PPPs and Exchange Rates
Evidence from Online Data in Seven Countries

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MIT and NBER

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Agenda

- Motivation
- Data
- RERs
- Shock Adjustments (half-lives, persistence comparisons)
- Relative prices vs E shocks
Conclusions

- RERs shock adjustment is much faster than previously recorded → months, not years
  - Micro-data necessary to compare relative price levels
  - Tradable, perfectly matched goods

- Deviations of RER from normal levels increase pressure to adjust either Relative Prices or E

- Adjustment margin and speeds vary by country
  - Argentina, China, Australia → mostly prices
  - Brazil, South Africa, UK → mostly E
Motivation

- PPP and Exchange Rates
  - Does PPP hold?
    - Absolute PPP $\rightarrow$ Law of one price, RER=1
    - Relative PPP $\rightarrow$ RER constant
  \[ RER = \frac{P_{lc} \cdot E_{usd/lc}}{P_{us}} \]

- Empirical Literature finds that:
  - Absolute PPP does not hold
  - Relative PPP may hold, but only in the long-run
    - Extremely slow speed of convergence $\rightarrow$ half-life of RER shocks is 3-5 years (Rogoff (96))
Motivation

Main reasons for PPP’s empirical failure:

1. Limits to Arbitrage
   - non-traded goods, transaction costs, imperfect competition

2. Statistics:
   - CPI-based RERs
     - No levels (only indices)
     - Different methodologies across countries
     - Different baskets (products, sectors, and weights)
     - Good are not identical
     - Aggregation biases

   - The measured RER is different from the theoretical RER.
Motivation

- Micro-level prices can help
  - Crucini, Shintani & Telmer (2002-2013): at lower levels of aggregation PPP holds better
  - Cavallo, Neiman, & Rigobon (2014): global firms, Absolute PPP holds within currency unions and large multinationals

- But international micro-level data collection is very limited
  - Single-item indices → e.g. Big Mac, Starbucks Index
  - Cost of living surveys (built for expat-costs) → eg. EIU, Mercer → annual, many countries, but relatively few and broad product categories
  - ICP - World Bank → better on goods coverage, but very low frequency (3-5 years), methodology changes over time, and focus is on real GDP comparisons

- Limitations
  - Traditional data collection is expensive
    - Collecting prices + matching individual goods across countries
  - NSOs (the data collectors) have little incentive to work on international comparisons
Online Data and the Billion Prices Project

- Academic project at MIT to collect data from retailers that post prices online.
- Started in 2008, joint with Roberto Rigobon (MIT)
- Objective: inflation measurement and macro/international research
- We collect daily data from hundreds of large retailers, for all goods sold, in 50 countries.

1. Use scraping technology
2. Connect to thousands of online retailers every day
3. Find individual items
4. Store and process key item information in a database
5. Develop real-time statistics based on micro-level data

- Date
- Item
- Price
- Description
How does *Data Scraping* work?

- Every day, our software downloads a public webpage, analyses its HTML code, extract price data, and stores it in a database.
## Alternative Data Sources for PPPs

<table>
<thead>
<tr>
<th></th>
<th>BPP Online Data</th>
<th>ICP - OECD - Eurostat</th>
<th>Cost of Living Indices (EIU, Mercer, etc)</th>
<th>Single-Product (Big Mac, Ikea Billy)</th>
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<tbody>
<tr>
<td>Coverage</td>
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<td>Countries</td>
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<tr>
<td>Comparable over time</td>
<td></td>
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<td>Products</td>
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<tr>
<td>Varieties per product</td>
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<tr>
<td>Product Matching</td>
<td></td>
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<tr>
<td>Frequency</td>
<td></td>
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</tr>
</tbody>
</table>
Are Online Prices similar to Offline Prices?

- Our Online Price Indices match CPIs → implies price changes are similar

- But for PPP comparisons, price levels are key.
Are Price Levels different?

- Cavallo (2015) → simultaneous random sampling of online and offline prices using barcode-scanning app and crowdsourced workers

BPP App

Compare online and offline prices
Are Price Levels different?

