Recent Research related to the International Comparison Program (ICP) and its Implications

D.S. Prasada Rao
The University of Queensland

Areas of ICP Related Research

The main objective is to focus on four areas of my current research (jointly with other colleagues) on ICP related topics and examine possible implications for ICP.

- **Measures of reliability for Purchasing Power Parities from ICP**
  - **Implications for Poverty Estimates**
- **Adjustment of PPPs for quality differences (jointly with Naohito Abe, Kyoji Fukao and Kenta Ikeuchi)**
  - **Focus on services**
- **Spatial Chaining for International Comparisons (Jointly with Robert Hill, Reza Hajargasht and Sriram Shankar)**
  - **Results and implications**
- **Use of Scanner data for Regional Price comparisons (Tiziana Laureti)**
  - **Aggregation below basic heading level**
  - **Representativity/importance**
  - **Weighted CPD**

Reliability of PPPs from the International Comparison Program

PPPs from ICP 2011
(selected countries)

Country	Exch. Rate US$	PPP	PLI% (World=100)
P.R. China	6.461	3.506	70.0
Hong Kong	7.784	5.462	90.5
India	46.67	15.109	41.7
Australia	0.969	1.511	201
Japan	79.809	107.454	173.6
Luxembourg	0.719	0.906	162.4
Ethiopia	16.899	4.919	37.5
Austria	0.719	0.830	148.8

Source: World Bank, 2014, Results from ICP 2011.

Estimates of real per capita income – 2011
(Extrapolations from ICP 2005 and ICP 2011 results)

Country	Extrapolation from 2005	ICP 2011
Bangladesh	1,733	2,800
China	8,321	10,057
India	3,677	4,735
Malaysia	16,003	20,926
Ghana	1,874	3,426
Ethiopia	1,030	1,241
South Africa	10,704	12,111
Brazil	11,514	14,639
Germany	40,980	40,990
UK	34,799	35,091

Sensitivity Global and Regional Poverty Estimates to changes in PPPs

International Poverty Line = $1.90;   Year = 2011

Country	**India**	**China**	**Ethipoia**
PPP	**14.98**	**3.70**	**4.92**
Pop. (mill)	**1263.07**	**1344.13**	**87.80**
No. of poor IPL $1.90	**268.1**	**106.2**	**29.5**
No. of poor IPL -1%	243.6	103.2	28.8
No. of poor IPL +1%	**276.2**	**109.1**	**30.0**
No. of poor IPL -5%	227.9	91.8	26.1
No. of poor IPL +5%	**306.8**	**121.0**	**32.6**
No. of poor IPL -10%	190.1	78.0	22.8
No. of poor IPL +10%	**348.2**	**135.9**	**35.6**

Aggregation Methods for PPP Computation

CPD method:

$$p_{ij} = P_i PPP_j u_{ij} \qquad \ln p_{ij} = \ln P_i + \ln PPP_j + v_{ij}$$

$$\ln p_{ij} = \sum_{i=1}^{N} \eta_i D_i + \sum_{j=1}^{M} \pi_j D_j * + v_{ij}$$

GEKS Method:

$$PPP_{jk} = \prod_{l=1}^{M} \left[F_{jl} \cdot F_{lk} \right]^{1/M}$$

Geary-Khamis Method:

$$PPP_j = \frac{\sum_{i=1}^{n} p_{ij} q_{ij}}{\sum_{i=1}^{n} P_i q_{ij}} \qquad P_i = \frac{\sum_{j=1}^{m} \left(p_{ij} q_{ij} / PPP_j \right)}{\sum_{j=1}^{m} q_{ij}}$$

Weighted CPD (Rao Method):

$$PPP_j = \prod_{i=1}^{N} \left(\frac{p_{ij}}{P_i} \right)^{w_{ij}} \qquad P_i = \prod_{j=1}^{M} \left(\frac{p_{ij}}{PPP_j} \right)^{w_{ij}^*}$$

Ikle Method:

$$\frac{1}{P_i} = \sum_{j=1}^{M} \frac{PPP_j}{P_{ij}} w_{ij}^* \qquad \frac{1}{PPP_j} = \sum_{i=1}^{N} \left(\frac{P_i}{P_{ij}} w_{ij} \right) \qquad w_{ij} = \frac{p_{ij} q_{ij}}{\sum_{i=1}^{N} p_{ij} q_{ij}} \qquad w_{ij}^* = \frac{w_{ij}}{\sum_{j=1}^{M} w_{ij}}$$

Computation of standard errors for PPPs

- **We have Angus' paper on "Calibrating measurement uncertainty in PPP exchange rates"**
  - **Standard errors for weighted CPD**
  - **Standard errors for binary Tornqvist and Tornqvist based EKS**
- **Hajargasht and Rao (2010) have shown that:**
    - **Lognormality of disturbances in the CPD model leads to weighted CPD**
    - **If disturbances in CPD model follow inverse Gamma then Ikle method can be derived**
    - **MoM estimator with suitable moment conditions lead to geary-Khamis method**
- **Hajargasht and Rao (2015) provided a comprehensive Method of Moments approach to derive:**
  - **PPPs at the basic heading level**
  - **Weighted MoM leading to Weighted CPD, Ikle and GK methods**

Stochastic framework based on CPD Model

- **We start with the CPD Model:** $p_{ij} = P_i \cdot PPP_j \cdot u_{ij}^*$
- **We express the model as:** $r_{ij}(p_{ij}, P_i, PPP_j) = u_{ij}$
- **We rewrite the CPD model in three equivalent forms:**

$$Geometric: \quad r_{ij} = \ln p_{ij} - \ln P_i - \ln PPP_j$$

$$Arithmetic: \quad r_{ij} = \frac{p_{ij}}{P_i PPP_j} - 1$$

$$Harmonic: \quad r_{ij} = \frac{P_i PPP_j}{p_{ij}} - 1$$

Stochastic framework based on CPD Model

- In our previous work we used lognormal, Gamma and Inverse Gamma distributions and used M-estimators (weighted likelihood functions) to derive weighted CPD, Ikle and arithmetic systems.
- In this paper we use the method of moments estimation to derive different systems.
- We specify different moment conditions through different R matrices in the following moment conditions:

$$\frac{1}{NM}\mathbf{R}'\mathbf{r} = \mathbf{0}$$

- We derive four systems of which two of them use the optimum R matrix which is given by: $\mathbf{R} = E\left[\partial\mathbf{r}/\partial\boldsymbol{\beta}'\right]$

Four multilateral systems

- **Geometric r_{ij} and weighted least squares – Weighted CPD**

$$\ln PPP_j = \sum_{i=1}^{N} w_{ij} \ln \frac{p_{ij}}{\hat{P}_i} \qquad \ln \hat{P}_i = \sum_{j=1}^{M} w_{ij}^* \ln \frac{p_{ij}}{PPP_j}$$

- **Arithmetic r_{ij} and optimal choice of moment conditions with exp. Share weights:**

$$PPP_j = \sum_{i=1}^{N} w_{ij} \frac{p_{ij}}{\hat{P}_i} \qquad \hat{P}_i = \sum_{j=1}^{M} w_{ij}^* \frac{p_{ij}}{PPP_j}$$

- **Harmonic r_{ij} and optimal choice of moment conditions with expenditure share weights – Ikle system**

$$\frac{1}{PPP_j} = \sum_{i=1}^{N} w_{ij} \frac{\hat{P}_i}{P_{ij}} \qquad \frac{1}{P_i} = \sum_{i=1}^{M} w_{ij}^* \frac{PPP_j}{P_{ij}}$$

- **Arithmetic r_{ij} and optimal choice of moment conditions with quantity weights Geary-Khamis system**

$$PPP_j = \frac{\sum_{i=1}^{N} p_{ij} q_{ij}}{\sum_{i=1}^{N} \hat{P}_i q_{ij}} \qquad \hat{P}_i = \sum_{j=1}^{M} \left(\frac{p_{ij} q_{ij}}{PPP_j} \right) \Big/ \sum_{j=1}^{M} q_{ij}$$

Expressions for Covariance matrices

- **Weighted CPD (geometric)**

$$Var(\ln P, \ln PPP) = \left[\mathbf{X}^{*}{}'\mathbf{W}\mathbf{X}^{*}\right]^{-1} \mathbf{X}^{*}{}'\mathbf{W}\hat{\boldsymbol{\Omega}}\mathbf{W}\mathbf{X}^{*}{}' \left[\mathbf{X}^{*}{}'\mathbf{W}\mathbf{X}^{*}{}'\right]^{-1}$$

- **Ikle system and GK models – matrices $\hat{\mathbf{R}}$ and $\hat{\mathbf{W}}$ differ for the two systems for the general formula is the same.**

$$Var(\widehat{\boldsymbol{\beta}}_{MM}) = \left[\hat{\mathbf{R}}'\mathbf{W}\hat{\mathbf{D}}\right]^{-1} \hat{\mathbf{R}}'\mathbf{W}\hat{\boldsymbol{\Omega}}\mathbf{W}\hat{\mathbf{R}}\left[\hat{\mathbf{D}}'\mathbf{W}\hat{\mathbf{R}}\right]^{-1}$$

- **Choice of Ω matrix:**

Homoscedastic model: $\hat{\boldsymbol{\Omega}} = \hat{\sigma}^2 \mathbf{I}_{MN \times MN}$

Unrestricted White's Heteroscedastic model: $\hat{\boldsymbol{\Omega}} = Diag(\hat{u}_{ij}^2)$

Heteroscedasticity – different variances in different countries

$$\hat{\boldsymbol{\Omega}} = Diag\left(\sum_{i=1}^{N} \hat{u}_{ij}^2 / N\right) \otimes \mathbf{I}_N$$

