International Value-Added Linkages in Development Accounting

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1 Motivation and Outline

- **Development accounting:** quantitative assessment of the contribution of measurable production factors and unmeasurable "productivity" to income.

Benchmark aggregate production/income function:

$$Y_n = A_n K_n^{\alpha} H_n^{1-\alpha}$$

- **Main result:** cross-country variation in aggregate "productivity" (A_n) much more important than factor endowments (K_n, H_n) for understanding the cross-country variation in incomes.

1 Motivation and Outline

As of now, the answer to the development-accounting question — do observed differences in the factors employed in production explain most of the cross-country variation in income — is: ***no, way no.***

– Francesco Caselli, 2005,
"Accounting for Cross-Country Income Differences,"
Handbook of Economic Growth

1 Motivation and Outline

Aggregate income function in the open economy:

$$Y_n = F_n A_n K_n^{\alpha} H_n^{1-\alpha}$$

- F_n captures the price of n's output relative to the price of **all** outputs absorbed in n's final consumption. Depends on
  - bilateral "trade determinants": $\{\gamma_{n'n}\}_{n',n}$
  - all countries' factor endowments: $\{K_n, H_n\}_n$
  - distribution of expenditure: $\{T_n\}_n$

  ◂ Picture
- We calibrate a many-country trade model with data from the world input output database (WIOD) to back out F_n across 40 major economies.
- We perform counterfactuals illustrating the effect on countries' real incomes (via F_n) of changes in $\{T_n\}_n$ and $\{\gamma_{n'n}\}_{n',n}$.

1 Motivation and Outline

Preview of Results:

1. The standard development accounting framework attributes approx. 25% of the variation in incomes among our sample economies to measurable production factors, $\{K_n, H_n\}_n$.

2. Our augmented framework attributes at least 50% of the variation in incomes to "measurables", $\{K_n, H_n, F_n\}_n$.

   It reduces reliance on implied TFP, $\{A_n\}_n$, by more than half.

3. Counterfactuals consistent with earlier studies:
   - small "transfer effects". (Dekle et al. 2007, 2008)
   - sizeable gains from trade. (Waugh, 2010)

1 Motivation and Outline

Related Literature:

1. **Development accounting:**
   Hall and Jones (1999), Hsieh and Klenow (2010), Caselli (2005, 2015).
2. **Factor bias of technology in open economies:**
   Fadinger (2011), Morrow and Trefler (2014).
3. **International trade and income:**
   Eaton and Kortum (2002), Dekle et al. (2007, 2008), Waugh (2010), Feenstra et al. (2009, 2015).
4. **Income differences from domestic input-output structure:**
   Jones (2011), Fadinger et al. (2015), Grobovšek (2015).
5. **International input-output linkages and business cycles:**
   Bems, Johnson and Yi (2011), Johnson and Noguera (2012), Johnson (2013), Bems (2014), Duval et al. (2015).

1 Motivation and Outline

2 Model

Static many-country quantitative trade model:

1. Gains from trade due to Ricardian comparative advantage (*productivity differences*):
   1. Armington model ◂ Details
   2. Eaton-Kortum model ◂ Details
2. Production of goods is Cobb-Douglas in physical and human capital (physical capital share $\equiv \alpha$).
3. Constant elasticity of trade flows with respect to trade costs (trade elasticity $\equiv \theta$).
4. Country-n trade deficit is captured by "transfer" T_n; $\sum_n T_n = 0$.

Real GDP in country n (at consumer prices):

$$Y_n \equiv \frac{r_n K_n + w_n L_n}{P_n}.$$

2 Model

1) From Cobb-Douglas production:

$$r_n K_n + w_n L_n = \underbrace{\frac{1}{h_n^{1-\alpha}} \left(\frac{r_n}{\alpha}\right)^{\alpha} \left(\frac{w_n}{1-\alpha}\right)^{1-\alpha}}_{\equiv f_n} K_n^{\alpha} H_n^{1-\alpha}.$$

2) From Armington/Eaton-Kortum trade:

- Share of country-n' value added in country-n consumption:

$$v_{n'n} \equiv \frac{\gamma_{n'n} f_{n'}^{-\theta}}{\sum_{n'} \gamma_{n'n} f_{n'}^{-\theta}} \qquad \gamma_{n'n} > 0, \sum_{n'} \gamma_{n'n} = 1,$$

- Consumer prices:

$$P_n = \frac{1}{A_n} \left(\sum_{n'} \gamma_{n'n} f_{n'}^{-\theta} \right)^{-\frac{1}{\theta}},$$

where $\{\gamma_{n'n}\}_{n'n}$ captures determinants of bilateral trade.

2 Model

Expression for development accounting:

$$\ln y_n = \underbrace{\underbrace{\ln k_n^{\alpha} h_n^{1-\alpha}}_{\equiv \ln y_n^{ED}} + \underbrace{\ln \frac{f_n}{\left(\sum_{n'} \gamma_{n'n} f_{n'}^{-\theta}\right)^{-\frac{1}{\theta}}}}_{\equiv \ln F_n}}_{\equiv \ln y_n^{EL}} + \ln A_n$$

where $y_n = Y_n/L_n$, $k_n = K_n/L_n$.

2 Model

Value-added linkages:

$$v_{n'n} \equiv \frac{\gamma_{n'n} f_{n'}^{-\theta}}{\sum_{n'} \gamma_{n'n} f_{n'}^{-\theta}}. \tag{1}$$

Then:

$$f_n K_n^{\alpha} H_n^{1-\alpha} = \sum_{n'} v_{nn'} \left(f_{n'} K_{n'}^{\alpha} H_{n'}^{1-\alpha} + T_{n'} \right). \tag{2}$$

Choosing the factor cost of country N as the numeraire,

$$f_N = 1. \tag{3}$$

Given (1)-(3); values for α, θ; data $\{K_n, H_n, \{v_{n'n}\}_{n'}, T_n\}_n$, we can:

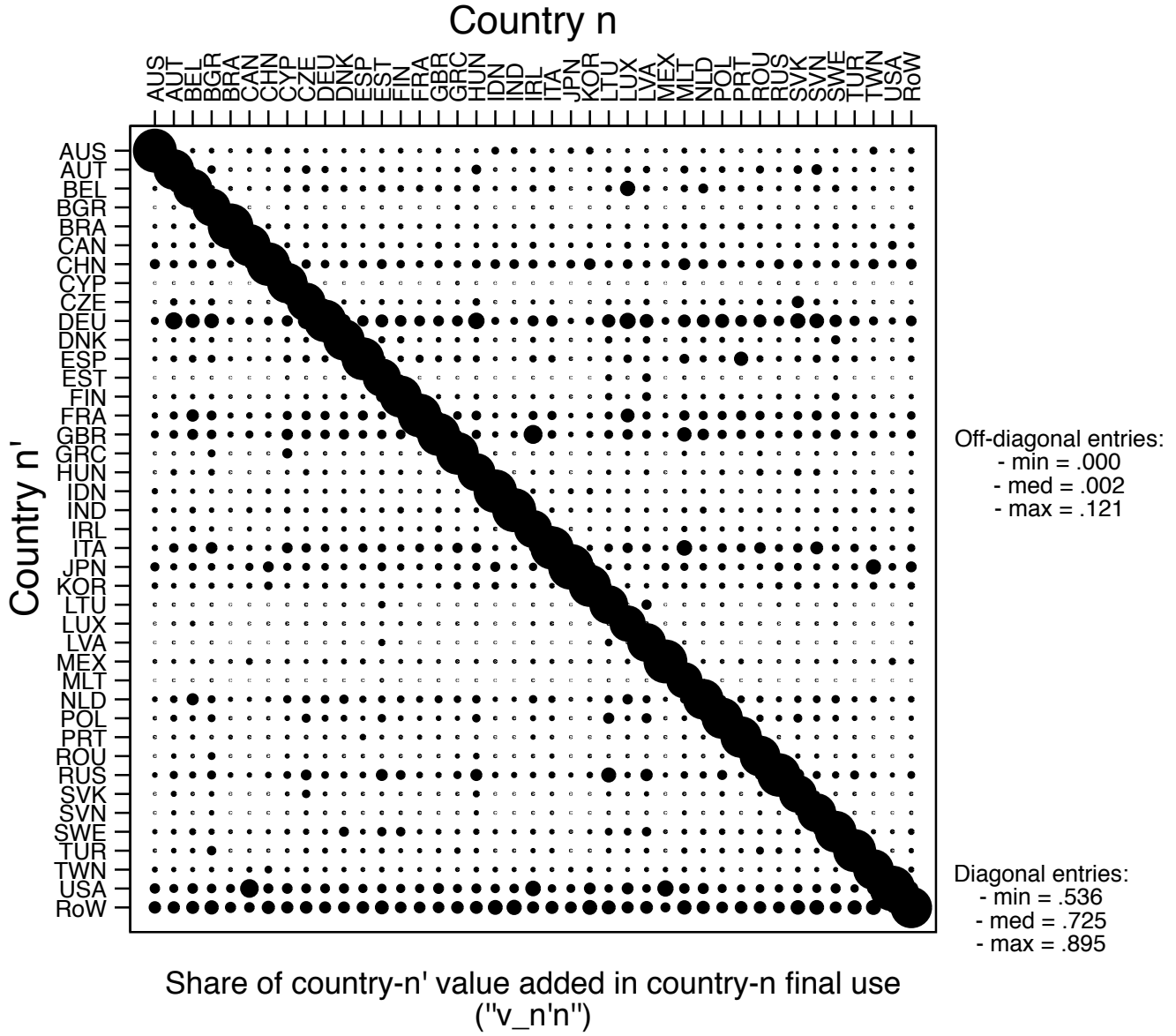
- solve for $\{f_n\}_n$,
- find $\{\gamma_{n'n}\}_{n',n}$ such that $\{v_{n'n}\}_{n',n}$ matched perfectly.

3 Data

Data Sources:

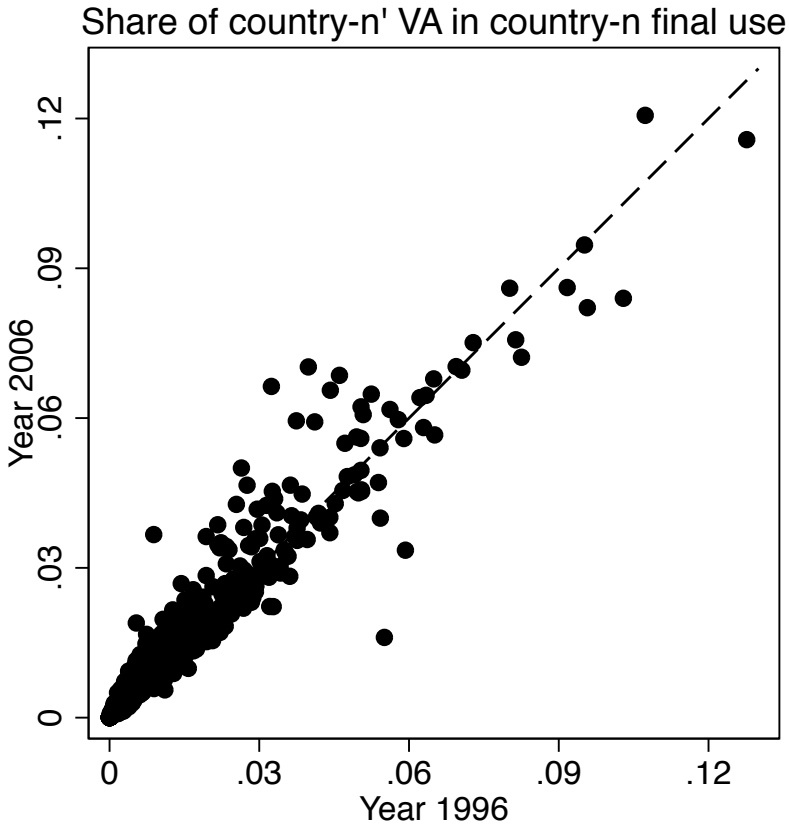
- Incomes and production factors, $\{Y_n, K_n, L_n\}_n$:
  Penn World Tables 9.0, methodology as in Caselli (2005).
- Labour productivity, $\{h_n\}_n$:
  Barro and Lee (2010), methodology as in Caselli (2005).
- International VA linkages, $\{v_{n'n}\}_{n',n}$, trade balances $\{T_n\}_n$
  World Input-Output Database: Timmer et al. (2012).
  - international input-output table covering 40 broad use categories (35 industries, 5 final sectors) ◂ Example
  - 17 years: 1995-2011.
  - 40 economies (plus "Rest of the World"):
    Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands, Poland, Portugal, Romania, Russia, Slovak Republic, Slovenia, Spain, Sweden, Taiwan, Turkey, UK, US.