- Cavallo (2015) → simultaneous random sampling of online and offline prices using barcode-scanning app and crowdsourced workers

Table 2: Examples of Online - Offline Price Level Difference

<table>
<thead>
<tr>
<th>Country</th>
<th>Retailer</th>
<th>Observations</th>
<th>Identical (In %)</th>
<th>Higher Online (%)</th>
<th>Lower Online (%)</th>
<th>Online Markup (%)</th>
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<tbody>
<tr>
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<td>Coto</td>
<td>100</td>
<td>18</td>
<td>79</td>
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<td>308</td>
<td>36</td>
<td>21</td>
<td>42</td>
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<td>90</td>
<td>4</td>
<td>6</td>
<td>-11</td>
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<tr>
<td>Canada</td>
<td>Toystrus</td>
<td>795</td>
<td>87</td>
<td>7</td>
<td>6</td>
<td>0</td>
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<tr>
<td>Canada</td>
<td>Walmart</td>
<td>951</td>
<td>92</td>
<td>6</td>
<td>2</td>
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<tr>
<td>Germany</td>
<td>Galleriak</td>
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<tr>
<td>Germany</td>
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<tr>
<td>U.S.</td>
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<tr>
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<td>56</td>
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<td>3</td>
<td>4</td>
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<td>2</td>
<td>1</td>
<td>3</td>
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<tr>
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<td>-7</td>
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<td>5</td>
<td>8</td>
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<td>Uk</td>
<td>Ms</td>
<td>418</td>
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<td>3</td>
<td>7</td>
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<td>Uk</td>
<td>Tesco</td>
<td>673</td>
<td>94</td>
<td>2</td>
<td>5</td>
<td>-11</td>
</tr>
</tbody>
</table>

Mean: 684, Median: 673

Note: Retailers independently selected, not necessarily the same as PPP or inflation sources. Preliminary Results.
PPP series with Online Data

- Main Characteristics
  - 350 narrow product categories
  - 30 thousand individually matched items
  - 7 countries
  - Food, fuel, and electronics
  - Sector and Country-Level Indices
  - Daily frequency

Illustration: Coke Prices

- Compare prices for a bottle of Coke across countries
- Repeat for hundreds of products
- Compute daily RERs at different levels of aggregation
Methodology

- We measure:

\[
RER = \frac{P_{lc} \cdot E_{usd/lc}}{P_{us}}
\]

- \( P_{lc} \) is price in local currency
- \( P_{us} \) is price in the US
- \( E_{usd/lc} \) is US dollars per local currency

- Three computational steps:
  1. Good-level RER
  2. Un-weighted geometric mean within sector
  3. Weighted mean across sectors \( \Rightarrow \) Fisher index using weights from
A country-level RER for tradable goods

Real Exchange Rate

- The relative cost of a large basket of identical goods when expressed in the same currency

\[ RER = \frac{P_{lc} \cdot E}{P_{us}} \]

Components: Prices and E

- Is there a link between Relative Prices and Exchange Rates?
EXAMPLES OF PRODUCT CATEGORIES

<table>
<thead>
<tr>
<th>FOOD</th>
<th>ELECTRONICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee_Illy_Ground (excluding decaf)</td>
<td>Television_Samsung_LED 32inch basic</td>
</tr>
<tr>
<td>CoffeeRegular_Ground (excluding decaf)</td>
<td>Television_Samsung_LED 32inch All Other (including Full HD, Smart, 3D)</td>
</tr>
<tr>
<td>CoffeeRegular_Beans (excluding decaf)</td>
<td>Television_Samsung_LED 40-43inch basic</td>
</tr>
<tr>
<td>Coffee_Decaf</td>
<td>Television_Samsung_LED 40-43inch All Other (including Full HD, Smart, 3D)</td>
</tr>
<tr>
<td>Coffee_All Other</td>
<td>Television_Sony_LED 32inch basic</td>
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<tr>
<td>Ketchup_Heinz-Regular</td>
<td>Television_Sony_LED 32inch All Other (including Full HD, Smart, 3D)</td>
</tr>
<tr>
<td>Ketchup_Heinz_Low Sodium, no salt</td>
<td>Television_Sony_LED 40-43inch basic</td>
</tr>
<tr>
<td>Ketchup_Heinz_All Other (e.g., flavored)</td>
<td>Television_Sony_LED 40-43inch All Other (including Full HD, Smart, 3D)</td>
</tr>
<tr>
<td>Ketchup_All Other Regular</td>
<td>Television_Sony_LED 44-47inch All Other (including Full HD, Smart, 3D)</td>
</tr>
<tr>
<td>Ketchup_All Other_All Other (e.g., flavored)</td>
<td>Television_LG_LED 32inch basic</td>
</tr>
<tr>
<td>Soy Sauce_All Other-Regular</td>
<td>Television_LG_LED 32inch All Other (including Full HD, Smart, 3D)</td>
</tr>
<tr>
<td>Soy Sauce_All Other_Low Sodium, no salt, light</td>
<td>Television_LG_LED 40-43inch basic</td>
</tr>
</tbody>
</table>