Binary Tornqvist Index

We derive binary Tornqvist indices by applying weighted least squares (expenditure share weights) to the model:

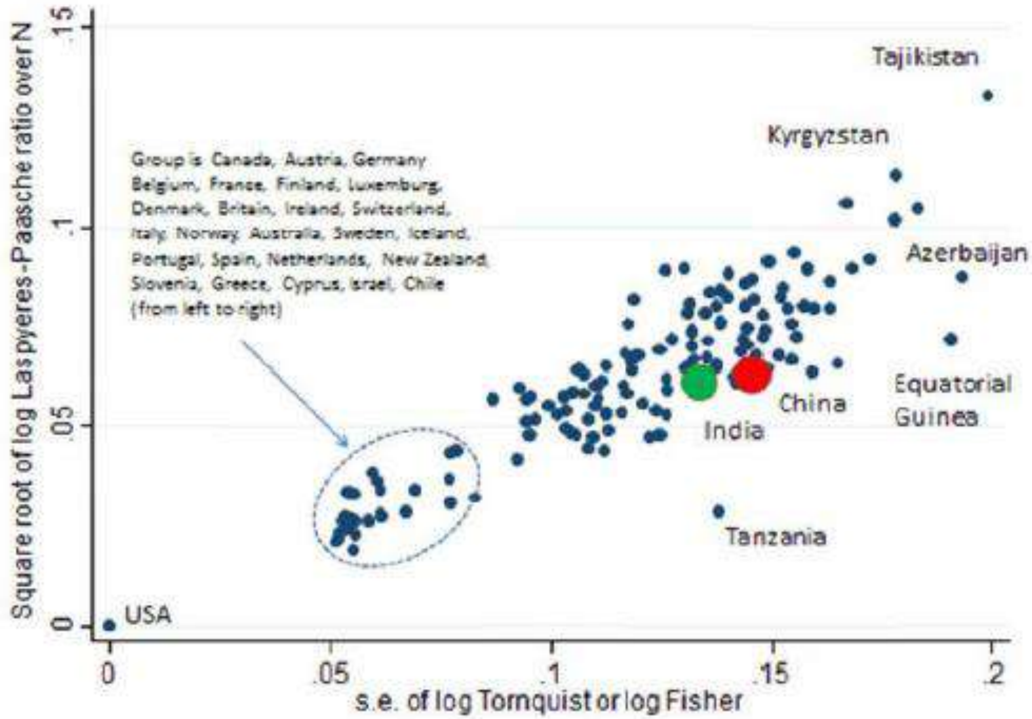
$$\ln\left[p_{ij}/p_{iM}\right] = PPP_j + u_{ij}$$

The estimated variances for *ln PPP$_j$* are given by:

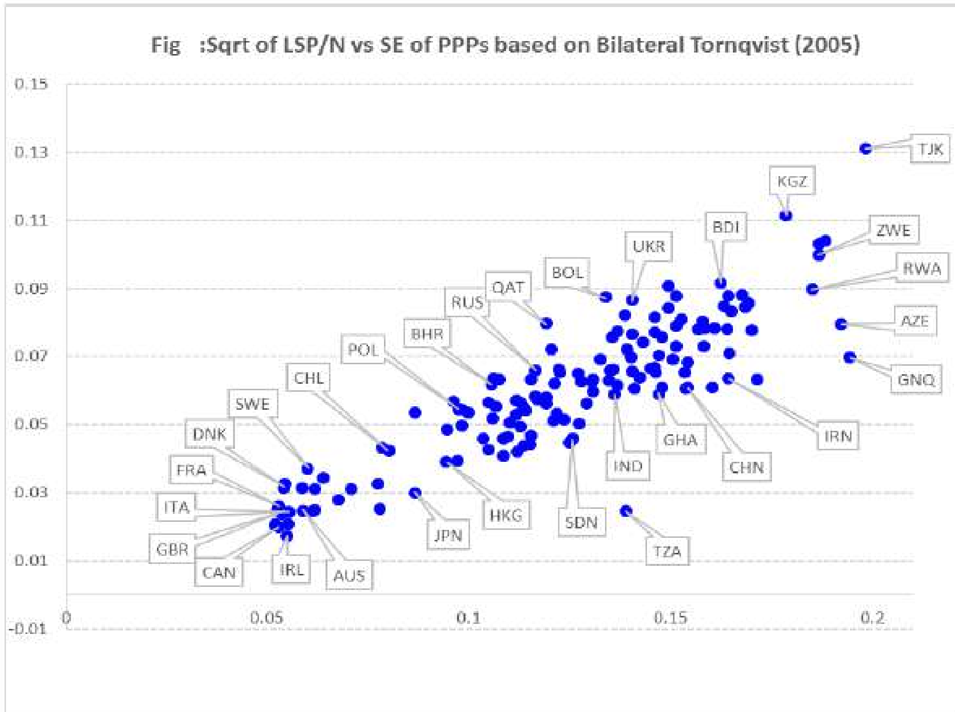
$$Var(\ln PPP_j) = \sum_{i=1}^{N} w_{ij}^{*2}\hat{\sigma}_j^2$$

where

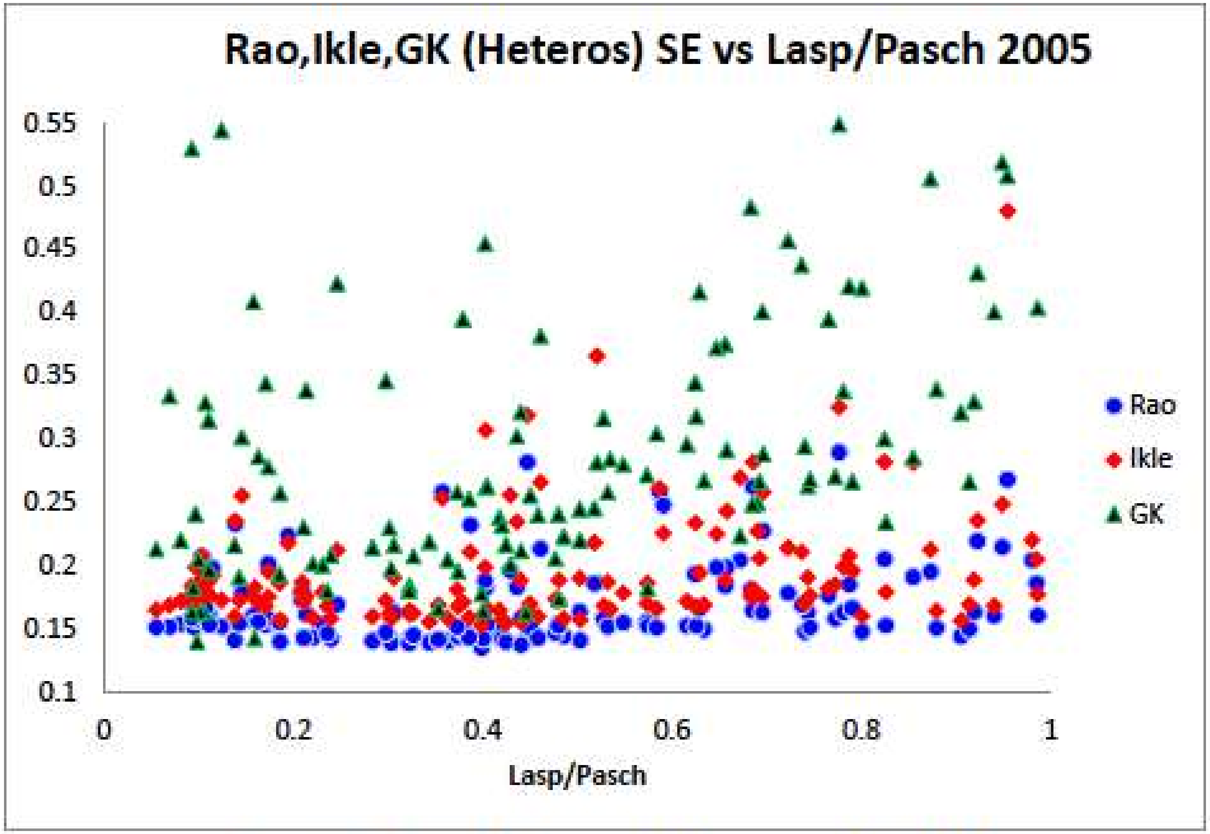
$$\hat{\sigma}_j^2 = \frac{1}{N}\sum_{i=1}^{N}\left\{\ln\left[p_{ij}/p_{iM}\right] - \ln PPP_j\right\}^2$$



Source: Deaton (2012), p. 11.



Source: our calculations


Rao,Ikle,GK (Heteros) SE vs Lasp/Pasch 2005
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0
0.2
0.4
0.6
0.8
1
Lasp/Pasch
Rao
Ikle
GK

Results presented this far assume that disturbances in the CPD model are uncorrelated.

Is there evidence to the contrary?

