Who Shrunk China? Puzzles in the Measurement of Real GDP

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- Compare:
  - Nominal GDP p.c. (i.e., converted at nominal exchange rates): $1,721
    - By convention, real GDP priced in U.S. dollars
- Where do the numbers come from?
  - National data: Annual, from national accounts
  - International data: Every five years or so, from successive rounds of the International Comparison Program (ICP)
    - World Bank (2007): Extrapolated from pre-2005 ICP rounds
    - World Bank (2008): Based on the 2005 ICP
  - Penn World Tables (PWT) also based on ICP

The Suspects

[Deaton and Heston (2010)]

- Chinese price data biased towards urban areas
  - National price level biased upwards implies real GDP biased downwards
  - PWT 7.0 adjusted Chinese prices downwards by 20%
- Different index-number formulae imply different results
  - ICP and World Bank use GEKS
  - PWT uses Geary-Khamis ("GK")
- Different methods of linking countries imply different results
  - ICP and World Bank: Compute real GDP for regions first, then use "link" countries to connect regions
  - PWT and here: Compute real GDP over all countries simultaneously
- Different concepts of real GDP
  - Digression: Most uses of PWT are for growth regressions
  - BUT: Most index-number theory, and the method of construction of PWT, is for consumption/expenditure
  - Biases go in different directions:
    - Consumers substitute *away from* higher-priced goods
    - Producers substitute *towards* higher-priced goods

Our Contribution

- Quantify the Deaton-Heston explanations
- Systematically compare different index-number formulae
- New results on measuring "true" GDP
- Bottom line: We estimate a lower bound of $5,349, 30% more than World Bank (2008)

Related Literature

- Index Number Classics
  - GK System: Geary (*JRSS* 1958), Khamis (*JRSS* 1962)
  - GEKS Index: Gini (1924), Eltetö-Köves (1964), Szulc (1964)
  - CCD Index: Caves-Christensen-Diewert (*Em* 1982, *EJ* 1982)
  - "True" Indexes: Konüs-Byushgens (1926), Diewert (*JEm* 1976)
- Precursors
  - GAIA System: Neary (*AER* 2004), Feenstra-Ma-Rao (*MacDyn* 2009)
  - GK applied to GDP: Feenstra-Heston-Timmer-Deng (*REStats* 2009)
- Data
  - PWT: Summers-Heston (*QJE* 1991)
  - PWT 8.0: Feenstra-Inklaar-Timmer (2012)

Outline of the Talk

1. Real Consumption
2. Real GDP on the Expenditure Side
3. Real GDP on the Output Side
4. Summary and Conclusion

Outline of the Talk

The GK System

Reference prices for goods:

$$\pi_i^e = \frac{\Sigma_{j=1}^{C}(p_{ij}/PPP_j^e)q_{ij}}{\Sigma_{j=1}^{C} q_{ij}}, \quad i = 1, \ldots, M$$

Purchasing Power Parities for countries:

$$PPP_j^e = \frac{\Sigma_{i=1}^{M} p_{ij} q_{ij}}{\Sigma_{i=1}^{M} \pi_i^e q_{ij}}, \quad j = 1, \ldots, C$$

Real consumption for countries:

$$\Sigma_{i=1}^{M} \pi_i^e q_{ij} = \frac{\Sigma_{i=1}^{M} p_{ij} q_{ij}}{PPP_j^e}, \quad j = 1, \ldots, C$$

- PRO: Aggregates consistently across countries and goods [PWT]
- CON: Fixed weights; assumes no substitution in consumption
  - So: "Gerschrenkron Effect": Using a different set of prices *over*-estimates a country's real consumption
  - Recall: Using nominal exchange rates *under*-estimates poor countries' real consumption

Consumption: US versus China

Country	Nominal Consump. per capita	Consumption Indexes
		Geary-Khamis
US	100	100
China	2.3	6.0

Fisher and GEKS Indexes

Fisher quantity index:

$$Q_{jk}^F \equiv \left(Q_{jk}^L Q_{jk}^P\right)^{0.5} = \left(\frac{\sum_{i=1}^M p_{ij}q_{ij}}{\sum_{i=1}^M p_{ij}q_{ik}} \frac{\sum_{i=1}^M p_{ik}q_{ij}}{\sum_{i=1}^M p_{ik}q_{ik}}\right)^{0.5}, \quad j,k = 1,2,\ldots,C$$

- PRO: "Exact": Equals the true price index for some preferences
  - Konüs-Byushgens (1926): Homogeneous quadratic utility function
- CON: Bilateral only: intransitive
  - Deaton-Heston: Maybe the best we can hope for in intl. comparisons?