Methodology

1. **Define a Product**

- Very narrow product definition
- Must be available in multiple countries
- Branded and Unbranded categories
Methodology

1. Define a Product
2. Select, clean, size individual items

- Very narrow product definition
- Must be available in multiple countries
- Branded and Unbranded categories

- Dozens of items per product in each country
- Different retailers, brands, and sizes

Coffee - Regular - Ground

USA
Price in Dollars

USA
Price in Dollars Per Gram

01jan2014 01feb2014 01mar2014 01apr2014 01may2014

0 20 40 60 80

01jan2014 01feb2014 01mar2014 01apr2014 01may2014

0 0.01 0.02 0.03 0.04

More
Methodology

1. Define a Product
2. Select, clean, size individual items
3. Product RER

- Very narrow product definition
- Must be available in multiple countries
- Branded and Unbranded categories

- Dozens of items per product in each country
- Different retailers, brands, and sizes
- Product availability varies across countries and time
- If a good is not available in the US, it will not appear in our series

$P_{lc}$ and $P_{US}$

**UK Average Unit Price**
- Price in GBP
- Date range from 01 Jul 2010 to 01 Jul 2013

**US Average Unit Price**
- Price in Dollars
- Date range from 01 Jul 2010 to 01 Jul 2013
Methodology

1. Define a Product
   - Very narrow product definition
   - Must be available in multiple countries
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2. Select, clean, size individual items
   - Dozens of items per product in each country
   - Different retailers, brands, and sizes

3. Product RER
   - Product availability varies across countries and time
   - If a good is not available in the US, it will not appear in our series

Product RER
Methodology

1. Define a Product
   - Very narrow product definition
   - Must be available in multiple countries
   - Branded and Unbranded categories

2. Select, clean, size individual items
   - Dozens of items per product in each country
   - Different retailers, brands, and sizes

3. Product RER
   - Product availability varies across countries and time
   - If a good is not available in the US, it will not appear in our series
   - Multiple item varieties per product improves our estimate

Product RER

RER - UK/US
Coffee-Regular-Ground

Real Exchange Rate

01 Jul 2010 to 01 Jul 2013

Graph showing the real exchange rate over a period from 2010 to 2013.
Methodology

1. Define a Product
   - Very narrow product definition
   - Must be available in multiple countries
   - Branded and Unbranded categories

2. Select, clean, size individual items
   - Dozens of items per product in each country
   - Different retailers, brands, and sizes

3. Product RER
   - Product availability varies across countries and time
   - If a good is not available in the US, it will not appear in our series
   - Multiple item varieties per product improves our estimate

4. Repeat for hundreds of Products

5. Sector RER (E.g. Food)
   - Food
   - Fuel
   - Electronics

6. Country Level RER (weighted)
   - Compare Eppp and E
Aggregate Results

Argentina

Brazil

South Africa

Real Exchange Rate (RER) for Argentina, Brazil, and South Africa.

Components of RER showing Relative Price and ARS/USD (Nominal Exchange Rate) for Argentina, BRL/USD (Nominal Exchange Rate) for Brazil, and Relative Price and ZAR/USD (Nominal Exchange Rate) for South Africa.
Aggregate Results

United Kingdom

Real Exchange Rate (RER)

Components of RER

Australia

Real Exchange Rate (RER)

Components of RER

China

Real Exchange Rate (RER)

Components of RER
Aggregate Results

- Most RERs appear to fluctuate around certain levels (relative PPP)
  - Are these levels reasonable?
  - Comparison to ICP
Rates of Convergence and Half-Lives of RER Shocks

- There is much faster mean-reversion in these RERs than in the literature

<table>
<thead>
<tr>
<th></th>
<th>Half-Life (in days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily Data</td>
</tr>
<tr>
<td>ARGENTINA</td>
<td>289</td>
</tr>
<tr>
<td>AUSTRALIA</td>
<td>92</td>
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<tr>
<td>BRAZIL</td>
<td>58</td>
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<tr>
<td>CHINA</td>
<td>204</td>
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<tr>
<td>SOUTH AFRICA</td>
<td>27</td>
</tr>
<tr>
<td>UK</td>
<td>73</td>
</tr>
</tbody>
</table>