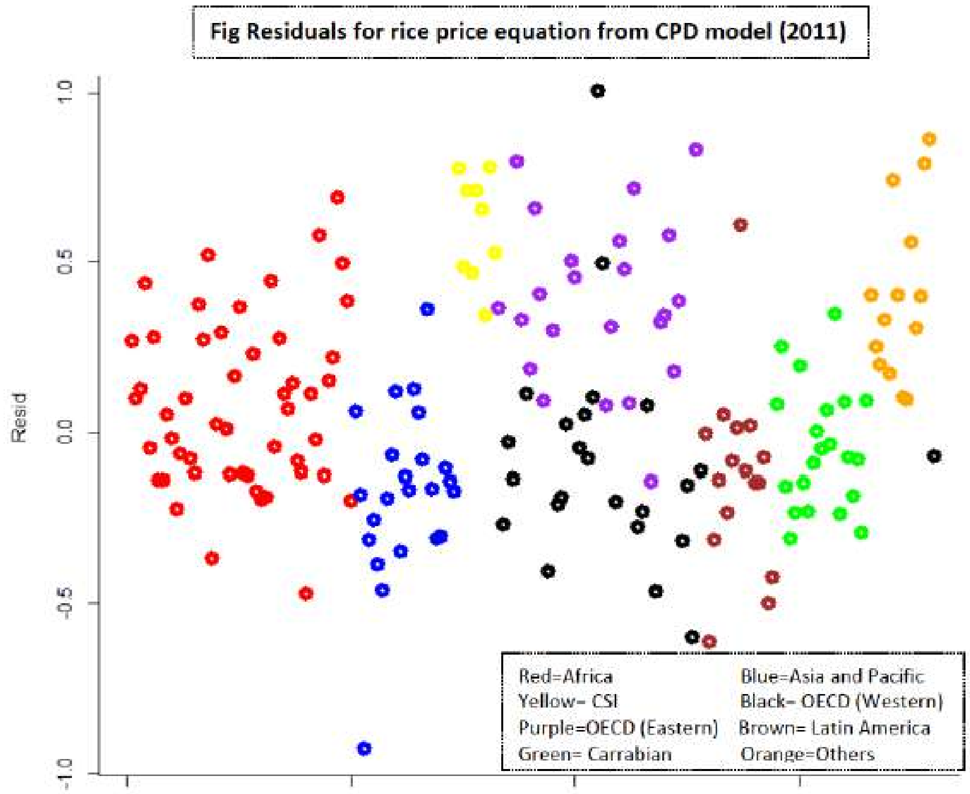


Fig Residuals for rice price equation from CPD model (2011)
Resid
1.0
0.5
0.0
-0.5
-1.0
Red=Africa
Blue=Asia and Pacific
Yellow= CSI
Black= OECD (Western)
Purple=OECD (Eastern)
Brown= Latin America
Green= Carrabian
Orange=Others

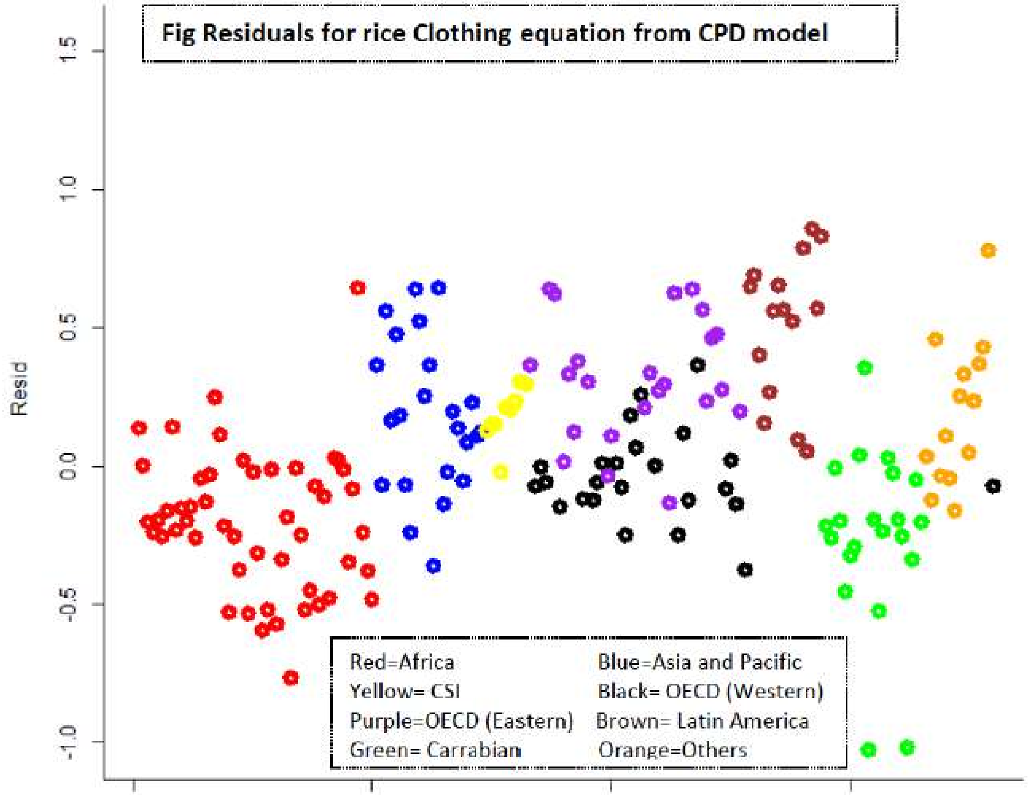


Fig Residuals for rice Clothing equation from CPD model
Resid
1.5
1.0
0.5
0.0
-0.5
-1.0
Red=Africa
Blue=Asia and Pacific
Yellow= CSI
Black= OECD (Western)
Purple=OECD (Eastern)
Brown= Latin America
Green= Carrabian
Orange=Others

Alternative specifications for covariance matrices

Homoskedastic Estimator: The estimated covariance matrix is given by

$$\hat{\boldsymbol{\Omega}} = \hat{\sigma}^2 \mathbf{I}_{MN \times MN} \tag{22}$$

where where $\hat{\sigma}^2 = \dfrac{\hat{\mathbf{r}}'\hat{\mathbf{r}}}{MN}$ and $\hat{\mathbf{r}}$ is a vector of residuals computed using the models specified in equations

White's Heteroscedastic Estimator: The estimated covariance matrix is given by

$$\hat{\boldsymbol{\Omega}} = Diag(\hat{r}_{ij}^2) \tag{23}$$

where $\hat{r}_{ij}$ is the residual computed from equations (6), (7) or (8) whichever is appropriate for the method and computed for a specific commodity in a given country.

Cluster Robust with respect to Countries: The estimated covariance matrix is given by

$$\hat{\boldsymbol{\Omega}} = diag(\hat{\boldsymbol{\sigma}}^j) \quad \text{where} \quad \hat{\boldsymbol{\sigma}}^j = \hat{\mathbf{r}}^j \hat{\mathbf{r}}^{j\prime} \tag{24}$$

where $\hat{\mathbf{r}}^j = \{\hat{r}_{ij}, \ i = 1, \ldots, N\}$ is the residual computed from equations (6), (7) or (8) whichever is appropriate for the method .

Cluster Robust with respect to Items: The estimated covariance can be obtained as

$$\sigma_{i,i}^{j,k} = \hat{r}_{ij} \hat{r}_{ik}$$

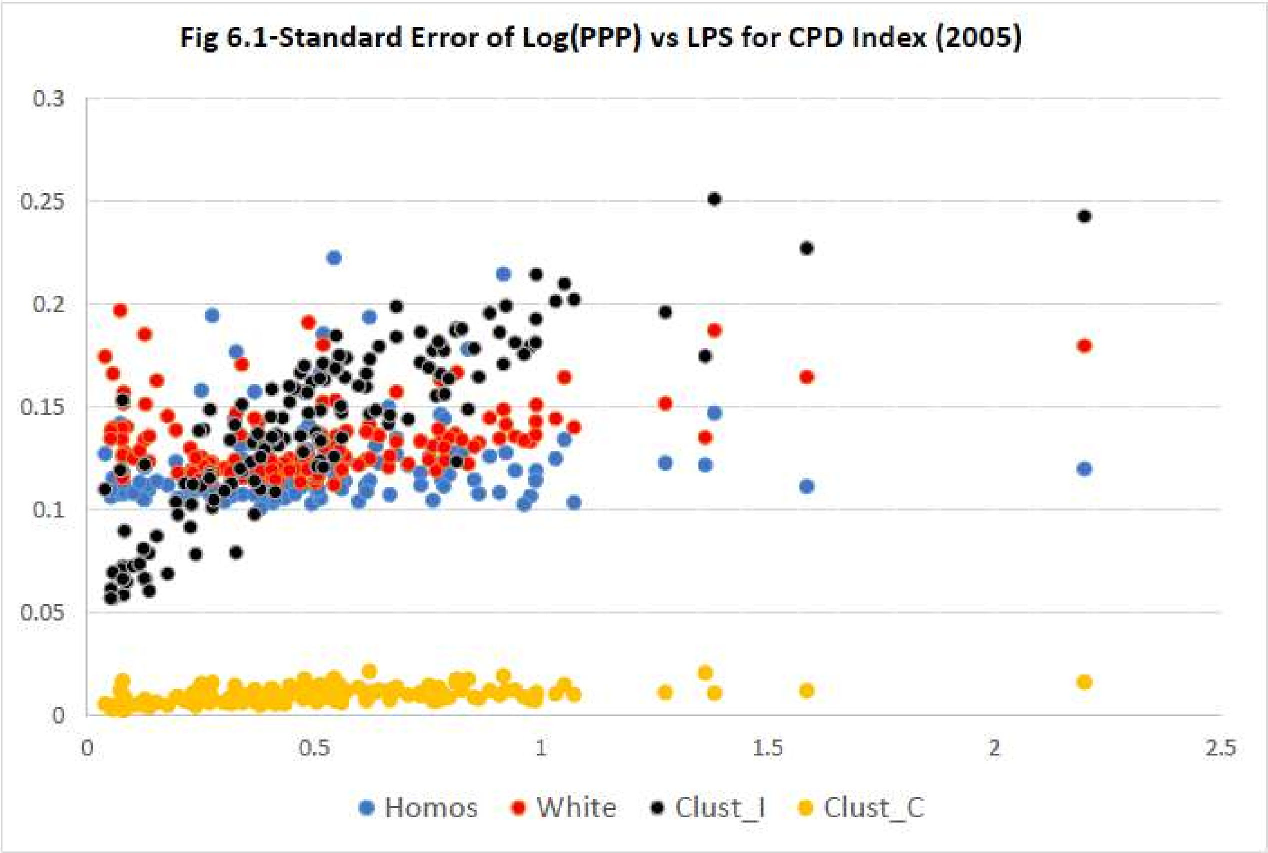


Fig 6.1-Standard Error of Log(PPP) vs LPS for CPD Index (2005)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
Homos
White
Clust_I
Clust_C