GEKS [Multilateral Fisher]:

$$Q_{jk}^{GEKS} = \prod_{l=1}^{C} \left(Q_{jl}^F Q_{lk}^F\right)^{1/C}, \quad j,k = 1,2,\ldots,C$$

- PRO: Transitive (by construction)
- CON: Exact only when Fisher is exact

Törnqvist and CCD Indexes

Törnqvist quantity index:

$$Q_{jk}^T = \prod_{i=1}^{M} \left(\frac{q_{ij}}{q_{ik}} \right)^{\frac{s_{ij}+s_{ik}}{2}} \quad \text{where:} \quad s_{ij} = \frac{p_{ij}q_{ij}}{\sum_{i=1}^{M} p_{ij}q_{ij}}, \quad j,k = 1,2,\ldots,C$$

- PRO: "Exact" for translog distance function
  - Diewert (1976): Non-Homogeneous
- CON: Bilateral only: intransitive

CCD [Multilateral Törnqvist]:

$$Q_{jk}^{CCD} = \prod_{l=1}^{C} \left(Q_{jl}^T Q_{lk}^T \right)^{1/C}, \quad j,k = 1,2,\ldots,C$$

- PRO: Transitive (by construction)
- CON: Exact only when Törnqvist is exact *and* tastes are homothetic

Consumption: US versus China

Country	Nominal Consump. per capita	Consumption Indexes			
		Geary-Khamis	Fisher	GEKS	CCD
US	100	100	100	100	100
China	2.3	6.0	6.0	5.6	5.7

Expenditure Function Approach

Multilateral Allen (1949) quantity index [Neary (2004)]:

$$Q_{jk}^A = \frac{e(\pi, u_j)}{e(\pi, u_k)}, \qquad e(\pi, u_j) = \sum_{i=1}^{M} \pi_i q_{ij}^*$$

Issues in implementing this:

1. Choice of $e(\pi, u)$:
   - Here: AIDS [Deaton-Muellbauer (1980)]

$$\log e(p, u) = \alpha_0 + \alpha' \ln p + \tfrac{1}{2} \sum_{i=1}^{M} \sum_{j=1}^{M} \gamma_{ij} \ln p_i \ln p_j + b(p) \ln u,$$

$$b(p) = \eta \textstyle\prod_i p_i^{\beta_i}$$

$$\Rightarrow \frac{e(\pi, u_j)}{e(\pi, u_k)} = \left(\frac{u_j}{u_k} \right)^{b(\pi)}$$

   - Easy to switch from one reference price vector π^A to another π^B:

$$\frac{e(\pi^B, u_j)}{e(\pi^B, u_k)} = \left[\frac{e(\pi^A, u_j)}{e(\pi^A, u_k)} \right]^{b(\pi^B)/b(\pi^A)}$$

Expenditure Function Approach: Choice of π

2. Choice of reference prices π:
   1. GK prices
   2. GAIA ("Geary-Allen International Accounts") prices:

$$\pi_i^{GAIA} = \frac{\Sigma_{j=1}^{C}(p_{ij}/PPP_j^*)q_{ij}}{\Sigma_{j=1}^{C} q_{ij}^*}, \quad i = 1, \ldots, M$$

$$PPP_j^* = \frac{\Sigma_{i=1}^{M} p_{ij} q_{ij}}{\Sigma_{i=1}^{M} \pi_i^{GAIA} q_{ij}^*} = \frac{e(p_j, u_j)}{e(\pi^{GAIA}, u_j)}, \quad j = 1, \ldots, C$$

   3. Diewert prices [Barnett, Diewert and Zellner (2009)]:

$$Q_{jk}^D = \left[\prod_{l=1}^{C} \frac{e(p_l, u_j)}{e(p_l, u_k)} \right]^{1/C}$$

$$\text{AIDS:} \quad Q_{jk}^D = \left[\prod_{l=1}^{C} \left(\frac{u_j}{u_k} \right)^{b(p_l)} \right]^{1/C} = \left(\frac{u_j}{u_k} \right)^{\Sigma_{l=1}^{C} b(p_l)/C}$$