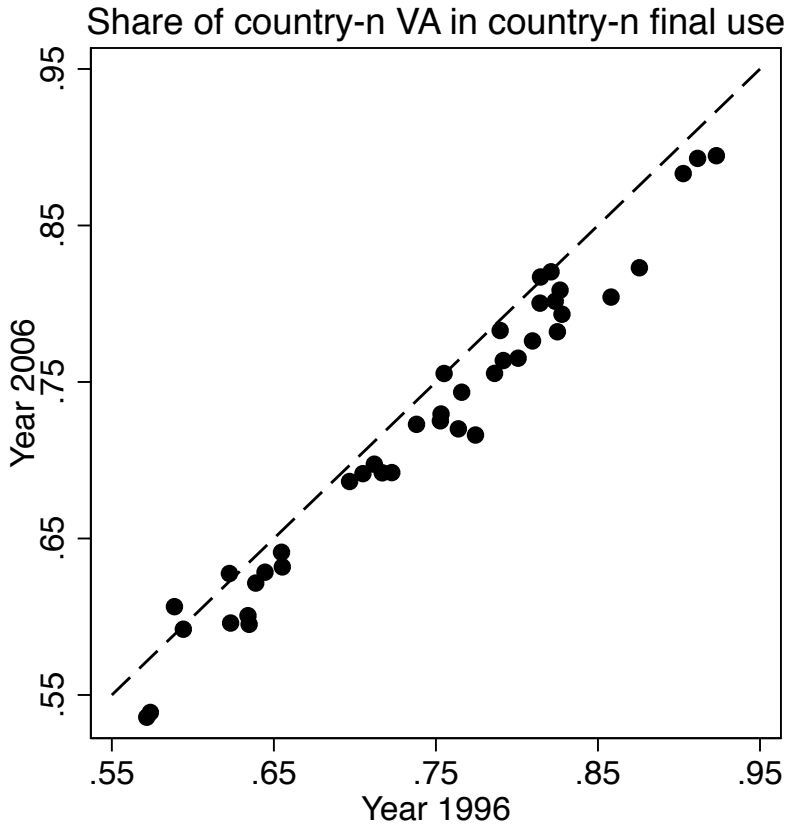
3 Data: Year 2006



◂ 1996

3 Data: Years 1996-2006





4 Development Accounting: $\theta \to 0$

$$\ln y_n \to \underbrace{\ln k_n^{\alpha} h_n^{1-\alpha}}_{\equiv \ln y_n^{ED}} \underbrace{+ \ln \prod_{n'} \left[\frac{u_n(\mathbf{t})}{u_{n'}(\mathbf{t})} \left(\frac{K_{n'}}{K_n} \right)^{\alpha} \left(\frac{H_{n'}}{H_n} \right)^{1-\alpha} \right]^{v_{n'n}}}_{\equiv \ln F_n} + \ln A_n$$

$$\equiv \ln y_n^{EL}$$

Details

$$Var(\ln y_n) = Var\left(\ln y_n^{E\cdot}\right) + Var(\ln A_n) + 2Cov\left(\ln y_n^{E\cdot}, \ln A_n\right)$$

Discuss

$$success \equiv \frac{Var\left(\ln y_n^{E\cdot}\right)}{Var(\ln y_n)} \qquad ignorance \equiv \frac{Var(\ln A_n)}{Var(\ln y_n)}$$

4 Development Accounting: $\theta \to 0$

Year 2006:

◂ 1996 ◂ Graph

	D
$Var\left(\ln y_n\right)$	.401
$Var\left(\ln y_n^{E\cdot}\right)$	.101
$Var\left(\ln A_n\right)$	.113
success	.25
ignorance	.28

Caselli (2005) finds values of "success" ranging from .23 (Europe) to .47 (Americas) in different subsamples for the year 1996.

4 Development Accounting: $\theta \to 0$

Year 2006:

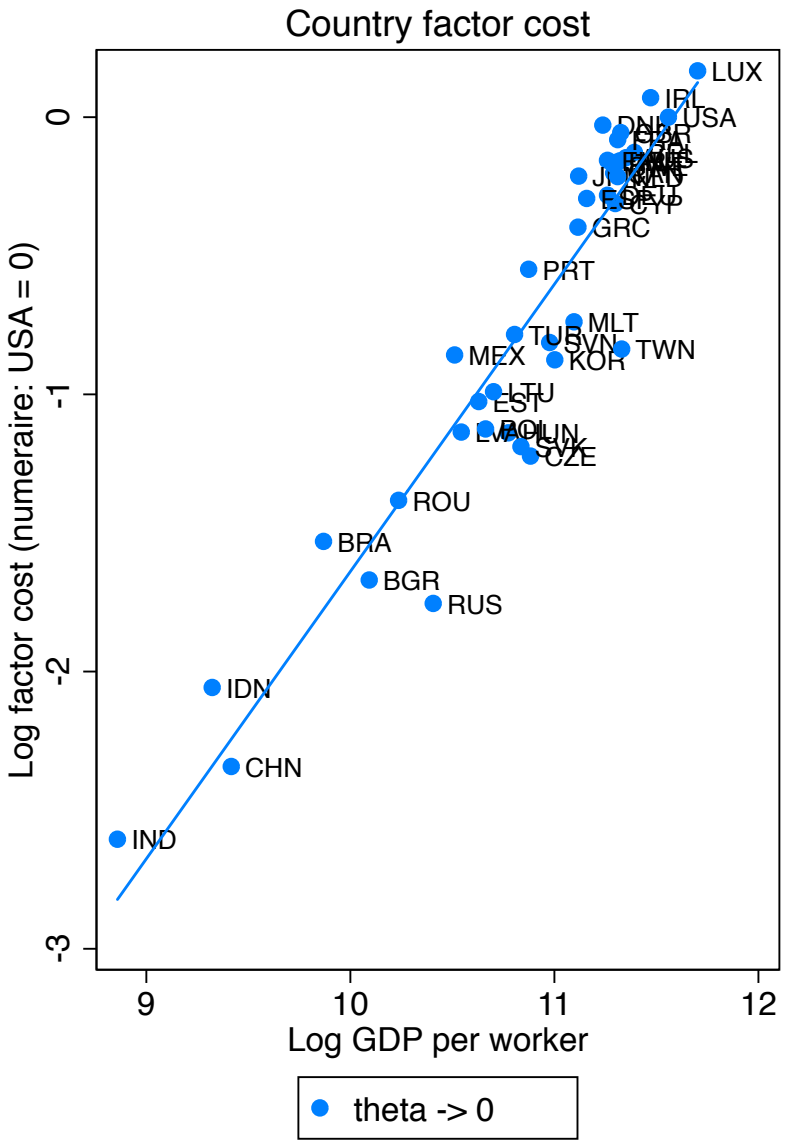
◂ 1996 ◂ Graph

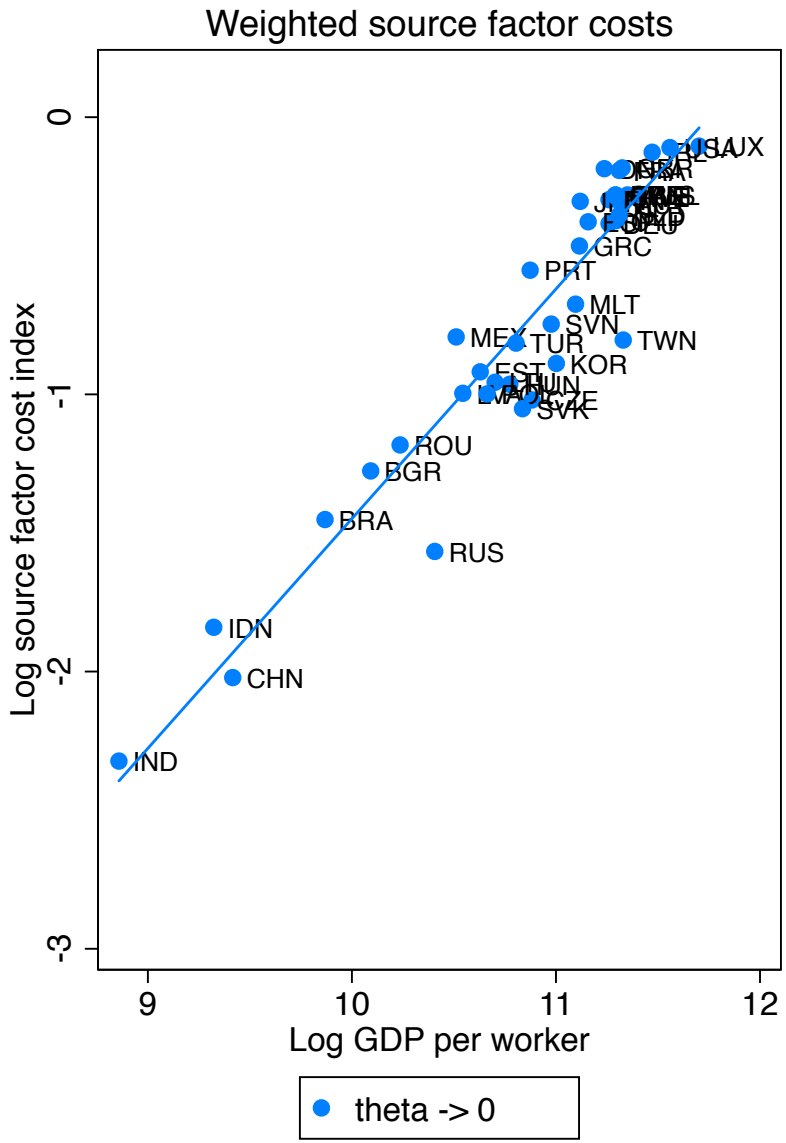
	D	L $(\theta \to 0)$
$Var\left(\ln y_n\right)$	.401	.401
$Var\left(\ln y_n^{E\cdot}\right)$	.101	.200
$Var\left(\ln A_n\right)$	.113	.046
success	.25	.50
ignorance	.28	.11

Caselli (2005) finds values of "success" ranging from .23 (Europe) to .47 (Americas) in different subsamples for the year 1996.

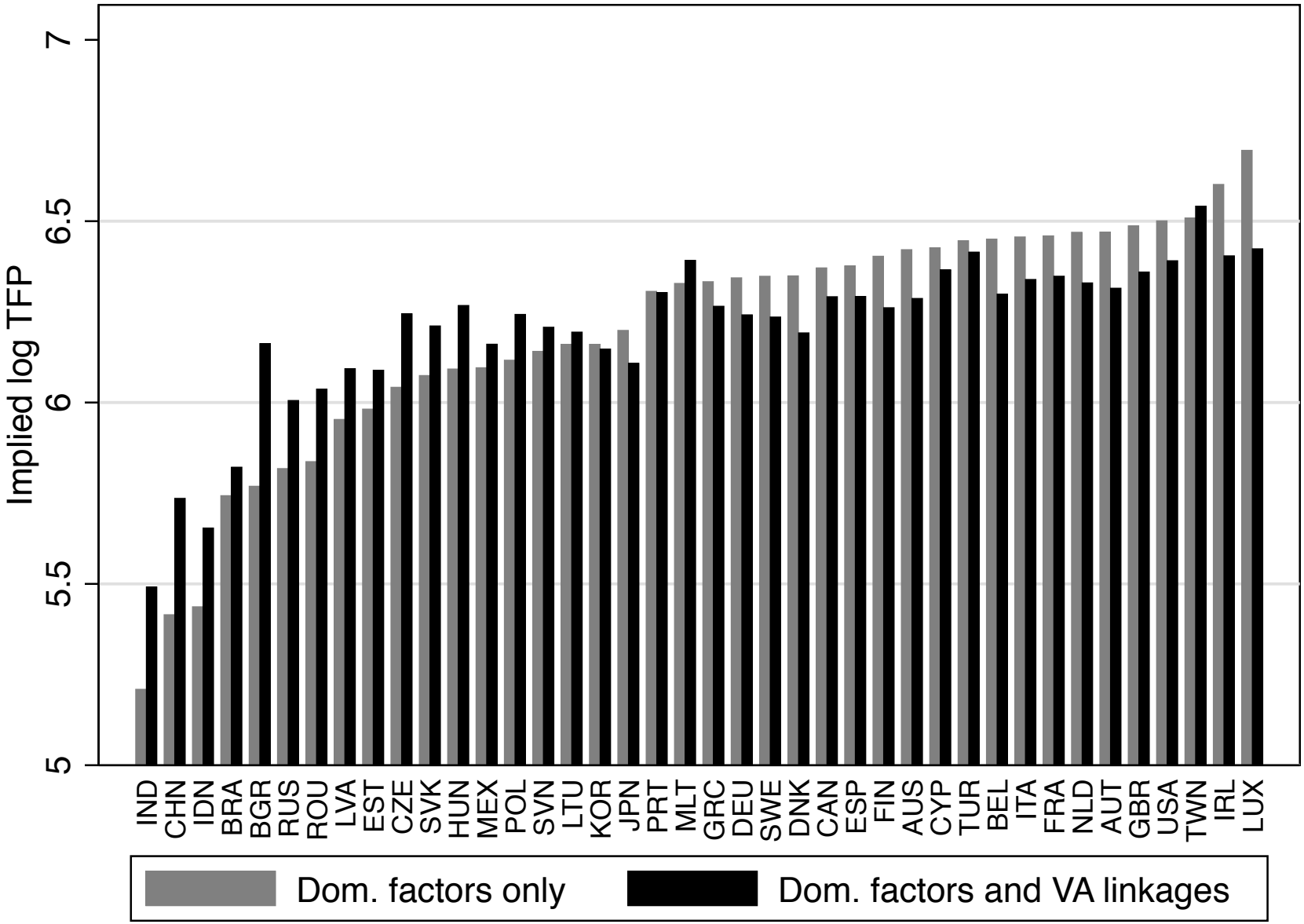
Magnitudes are similar for other years between 1995 and 2011.