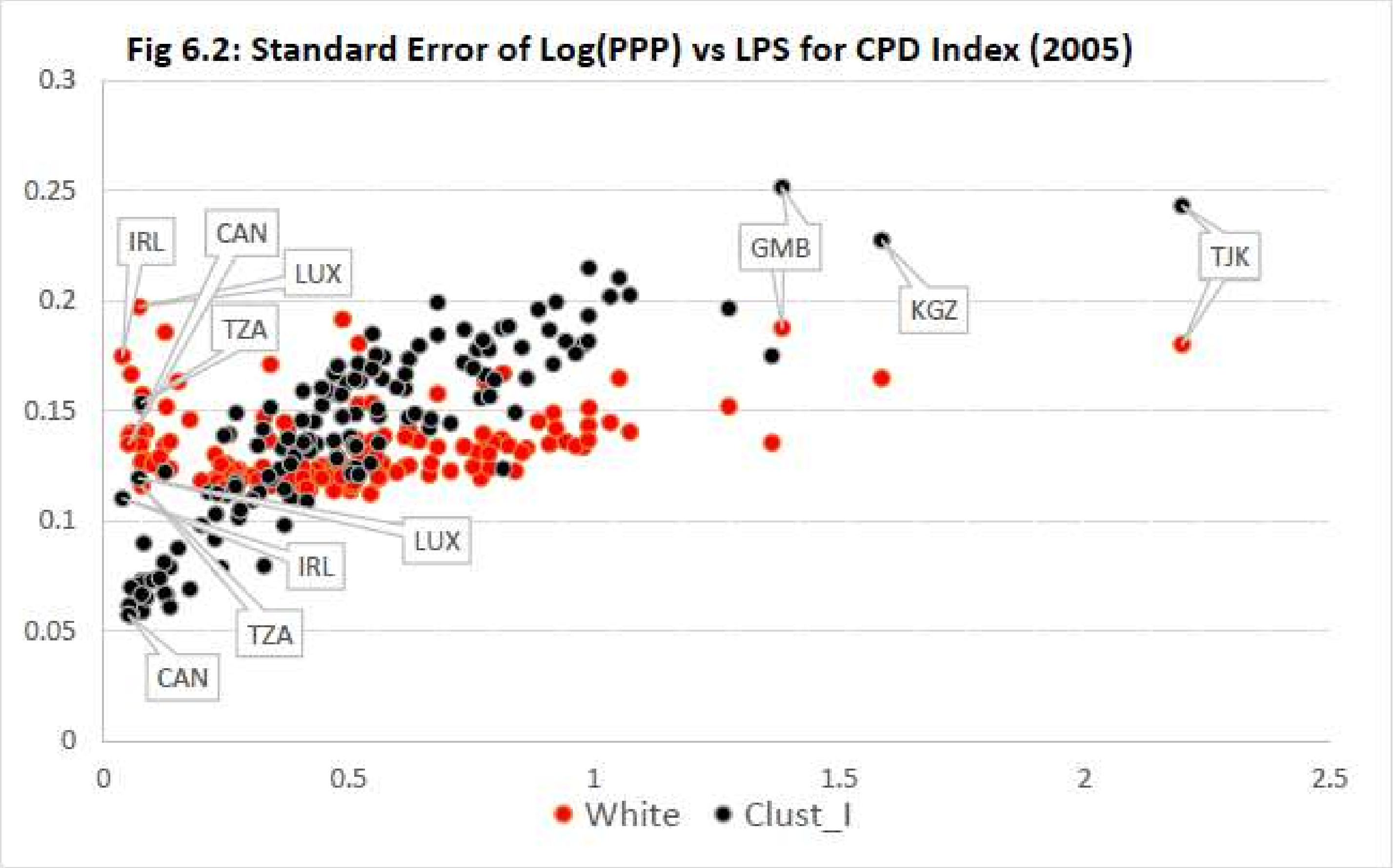


Fig 6.2: Standard Error of Log(PPP) vs LPS for CPD Index (2005)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
IRL
CAN
LUX
TZA
GMB
KGZ
TJK
LUX
IRL
TZA
CAN
White
Clust_I

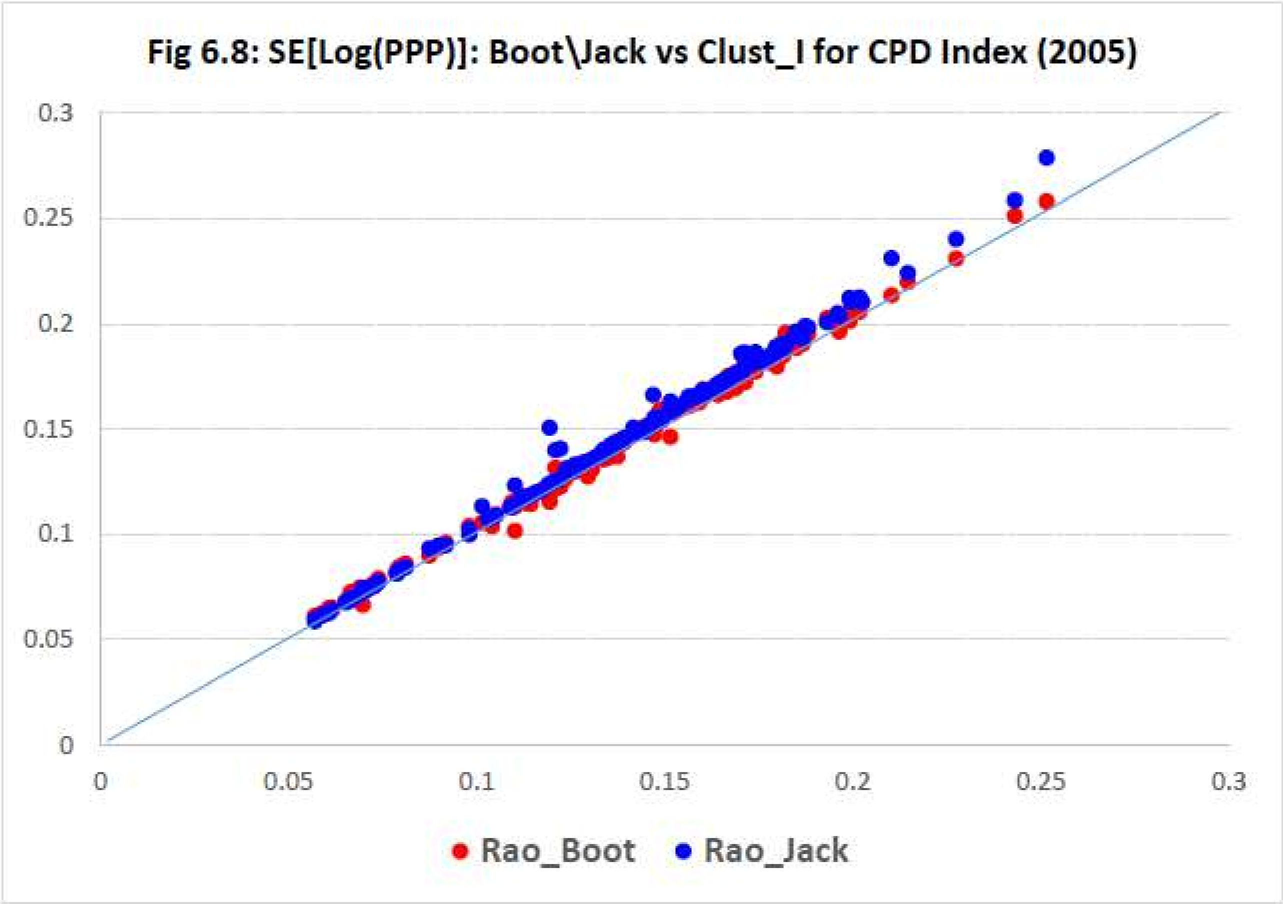
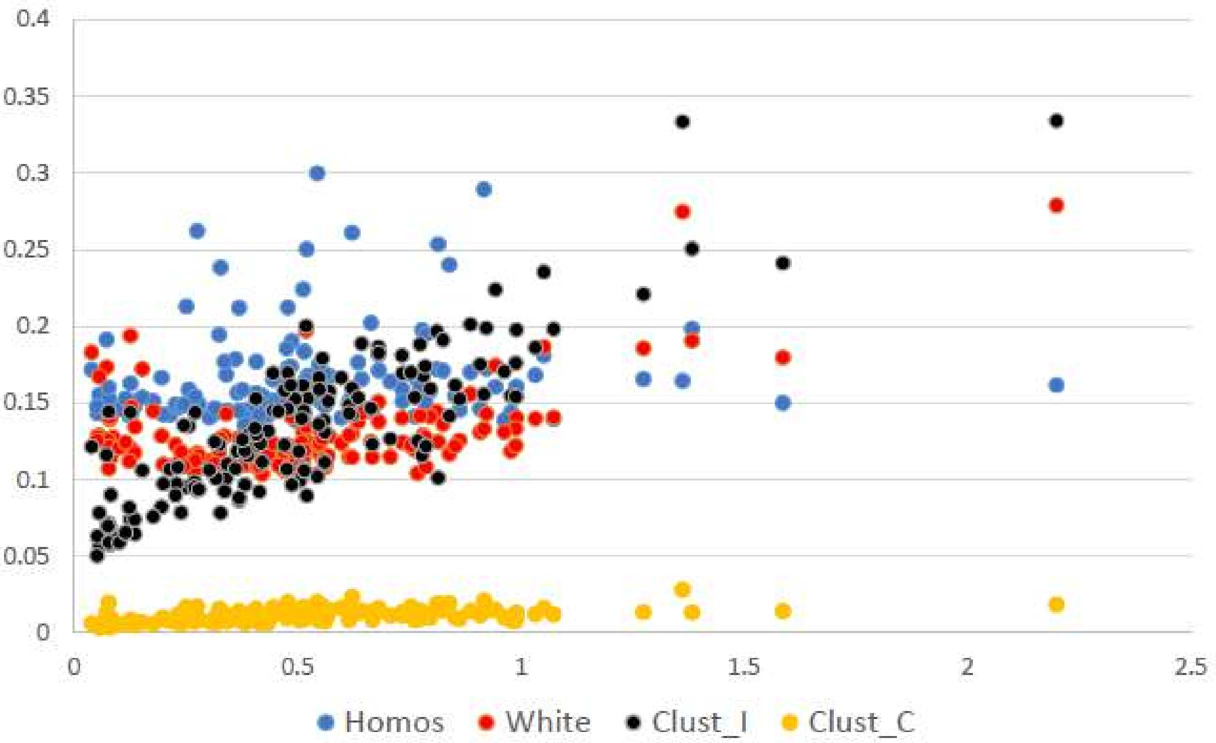