- Why faster adjustment?
  - Micro data more volatile $\rightarrow$ control for sale events, stockouts
  - Only tradable goods
  - Identical Goods across countries $\rightarrow$ perfect matching
Co-movement in Relative Prices and $E$

- Deviations of RER from normal levels increase pressure to adjust

![Real Exchange Rate (RER) Graph](image)

- Adjustment may come through relative prices or the exchange rate
  - Magnitude and persistence of each shock could matter
- Implies that $E$ co-moves with $P_u/P_l$, the PPP Exchange Rate
Argentina

\[ RER = \frac{P_{lc} \cdot E}{P_{us}} \]

If Absolute PPP holds, then \( RER = 1 \) and 
\( E_{ppp} = \frac{P_{us}}{P_{lc}} \)
Brazil

FX Implications
- Historical Benchmark
- PPP Benchmark

Valuation
- Brazil

Nominal Exchange Rate vs. PPP
- BR/USD (Implied by PPP)
- BRL/USD (Nominal Exchange Rate)
UK

FX Implications

Valuation

- United Kingdom

Nominal Exchange Rate vs. PPP

- GBP/USD (Implied by PPP)
- GBP/USD (Nominal Exchange Rate)
China

FX Implications

Valuation

Nominal Exchange Rate vs. PPP

CNY/USD (Implied by PPP)  CNY/USD (Nominal Exchange Rate)
A Vector Error Correction Model

- Time series suggest that Relative Prices and Exchange Rates are co-integrated (linear combination is stationary, in logs)

\[ rp_t = \beta_0 + \beta_1 e_t + \mu_t \]  \hspace{1cm} (1)

- We can estimate an Error Correction Model
  - Obtain speed of adjustment for each variable

\[ \Delta rp_t = \alpha_1 + \alpha_{rp}[rp_{t-1} - \beta_0 - \beta_1 e_{t-1}] + \sum \alpha_{11}^i \Delta rp_{t-i} + \sum \alpha_{12}^i \Delta e_{t-i} + \varepsilon_{rp_t} \]

\[ \Delta e_t = \alpha_2 + \alpha_e[rp_{t-1} - \beta_0 - \beta_1 e_{t-1}] + \sum \alpha_{21}^i \Delta rp_{t-i} + \sum \alpha_{22}^i \Delta e_{t-i} + \varepsilon_{et} \]

Error from LR relationship estimated in (1)
### Error Correction Model

**Table 1: Error Correction Model**

<table>
<thead>
<tr>
<th>Country</th>
<th>$\beta_0$</th>
<th>$\beta_1$</th>
<th>$\alpha_{rp}$</th>
<th>$\alpha_e$</th>
<th>$\frac{\alpha_{rp}}{\alpha_3}$</th>
<th>RP</th>
<th>Half-life</th>
<th>E Half-life</th>
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<tbody>
<tr>
<td>Argentina</td>
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<td>-1.26</td>
<td>-0.002**</td>
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<td>Australia</td>
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<td>-0.003***</td>
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<td>-0.015***</td>
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<td>-0.008**</td>
<td>0.43</td>
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</tbody>
</table>

**LR Pass-through**

**Speed of Adjustment (per day)**

**Implied Half-Lives (days)**
Extensions

- We can further:

1. Restrict the analysis to periods when the deviation is big (RER over a given threshold)
   - Speeds of adjustment increase

2. Distinguish between deviations in one sector/product vs deviations in multiple sectors/products
   - Single-sector deviations (eg Gas prices) tend to be corrected via prices, while multi-sector deviations lead to macro adjustments via the nominal exchange rate.
Conclusions

- RERs shock adjustment is much faster than previously recorded → months, not years
  - Micro-data necessary to compare relative price levels
  - Tradable, perfectly matched goods

- Deviations of RER from normal levels increase pressure to adjust either Relative Prices or E

- Adjustment margin and speeds vary by country
  - Argentina, China, Australia → mostly prices
  - Brazil, South Africa, UK → mostly E
Other Slides
Using CPIs: Relative Prices and E
Deviations in Many Products

- Signal: overvalued RER for over 70% of products

After 50 days, 76% of the paths experience a depreciation!