4 Development Accounting: $\theta \to 0$





4 Development Accounting: $\theta \to 0$



4 Development Accounting: $\theta > 0$

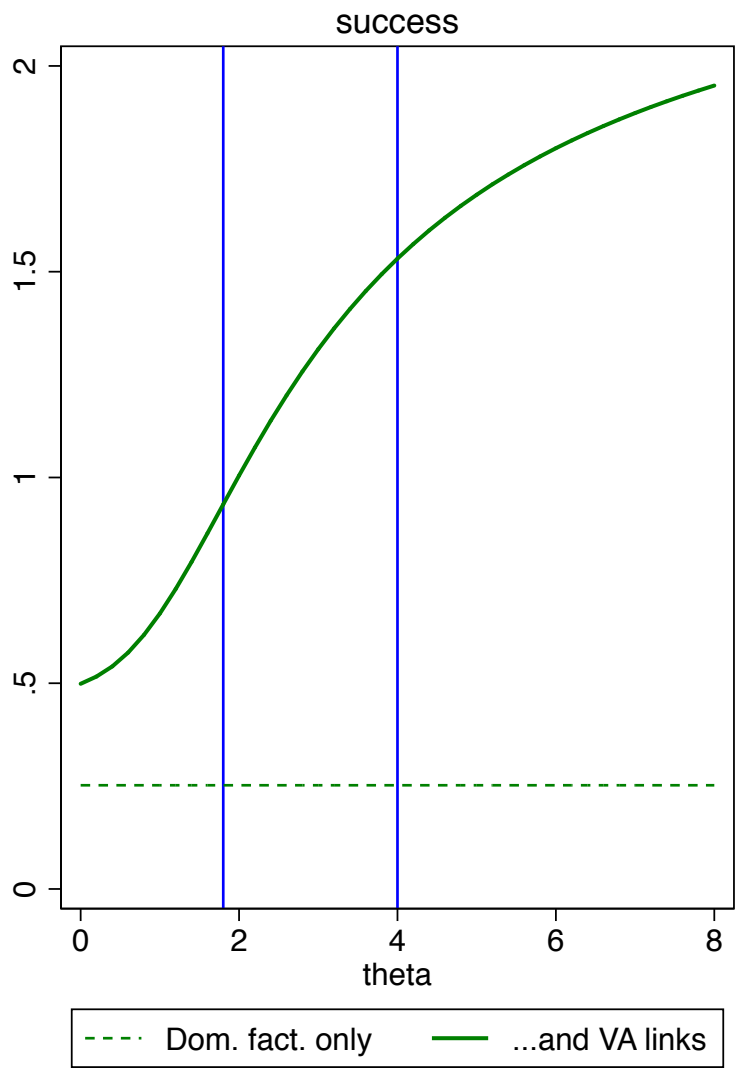
What is the "right" value for θ?

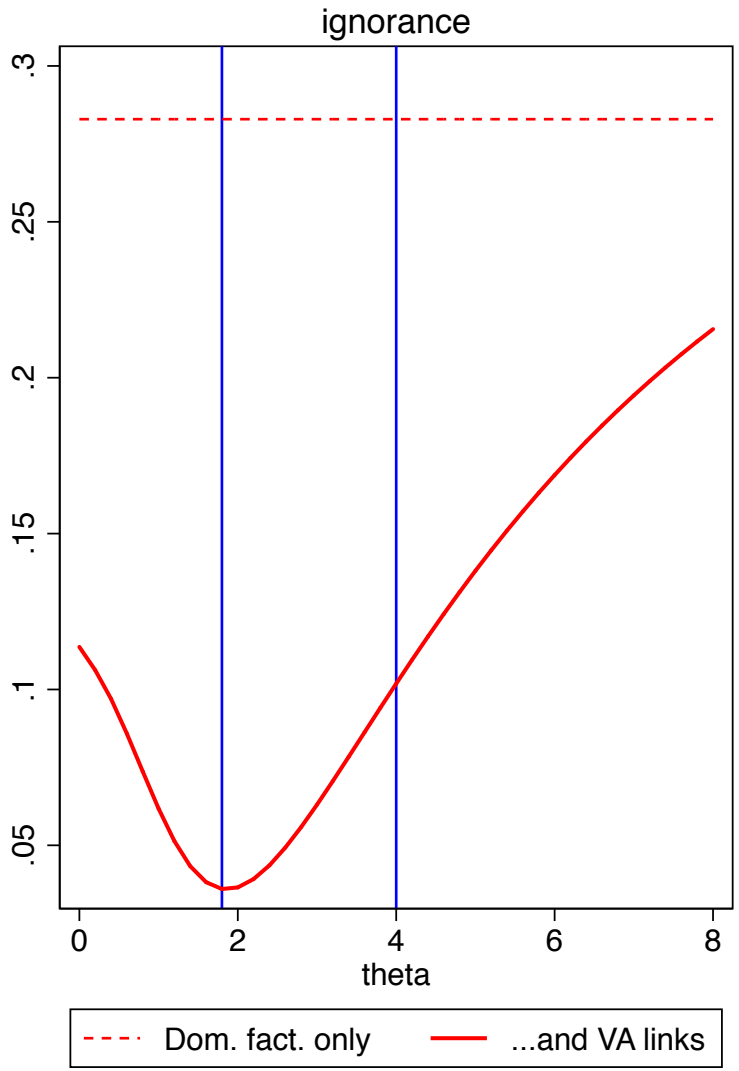
- The development-accounting expression above is derived from standard quantitative trade models.
- In these models, the parameter θ corresponds to the *gross* trade elasticity.
- Armington (Backus et al., 1994): subst. elasticity - $1 = \theta = 1.5$
  Eaton and Kortum (2002): $\theta = 8$
  Simonovska and Waugh (2014): $\theta = 4$.
- We present results for different values of θ
  (with $\theta = 4$ as our preferred value).

4 Development Accounting: $\theta > 0$

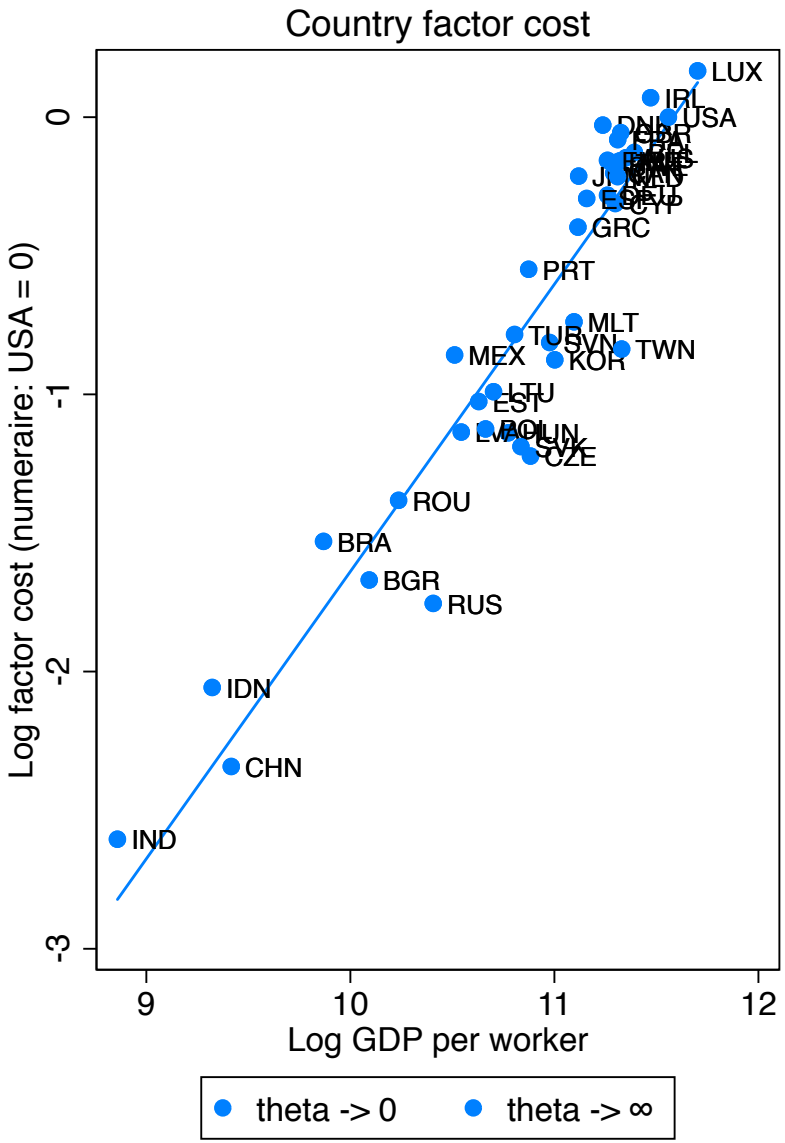
Year 2006:

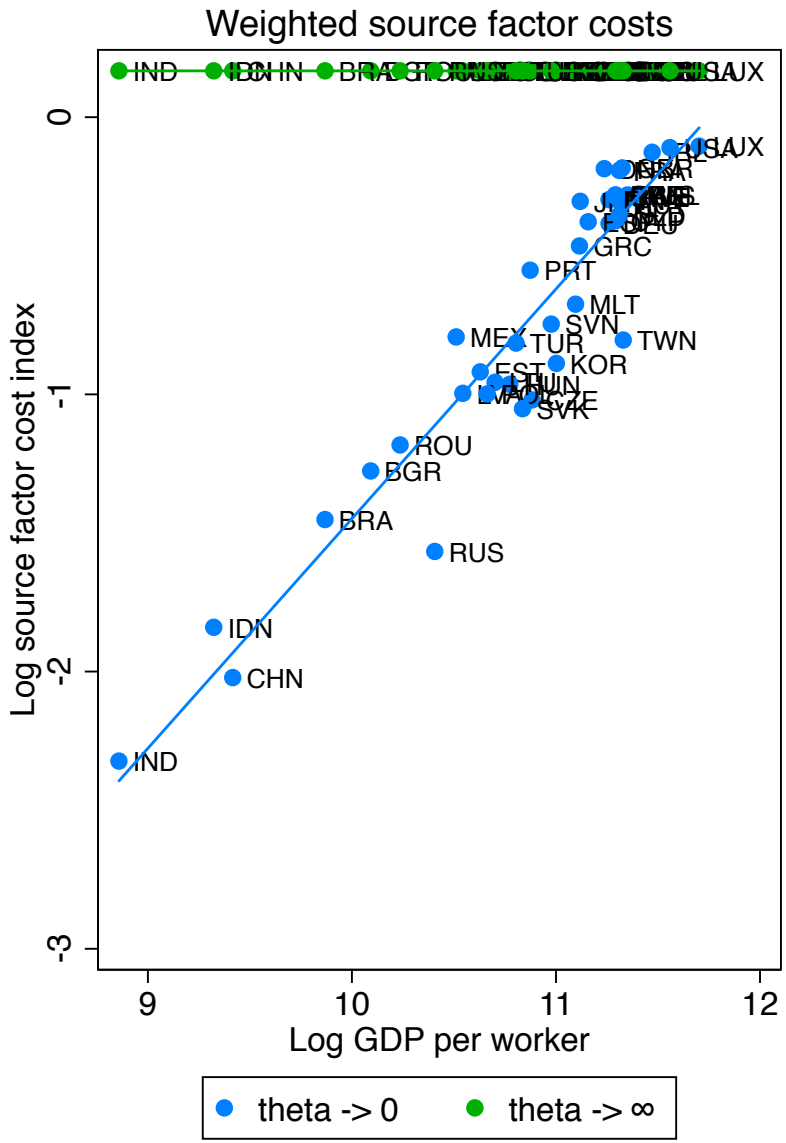
◂ 1996



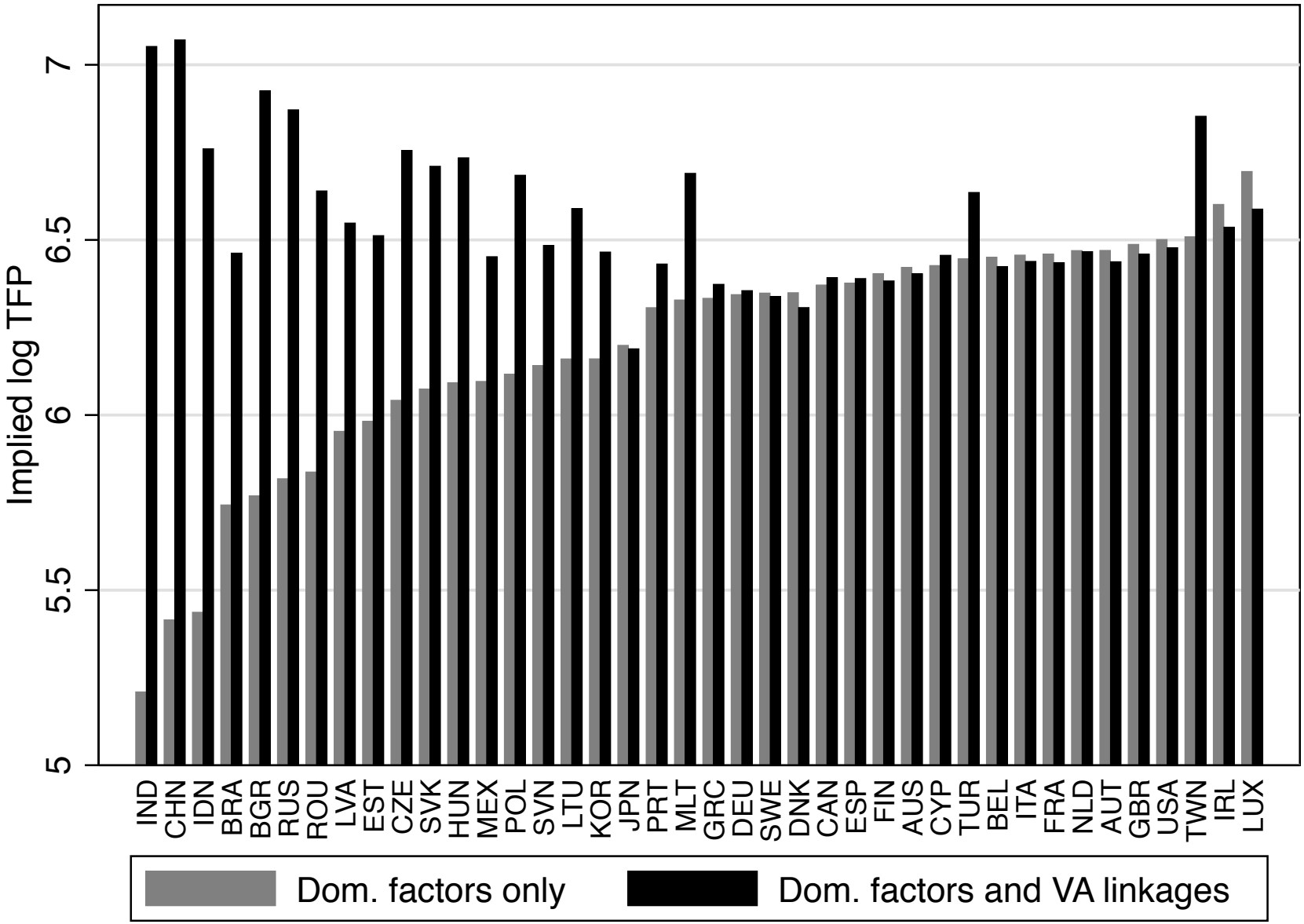


4 Development Accounting: $\theta > 0$





4 Development Accounting: $\theta > 0$



4 Development Accounting: $CGDP_n^e / CGDP_n^o$

- Feenstra et al. (2015) suggest that for open economies:

$$\ln y_n = \ln G_n + \ln k_n^{\alpha} h_n^{1-\alpha} + \ln A_n,$$

where $G_n \equiv CGDP_n^e / CGDP_n^o$, and

  - $CGDP_n^e$ is "expenditure side" real GDP ($= Y_n$).
  - $CGDP_n^o$ is "output side" real GDP (new since PWT 8.0!).

- They find little improvement in *success* and *ignorance*.

- Based on the PWT definition of $CGDP_n^o$, our model implies:

$$G_n = \gamma_{nn}^{-\frac{1}{\theta}} F_n,$$

where $F_n \equiv f_n / \left(\sum_{n'} \gamma_{n'n} f_{n'}^{-\theta} \right)^{-\frac{1}{\theta}}$;
and $\gamma_{nn}^{-\frac{1}{\theta}} > 1$ represents the "wedge" between the consumer and producer price of country-n output.

◂ Comparison

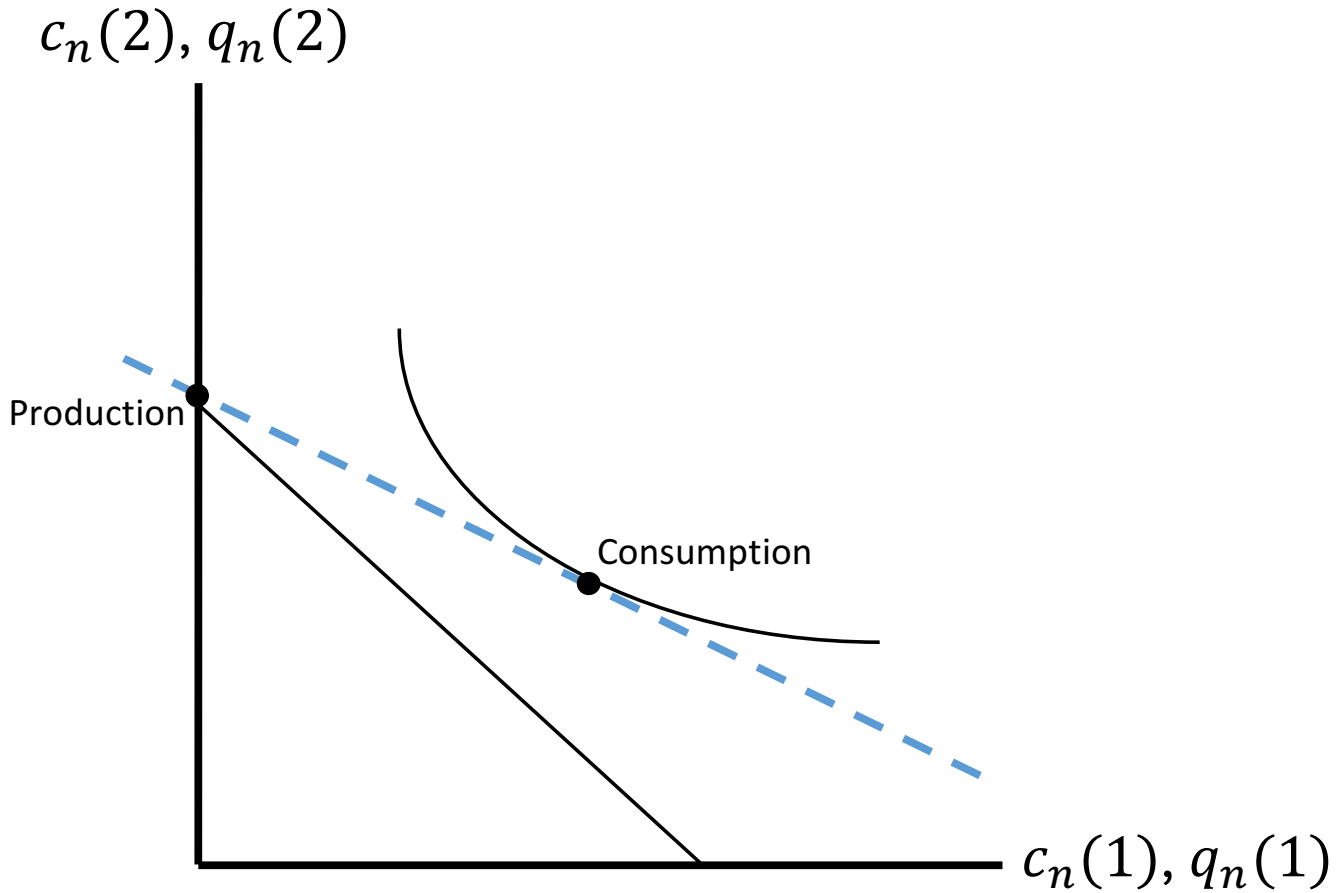
4 Development Accounting: Summary

- Incorporating international linkages into development accounting reduces our reliance on unmeasured "TFP" in explaining income differences between countries.
- Instead, we rely on broadly defined "trade determinants": $\{\gamma_{n'n}\}_{n',n}$, where...
  1. ...$\{\gamma_{n'n}\}_{n',n} \approx$ technology, preferences, trade costs.
  2. ...variation in $\{\gamma_{n'n}\}_{n',n}$ across countries can be disciplined with (trade) data!
- New focus (for the future!):
  - **Given** value-added linkages, international income differences are easier to explain.
  - What are the fundamental forces, captured by $\{\gamma_{n'n}\}_{n',n}$, which shape value-added linkages?