Fig 6.8: SE[Log(PPP)]: Boot\Jack vs Clust_I for CPD Index (2005)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.05
0.1
0.15
0.2
0.25
0.3
Rao_Boot
Rao_Jack

Fig 6.5-Standard Error of Log(PPP) vs LPS for Ikle (2005)



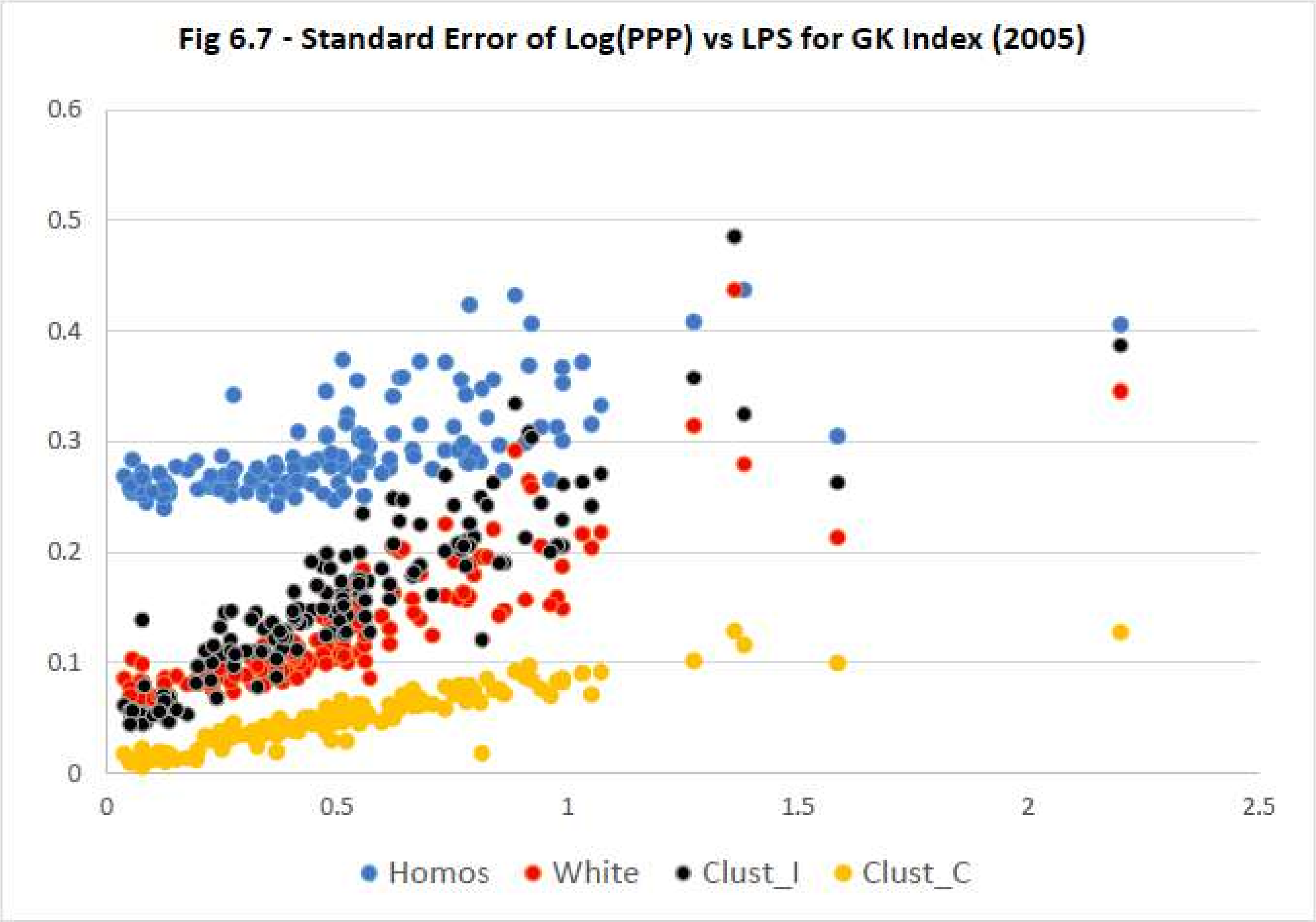


Fig 6.7 - Standard Error of Log(PPP) vs LPS for GK Index (2005)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
Homos
White
Clust_I
Clust_C

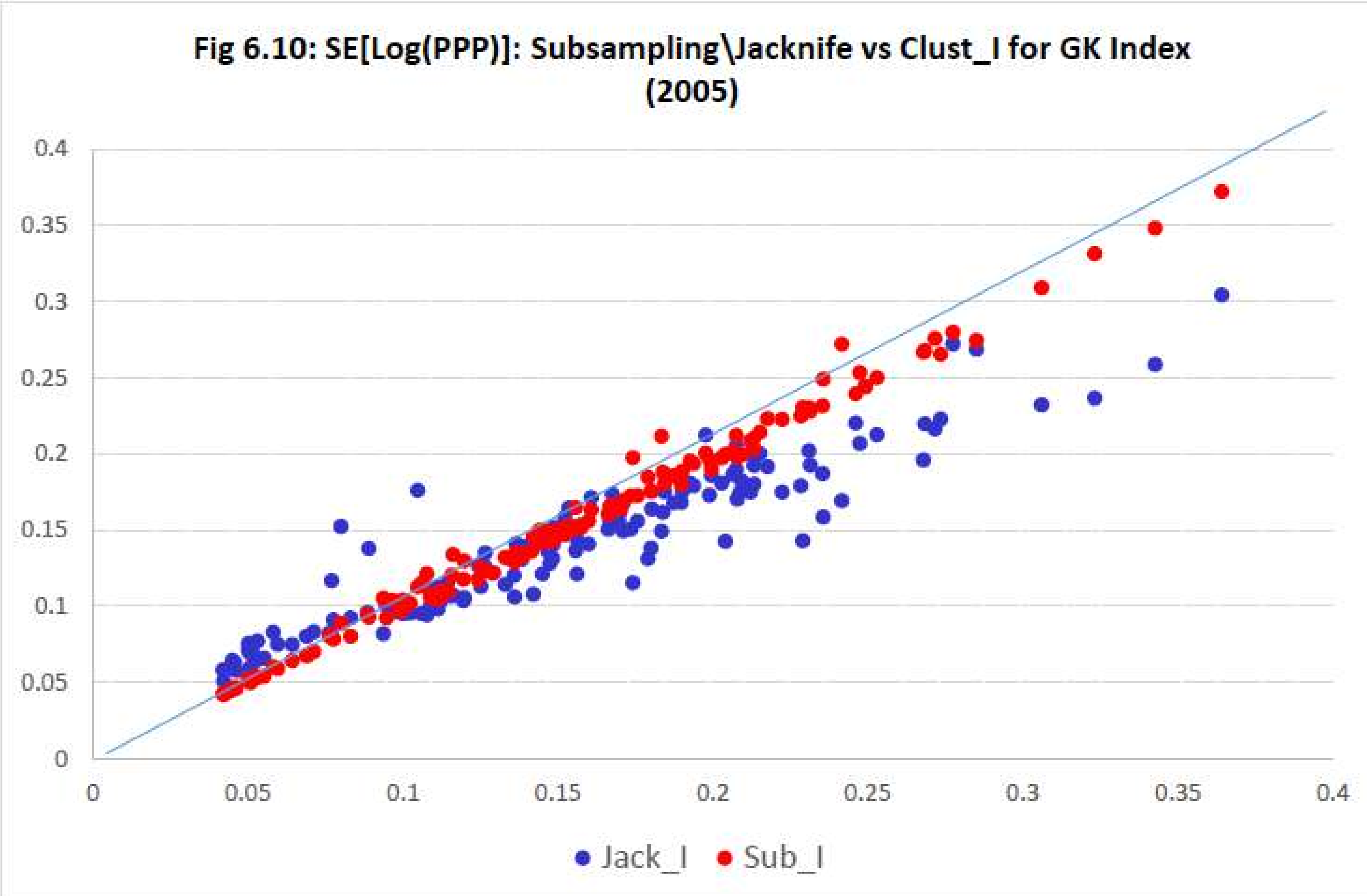


Fig 6.10: SE[Log(PPP)]: Subsampling\Jacknife vs Clust_I for GK Index (2005)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Jack_I
Sub_I

Adjustment for quality differences

Ones of the basic principles for ICP is to ensure comparability of products priced so that the estimated purchasing power parities reflect price level differences.

