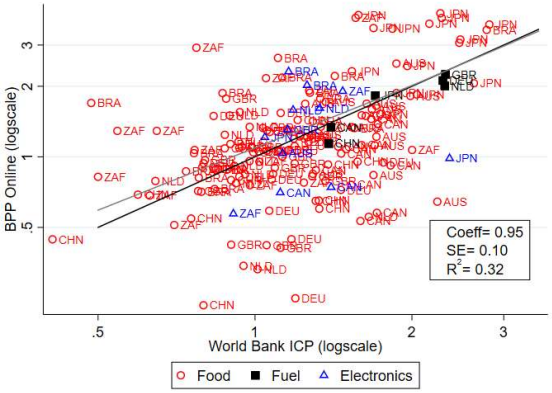
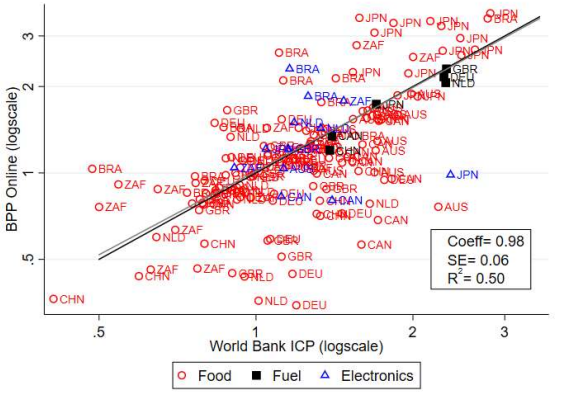


FIGURE A1: SHARE OF BASIC HEADINGS COVERED BY BPP

Note: Share of all basic headings in ICP food, fuel, and electronics categories. 2011 quarters shaded in gray.



PANEL A: ONLINE PPP IS AN ANNUAL AVERAGE



PANEL B: ONLINE PPP FROM QUARTER WITH SMALLEST DIFFERENCE

FIGURE A2. BASIC HEADING COMPARISON ICP VS BPP FOR 2011