$$\Rightarrow \quad b(\pi^D) = \frac{1}{C} \sum_{l=1}^{C} b(p_l)$$

Actual and Reference Prices

Table 3: Actual and Reference Prices

Category	Sample Mean	United States	Geary-Khamis	Neary, GAIA	South Korea
Food and non-alcoholic beverages	1	1.100	0.922	0.800	1.627
Alcoholic beverages and tobacco	1	1.395	0.872	0.587	1.162
Clothing & footwear	1	1.136	0.852	0.670	1.257
Gross rent, water, fuel and power	1	1.889	1.034	0.820	1.446
Household furnishings	1	1.302	0.898	0.589	0.988
Medical and health services	1	2.995	1.082	4.023	1.047
Transport	1	0.950	0.772	0.953	1.023
Communication	1	1.128	0.722	0.816	0.641
Recreation	1	1.231	0.788	0.663	1.121
Education	1	3.412	1.023	1.298	1.602
Restaurants	1	1.025	0.797	0.802	1.310
Other goods and services	1	1.632	1.000	1.000	1.215
$b(p)$	1	1.054	0.992	1.053	0.930

Source: Authors' calculations using 2005 ICP benchmark program data.

Consumption: US versus China

Country	Nominal Consump. per capita	Consumption Indexes				Using AIDS expenditure function and reference prices from:		
		Geary-Khamis	Fisher	GEKS	CCD	Geary-Khamis	GAIA	Diewert
US	100	100	100	100	100	100	100	100
China	2.3	6.0	6.0	5.6	5.7	5.4	4.5	5.4

Real Consumption 2005

Countries	Nominal consump. per capita	Consumption Indexes				Using AIDS expenditure function and reference prices from:		
		Geary-Khamis	Fisher	GEKS	CCD	Geary-Khamis	Neary, GAIA	Diewert
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
United States	100	100	100	100	100	100	100	100
%diff from GEKS		0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	89.5	77.5	76.6	79.3	80.7	77.9	76.7	77.9
%diff from GEKS		-2.27	-3.40	0.00	1.77	-1.77	-3.28	-1.77
Ireland	84.3	64.0	65.4	66.2	64.8	66.4	64.8	66.5
%diff from GEKS		-3.32	-1.21	0.00	-2.11	0.30	-2.11	0.45
Netherlands	75.6	70.6	70.2	72	73.6	69.8	68.2	69.9
%diff from GEKS		-1.94	-2.50	0.00	2.22	-3.06	-5.28	-2.92
Canada	73.1	72.9	73.1	73.5	73.3	74	72.7	74.1
%diff from GEKS		-0.82	-0.54	0.00	-0.27	0.68	-1.09	0.82
Korea, Rep.	29.7	38.0	38.9	37.5	37.8	38.2	36	38.3
%diff from GEKS		1.33	3.73	0.00	0.80	1.87	-4.00	2.13
Macedonia	7.6	19.8	18.8	19.2	19.5	19.4	17.6	19.6
%diff from GEKS		3.13	-2.08	0.00	1.56	1.04	-8.33	2.08
China	2.3	6.0	6.0	5.6	5.7	5.4	4.5	5.4
%diff from GEKS		7.14	7.14	0.00	1.79	-3.57	-19.64	-3.57
India	1.4	4.9	4.7	4.6	4.7	4.7	3.9	4.7
%diff from GEKS		6.52	2.17	0.00	2.17	2.17	-15.22	2.17
mean of %diff from GEKS		2.330	0.211	0.000	0.833	-1.085	-11.727	-0.405
s.e. of the mean difference		(0.54)	(0.449)	(0.00)	(0.191)	(0.409)	(0.830)	(0.402)
Regression of index on GEKS		0.981	0.990	1.000	1.005	1.021	1.081	1.017
s.e. of slope coefficient		(0.004)	(0.005)	`(0.000)	(0.002)	(0.004)	(0.005)	(0.004)

Urban Price Bias

- 2005 Chinese price surveys restricted to 11 urban areas
- PWT 7.0 and Deaton-Heston assume Chinese urban prices uniformly 20% higher than average urban-rural prices
- We estimate the price bias directly:
  - Data for 22 developing Asian countries other than China
    - Dummy for Fiji
  - Estimate: $\ln \frac{p_{ij}}{e_j} = \alpha + \beta \ln Y_j + u_{ij}$
    - LHS: 2005 ICP price in dollars of commodity group i in country j
    - RHS: Real per capita income in country j - four measures

▸ Details

  - Results: Our preferred specification implies a price reduction of 25%!