- **Strike a balance between comparability and representativity**
- **Use of *structured product descriptions* (SPDs) for products to be priced**

Despite attention to various price determining characteristics it is difficult to capture all aspects of quality differences – especially for services

SPDs for Train travel

Item Code	110732101	110732102	110732103	110732104	110732105
Item Name	Urban (city) bus, 5-15 km	Urban (city) bus, monthly	Interurban (InterCity) bus, 50 km	Interurban (InterCity) bus, 150 km	Interurban (InterCity) bus, 350 km
Quantity	1	1	1	1	1
Unit of measurement	Ticket	Ticket	Ticket	Ticket	Ticket
Transportation Type	Urban bus	Urban bus	Urban bus	Urban bus	Urban bus
Ticket type	One way fare, for adult passenger	Monthly pass, for adult passenger	One way fare, for adult passenger	One way fare, for adult passenger	One way fare, for adult passenger
Distance	5 - 15 Km	Not relevant	50 km	150 km	350 km
Time	Working day	Not relevant	Working day	Working day	Working day
Starting point	Survey city center	Not relevant	Survey city center	Survey city center	Survey city center
Price includes					
Exclude	Price reductions (such as discount or special offer only for best customers)	Extended services outside of urban area	Price reductions (such as discount or special offer only for best customers)	Price reductions (such as discount or special offer only for best customers)	Price reductions (such as discount or special offer only for best customers)
Reference quantity	1	1	1	1	1
Reference unit of measurement	Ticket	Ticket	Ticket	Ticket	Ticket

Japan-USA Bilateral Comparison

We made first attempt to quantify the extent of quality differences in services in the context of Japan-USA comparison.

- **We use a survey approach to estimate how much Japanese and US consumers are willing to pay (WTP)for quality of services.**
- **Using survey responses and after econometric estimation of WTP, we use Sato-Vartia index to construct a bilateral price index adjusting for quality differences.**

Service Sector Comparisons
Main Results

	with real estate	w.o. real estate
Sato_Vartia_PPP_ICP (US/JPN)	113	95
RMWTP_Japn_SV	1.10	1.09
RMWTP_US_SV	1.07	1.06
Geometric Mean of RMWTP (JPN/US)	1.08	1.09
PPP Quality Adjusted (US/JPN)	104	88
Per Capita Quantity Index Based on ICP (JPN/US)	0.46	0.33
Per Capita Quantity Index Quality Adjusted (JPN/US)	0.50	0.36
Total Value Added of Japan (trillion yen)	113	53.1
Total Value Added of the US (trillion $)	5.44	4.27
Note: Data of PPP and Total Value Added are taken from ICP's tables of Basic Heading 2014.		
SV stands for Sato-Vartia Index		

What are the implications for ICP?

- In the case of Japan-USA comparisons we need to make a downward adjustment for Consumption PPP – probably around 8%. And subsequent adjustments for PPP at the GDP level and revisions to estimates of the size of the Japanese economy will be necessary.
- If the size of adjustment for quality is around 8% for Japan, it is likely that larger adjustments are necessary for PPPs for countries like China and India and even larger adjustments for countries in Africa – could be to the tune of 20% or more!
  - Price levels for these countries need to be revised upwards
  - Reduction in the size of the economies
  - More importantly, this may have a major implications for estimates of extreme poverty.

What are the implications for ICP?

- Quality adjustment for PPPs is indeed necessary. We need to find cost-effective ways of adjusting for quality differences.
  - We are currently planning to conduct a further study involving China, Japan and USA (jointly with Dong Qiu and Yafei Wang)
  - Objective is to test the consistency of WTP estimates in a trilateral comparison.
  - This approach is resource intensive and not feasible on a large scale.
- The effect of revisions to PPPs on estimates of extreme poverty are of a concern.
  - My view on this is that this type of quality adjustment is not necessary when it comes to poverty work.
  - Poor people may be least concerned about frequency, punctuality or cleanliness – all they are concerned about the price they need to pay to travel from place A to place B.

What are the implications for ICP?

The main implications are:

1. **Maintain current approach and use PPPs for poverty work.**
2. **For making comparisons of real per capita GDP and standards of living, it is necessary to find ways of making adjustments for quality differences.**
   - Implications are that price levels will be higher for low income countries
   - Real per capita income will be lower.

Spatial chaining and implications for ICP

Shortest Path (SP) Approach

- **The basic premise here is that the best way to make comparison between two countries is *not necessarily the direct binary comparison.***
- **The GEKS procedure assumes that direct binary comparison is the best and provides a method to derive transitive indices which are closest to the binary indices**
- **Note that Robert Hill's earlier MST approach may lead to comparisons between countries which are worse than the original binaries.**
- **In principle, the SP approach identifies the best possible comparison between any pair of countries.**

Shortest Path (SP) Approach - Continued

- **For any chained path between two countries *b* and *k* given by $\{i_1, i_2, \ldots, i_m\}$, we define the total distance based on the distance measure as:**

$$D_{bi_1} + D_{i_1 i_2} + \ldots + D_{i_{m-1} i_m} + D_{i_m k}$$

- **Then the shortest path between two countries *b* and *k* is computed as:**

$$SP_{bk} = \min_{j,l,\ldots,m} \left\{ D_{bj} + D_{jl} + \ldots + D_{mk} \right\}$$

- **Given a matrix of distances, the shortest path can be computed using Dijkstra's algorithm**

Shortest Path Binary Price Comparisons – Axiomatic Properties

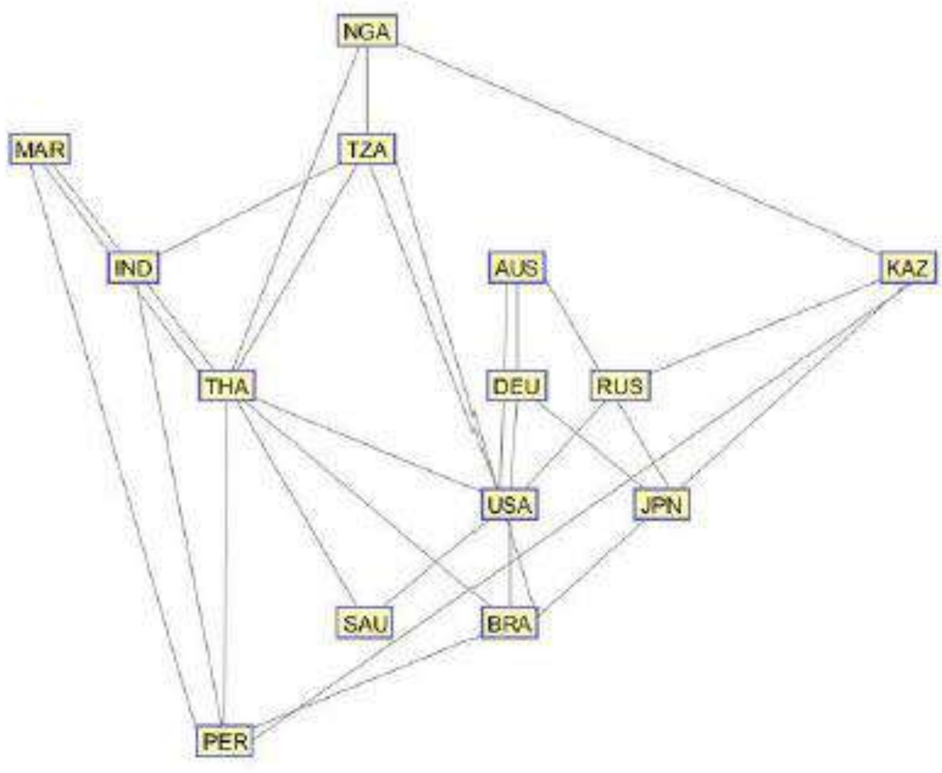
- The shortest path chained Fisher binary index defined as follows:

$$SP(P^F_{bk}) = P^F_{bj} \times P^F_{jl} \times \cdots \times P^F_{mk}.$$

- This binary index satisfies the following standard index number axioms.
  - Identity Axiom
  - Proportionality in Current prices
  - Inverse proportionality in Base prices
  - Commensurability – Invariance to Changes in the Units of Measurement
  - Monotonicity in current prices
  - Monotonicity in base prices
    - Monotonicity can be shown for LPS based shortest path comparisons
    - For WRPD measures, monotonicity holds only if the chain is unchanged

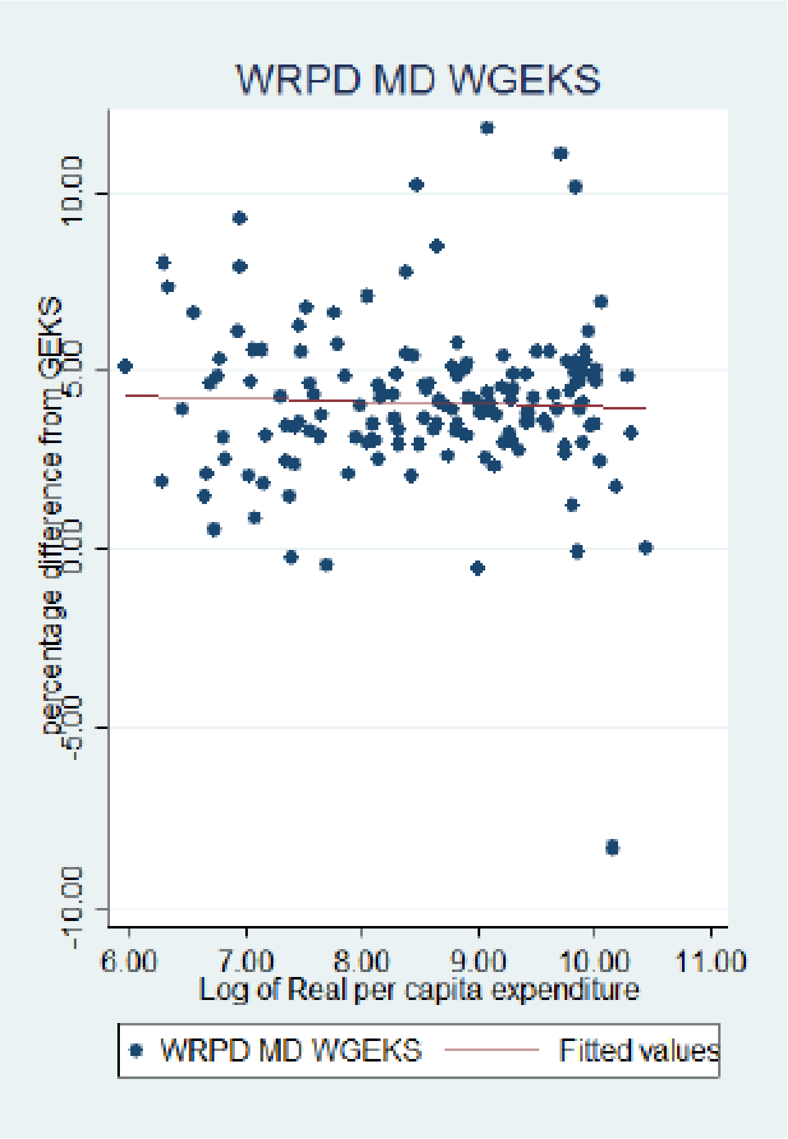
Implications for ICP

Number of countries = 14
Total number of possible links = 91
Number of links in the shortest path = 22



This means that a number of unreliable binary comparisons are no longer included in constructing PPPs

Implications for ICP?



This means that the shortest-path approach

- **revises PPP's downwards**
- **price levels go down, and real per capita GDP increases**
- **estimates of extreme poverty are revised downwards.**

100(GEKS - PPP Method)/GEKS

Number of Shortest paths without External links

LPS	Total bilaterals	Shortest paths without external countries
Africa	1225	150
Asia Pacific	253	43
CIS	36	6
EU-OECD	1035	101
Latin America	120	53
West Asia	55	14
W1		
Africa	1225	564
Asia Pacific	253	127
CIS	36	15
EU-OECD	1035	324
Latin America	120	75
West Asia	55	22

Proportion of Shortest paths without External links

LPS	
0.122	Africa
0.170	Asia-Pacific
0.167	CIS
0.098	OECD-Eurostat
0.442	Latin America
0.255	West Asia
WRPD1	
0.460	Africa
0.502	Asia-Pacific
0.417	CIS
0.313	OECD-Eurostat
0.625	Latin America
0.400	West Asia

Implications for ICP

In addition to this table we also find that

$$PPP_{USA,Jap}^{Lasp} < PPP_{USA,Jap}^{Paasche}$$

which suggests that USA-Japan direct comparisons is not a good one.

This table suggests that OECD-Eurostat is probably not a good region to make price comparisons. In particular, OECD consists of countries from different geographical regions.

- **My proposal from this work is to redistribute OECD countries to their respective regions for purpose for ICP. For example, include Japan, Korea, Australia and New Zealand in the Asia-Pacific comparisons.**
- **Once the world comparisons are finalized, tables for OECD countries can be constructed from global comparisons.**
- **This approach will eliminate the current asymmetry – all regions except OECD are geographical. It is consistent with the spirit of regionalization of ICP.**

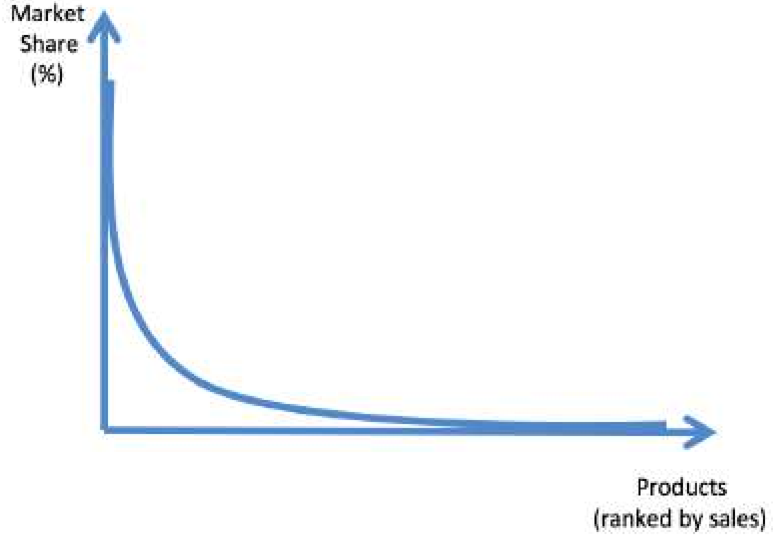
Scanner Data and Basic Heading PPPs

Scanner Data and Basic Heading PPPs

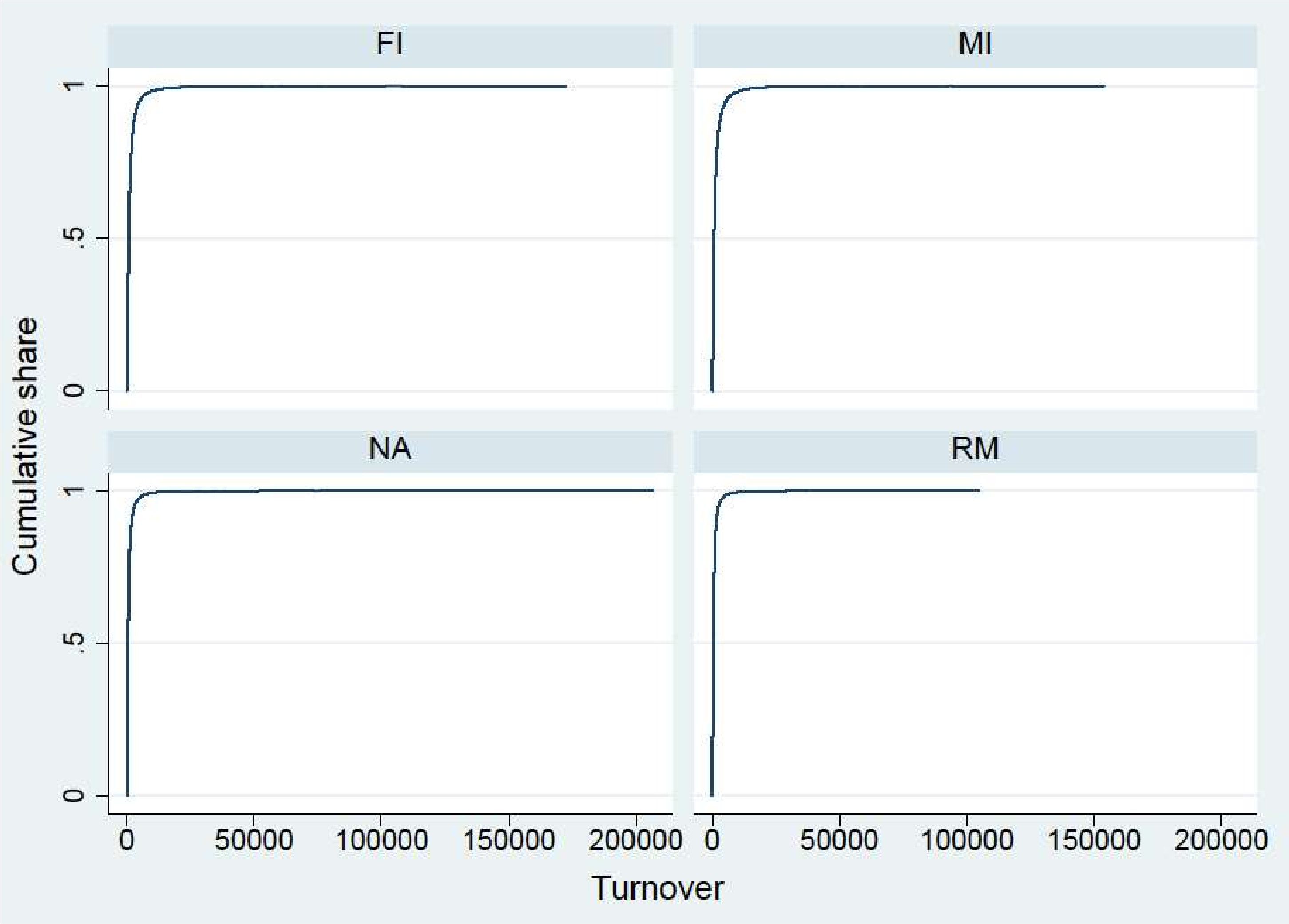
- **Within the current ICP Framework, we have only price data at the basic heading level.**
- **CPD method is used to aggregate price data supplied by the countries.**
- **Countries do not usually supply price data for all the items.**
- **Not all items priced are representative or important.**
- **The current recommendation is to run Weighted CPD with weights 3:1 for items considered important.**
  - **Are these weights ad hoc?**
  - **Will higher weights perform better?**
  - **What if importance is not identified properly?**

We can provide answers to these questions if we have scanner data. Scanner data records data on both prices and quantities at the point of sale.