Effects of Adjusted Prices

Country	Nominal Consump. per capita	Consumption Indexes				Using AIDS expenditure function and reference prices from:		
		Geary-Khamis	Fisher	GEKS	CCD	Geary-Khamis	GAIA	Diewert
US	100	100	100	100	100	100	100	100
China	2.3	6.0	6.0	5.6	5.7	5.4	4.5	5.4
with adjusted prices		7.4	7.3	6.8	6.9	6.6	5.5	6.6

Effects of Adjusted Prices

Method of adjusting Chinese prices	Consumption Indexes				Using AIDS expenditure function and reference prices from:		
	Geary-Khamis	Fisher	GEKS	CCD	Geary-Khamis	Neary, GAIA	Diewert
	(2)	(3)	(4)	(5)	(6)	(7)	(8)
20% reduction in prices	7.5	7.5	7.1	7.1	6.8	5.8	6.8
%diff from China in Table 1	25.0	25.0	26.8	24.6	25.9	28.9	25.9
Regression model 1	7.0	6.8	6.6	6.6	6.7	5.6	6.9
%diff from China in Table 1	16.7	13.3	17.9	15.8	24.1	24.4	27.8
Regression model 2	6.5	6.5	6.1	6.2	5.9	4.9	5.9
%diff from China in Table 1	8.3	8.3	8.9	8.8	9.3	8.9	9.3
Regression model 3	6.4	6.4	6.0	6.1	5.8	4.8	5.9
%diff from China in Table 1	6.7	6.7	7.1	7.0	7.4	6.7	9.3
Regression model 4	7.4	7.3	6.8	6.9	6.6	5.5	6.6
%diff from China in Table 1	23.3	21.7	21.4	21.1	22.2	22.2	22.2

Source: Authors' calculations using 2005 ICP benchmark program data and ADB (2007).

Summary: Real Consumption

- Using GK as in PWT rather than EKS as used by World Bank:
  - Raises Chinese real consumption
  - BUT: This reflects substitution bias
- Allowing for substitution using expenditure function methods *lowers* Chinese real consumption further
  - The mystery deepens!
- Correcting for urban bias of Chinese prices more than offsets this

Outline of the Talk

Real GDP on the Expenditure Side

- Consumption only one component of GDP
- Nominal GDP: $GDP_j = \Sigma_{l=1}^{M} p_{ij} q_{ij} + X_j - M_j$
  - Summed over *all* M final goods: consumption, investment, and government spending
- Real GDP in PWT:

$$RGDP_j^e = \frac{GDP_j}{PPP_j} = \sum_{l=1}^{M} \pi_i^e q_{ij} + \frac{X_j - M_j}{PPP_j}$$

- Feenstra-Inklaar-Timmer (2012):
  - Compute $RGDP_j^e$ for all 124 ICP countries in 2005
  - China: \$4,749, about 15% larger than World Bank estimate of \$4,088
  - Why?
    - Different index number formulae cannot account for this much
    - The missing culprit: Different methods of linking countries
  - Using adjusted consumption goods prices: \$5,349, a further 15% higher

Outline of the Talk

Real GDP on the Output Side

- Revenue or GDP Function for a competitive economy:

$$r_j(P_j, v_j) \equiv \underset{y_j \geq 0}{Max} \left[P_j' y_j : F_j(y_j, v_j) \leq 0 \right], \qquad y_j \equiv (q_j, x_j, -m_j)$$

- Real output measured at reference prices:

$$RGDO_j^*(\Pi) \equiv r_j(\Pi, v_j) \equiv \underset{y_j \geq 0}{Max} \left[\Pi' y_j : F_j(y_j, v_j) \leq 0 \right]$$

- We prove that a GK system of positive Π and PPP_j^0 exists
- Feenstra-Heston-Timmer-Deng (2009) estimate this system
  - Not so different from real GDP on the expenditure side
- BUT: This is a fixed-weight index and suffers from substitution bias
- . . . which in the production case, works in the right direction!
- Result: When j is a higher-income country than k:

$$\frac{RGDO_k^0(P_j)}{RGDO_j^0(P_j)} \leq \frac{r_k(P_j, v_k)}{r_j(P_j, v_k)}$$

Outline of the Talk

Summary and Conclusion

- Who Shrunk China?
  1. Substitution bias in consumption?
  2. Urban bias of Chinese prices?
  3. Different methods of linking countries?
  4. Different concepts of GDP?
  5. Substitution bias in production?

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Bias in wrong direction

Summary and Conclusion

- Who Shrunk China?
  1. Substitution bias in consumption? — Bias in wrong direction
  2. Urban bias of Chinese prices? — Major source of bias
  3. Different methods of linking countries?
  4. Different concepts of GDP?
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- How to make international comparisons?
  - Correcting for deviations from PPP essential
  - Different "true" index numbers give similar results
    - Choice should be based on theoretical considerations?
  - Different issues in comparisons of living standards and GDP

Thank you for listening. Comments welcome!

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