(a) Product market share (% of sales)



Cumulative Market Share by GTIN for Pasta products: Largest to Smallest



Which set of weights are the best?

Root Mean Squared Deviations

Basic heading		Importance Weights				
		3:1	5:1	10:1	100:1	1000:1
Rice		0.018588	0.018912	0.019225	0.019560	0.019596
Olive Oil		0.018984	0.018975	0.019098	0.019332	0.019361
Breakfast Cereal		0.014924	0.015079	0.015260	0.015475	0.015500
Mineral Water		0.026569	0.026846	0.027200	0.027681	0.027739
Eggs		0.03616	0.03678	0.03754	0.03853	0.03865

All products accounting up to 95% of market share are designated as important products.

PPPs with importance weights are compared with Expenditure Weighted CPD

Which set of weights are the best?

Root Mean Squared Deviations

Basic heading	Importance Weights				
	3:1	5:1	10:1	100:1	1000:1
Olive Oil	0.016587	0.015497	0.014580	0.013879	0.013826
Breakfast Cereal	0.017192	0.018332	0.019742	0.022040	0.022390
Mineral Water	0.029032	0.029760	0.030332	0.030831	0.030891
Eggs	0.042613	0.045535	0.049121	0.05497539	0.05586209

Importance is accorded randomly.

PPPs with importance weights are compared with Expenditure Weighted CPD

Which set of weights are the best?

Our experiments with scanner data lead to the following conclusions:

- **Quantity weighted CPD does not perform well.**
- **For most basic headings, importance weights 3:1 appear to produce results that are the closest expenditure share weighted CPD.**
- **When we accord importance randomly:**
  - **weights 3:1 still appear to perform well**
  - **but RMSD increases**
  - **for Olive Oil the results are a little strange.**
- **The main conclusion is that in the absence of scanner data, using 3:1 weights is not a bad approximation.**

Construction of Consistent Panels of PPPs

ICP Benchmarks – country participation

ICP Phase	Benchmark year	No. of participating countries
I	1970	10
II	1973	16
III	1975	34
IV	1980	60
V	1985	64
VI	1993	117
VII	2005	146
VIII	2011	177

OECD and Eurostat compile PPPs for their member countries every three years

Main Sources of PPPs

- PPPs from ICP benchmark studies
  - Compiled periodically, roughly once in 5 years
  - The 2011 round of ICP completed in 2014
- World Development Indicators (WDI)
  - Mainly extrapolations from the latest benchmark using movements in national deflators
- Penn World Tables – “gold standard”
  - Available since 1980’s
  - Covers 150 countries and a 60-year period
  - Major methodology changes implemented in Version 8.0
  - Extrapolations of benchmark PPPs
    - Uses benchmark information for interpolation between benchmarks
    - Uses movements in national price levels
  - Summers and Heston (1991) and Heston, Summers and Aten (2001) – are among the most cited

UQICD Approach

- **Use all available benchmark information – an unbalanced panel**
- **Set up an econometric model to predict PPP_i *combining ICP benchmark with other available information***
- **Write it in a state-space form**
- **Use a Kalman filter and smoother to produce predictions and associated standard errors**

PPP data from ICP

Sources of information for $p_{it} = ln(PPP_{it})$

1. ICP Benchmark PPPs: Observation of the variable of interest contaminated with noise
2. A Model Derived from the Theory of Price Levels: Links national level data to variable of interest.
3. Derived growth rates from movements in national price levels: Links national accounts data to variable of interest
4. Reference Country Definition: A restriction that must hold, $p_{reference\ country,\ t} = 0$

PPP Data from ICP

- **Surveys are very resource intensive,**
  - **Carried out by national statistical agency of those countries that participate in the ICP.**
  - **Internationally comparable basket is priced**
- **We can then write**

$$\tilde{p}_{it} = p_{it} + \xi_{1it}$$

where,

$\tilde{p}_{it}$ ICP benchmark observation for participating country i at time t

ξ_{1it} is a random error accounting for measurement error.

Theory of Price Levels

National price level ratio or "E*xchange rate deviation index*":

$$R_{it} = \frac{PPP_{it}}{ER_{it}}$$

ER_{it} exchange rate of currency of country *i* at time *t*,
(Kravis and Lipsey 1983 and 1986; Clague, 1988; Bergstrand, 1996)

- **Most developed countries $R_i \approx$ unity**
- **Most developing countries $R_i \ll$ unity.**

The fact that price levels in low income countries are low is known as the Penn Effect. Samuelson-Balassa hypothesis suggests an economic model predicting the Penn Effect based on the assumption that productivity varies more by country in the traded goods sectors than in other sectors.

The Theory of Price Levels

National Price Level differences (or exchange rate deviation index – PPP/Xr) are due to:

Productivity differences in traded and non-traded goods sectors across developed and developing countries.

Some of the primary drivers of Price Levels:

Size of the agriculture sector in the economy, openness, educational attainment, share of exportable services (such as tourism), resource abundance, size of the population, trade balance.

Regression model: Price levels

$$r_{it} = \mathbf{x}'_{it}\boldsymbol{\beta}_{it} + u_{it}$$

where,

$r_{it} = \ln(PPP_{it} / ER_{it})$; $\mathbf{x}'_{it}$ a set of conditioning variables

$\boldsymbol{\beta}_{it}$ a vector of parameters

u_{it} a random disturbance with specific distributional characteristics

We obtain a prediction:

$$\hat{p}_{it} = \mathbf{x}'_{it}\hat{\boldsymbol{\beta}}_{it} + \ln(ER_{it})$$

Updating PPPs over time

- **We assume some measurement error exists in national accounts and thus use**

$$PPP_{i,t} = PPP_{i,t-1} \times \frac{GDPDef_{i,[t-1,t]}}{GDPDef_{US,[t-1,t]}}$$

- **to define:**

$$p_{it} = p_{i,t\text{-}1} + c_{it} + \eta_{it}$$

where,

$$c_{it} = \ln\left(\frac{GDPDef_{i,[t,t-1]}}{GDPDef_{US,[t,t-1]}}\right)$$

η_{it} is a random error accounting for measurement error in the growth rates

Normalisation

- **The definition of PPP requires a choice reference country.**
- **The reference country is defined to have a PPP = 1 for all time periods.**
- **US is taken as the reference country, so**

$$p_{US,t} = 0$$

Econometric Model - Assumptions

a) **The errors in the regression relationship (4) are assumed to be spatially correlated**

$$\mathbf{u}_t = \phi \mathbf{W}_t \mathbf{u}_t + \mathbf{e}_t \qquad \phi < 1 \text{ and } \mathbf{W} \; (N \times N) \text{ is a spatial weights matrix}$$

b) **measurement errors in the observation of benchmark *PPP*$_{it}$ are heteroskedastic**

$$E(\xi_{1it}^2) \; = \; \sigma_\xi^2 V_{it} \qquad \sigma_\xi^2 \text{ is a constant of proportionality}$$

c) **measurement error in the growth rates are heteroskedastic**

$$\mathrm{E}\left(\eta_{it}^2\right) = \sigma_\eta^2 V_{it} \qquad \sigma_\eta^2 \text{ is a constant of proportionality}$$

$v_{ii,t}$ is an inverse measure of development of country *i*

A State-Space Representation

We can combine the model and sources of information into a state-space model:

1. **Observation Equations**

$$\mathbf{y}_t = \mathbf{Z}_t p_t + \mathbf{B}_t \mathbf{X}_t \theta + \zeta_t$$

2. **Transition Equations: show the evolution of the state variable over time**

$$\mathbf{p}_t = \mathbf{p}_{t\text{-}1} + \mathbf{c}_t + \boldsymbol{\eta}_t \qquad \mathrm{E}\left(\boldsymbol{\eta}_t \boldsymbol{\eta}_t'\right) \equiv \mathbf{Q}_t = \sigma_\eta^2 \mathbf{V}_t$$

V_t is diagonal and captures the extent of measurement error in the national accounts

More developed countries are assumed to collect the data more accurately.

"UQICD" – a new website for Panels of PPP

- **The URL for the website is: https://uqicd.economics.uq.edu.au**

  Rao, D. S. P. and Rambadi, A. N. (2014). *UQICD v2 User Guide.* The University of Queensland, https://ideas.repec.org/p/qld/uq2004/534.html.

- **The website has useful information apart from panel of PPPs.**
  - **Extrapolated PPPs (unconstrained) with SE's**
  - **Extrapolated PPPs with deflator constrained with SW's**
  - **Population, exchange rates**
  - **Real GDP per capita at current prices using PPPs**
  - **Real GDP at constant prices**
  - **PPPs and Real GDP for components**
  - **Nominal GDP (in local currency) at current and constant prices**

“UQICD” – features in the next version

- The next version of UQICD will represent a quantum leap from existing extrapolations.
- We plan to include measures of global and regional growth and inflation over time.
    - PPP based measures
    - Exchange rate measures
    - Role of PPP and Exchange rate movements on global inflation
- Panels of income distributions
    - Basic data collected
    - Recover income distributions from limited data
    - Make available a menu of options for users
        - different income distributions
            - log-normal, mixture of lognormal; Dagum distribution and mixture of Pareto-lognormal
            - Estimates of parameters and quantities of interest
            - Density and distribution functions