5 Counterfactuals ($\theta = 4.0$)

1. **Balanced Trade**
   1. Impact on per-worker real income ◂ Show
   2. Impact on per-worker real consumption ◂ Show
2. **Autarky**
   1. Impact on per-worker real income ◂ Show
   2. Autarky losses vs. relative factor costs ◂ Show

Appendix



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2 Armington Model

Back

There are N countries, each producing a unique good.
Representative agent in n maximises:

$$C_n = A_n \left[\sum_{n'} \omega_{n'n}^{\frac{1}{1+\theta}} c_{n'n}^{\frac{\theta}{1+\theta}} \right]^{\frac{1+\theta}{\theta}} \qquad \theta > 0, \quad \omega_{n'n} \geq 0.$$

s.t.

$$\sum_{n'} p_{n'n} c_{n'n} \leq r_n K_n + w_n L_n + T_n, \quad \sum_n T_n = 0.$$

Country n produces its good with the technology:

$$q_n = Z_n K_n^{\alpha} \left(h_n L_n \right)^{1-\alpha}.$$

Goods and factor markets are perfectly competitive.
International trade barriers lead to price wedges: $\tau_{n'n} \geq 1$.

2 Eaton-Kortum Model

Back

There are N countries. Representative agent in n maximises:

$$C_n = A_n \left[\int_0^1 c_n(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}} \qquad \sigma \geq 0.$$

s.t. $$\int_0^1 p_n(i)\, c_n(i)\, di = r_n K_n + w_n L_n + T_n, \quad \sum_n T_n = 0.$$

Country n' can produce good i for n with the technology:

$$q_{n'n}(i) = Z_{n'n}(i) \left\{ (1-\beta_n)^{\frac{1}{1+\theta}} \left[K_{n'n}(i)^{\alpha} H_{n'n}(i)^{1-\alpha} \right]^{\frac{\theta}{1+\theta}} + \beta_n^{\frac{1}{1+\theta}} Q_{n'n}(i)^{\frac{\theta}{1+\theta}} \right\}^{\frac{1+\theta}{\theta}}$$

where $Q_{n'n}(i)$ has same form as C_n; and $Z_{n'n}(i)$ is drawn from:

$$Pr(Z_{n'n} \leq Z) = e^{-\omega_{n'n} Z^{-\theta}} \qquad \omega_{n'n} \geq 0, \quad \theta > 0.$$

Goods and factor markets are perfectly competitive.
International trade barriers lead to price wedges: $\tau_{n'n} \geq 1$.

3 Data

World Input-Output Table for a given year:

			Use by country-industries							**Final use by countries**		
			Country 1			…	Country *N*			Country 1	…	Country *N*
			Industry 1	…	Industry *S*	…	Industry 1	…	Industry *S*			
Supply from country-industries	Country 1	Industry 1										
		…										
		Industry *S*										
	…	…										
	Country *N*	Industry 1										
		…										
		Industry *S*										
Gross output												
Value added												

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3 Data

Global Value-Chain Table for a given year:

		Final goods shipped by country-industries						
		Industry 1			…	Industry *S*		
		Country 1	…	Country *N*	…	Country 1	…	Country *N*
Value added from countries	Country 1							
	…							
	Country *N*							

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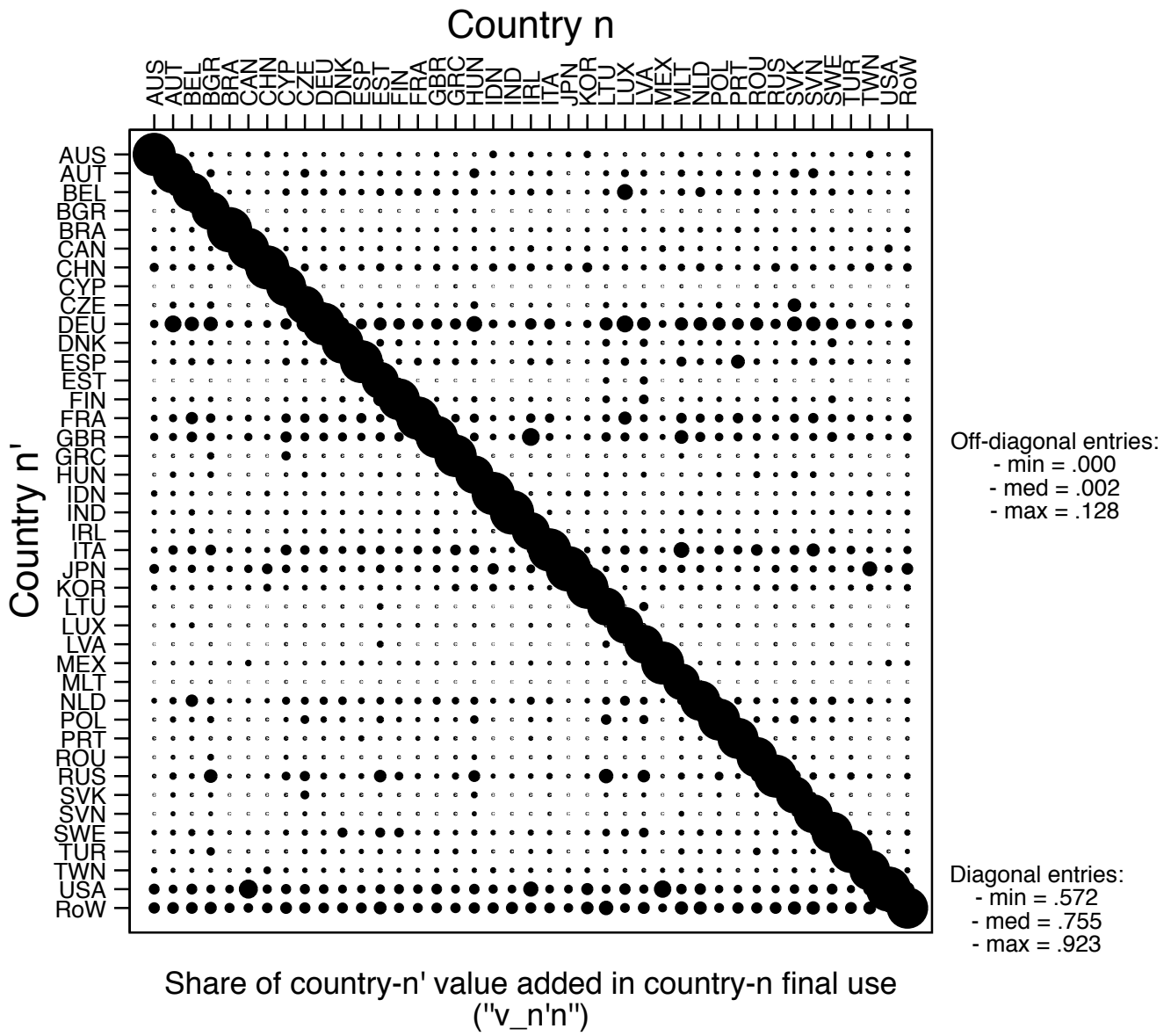
3 Data: Year 1996



◂ 2006

4 Development Accounting: $\theta \to 0$

We can write

$$f_n K_n^{\alpha} H_n^{1-\alpha} = \sum_{n'} v_{nn'} \left(f_{n'} K_{n'}^{\alpha} H_{n'}^{1-\alpha} + T_{n'} \right)$$

as

$$\begin{bmatrix} f_1 K_1^{\alpha} H_1^{1-\alpha} \\ \vdots \\ f_{N-1} K_{N-1}^{\alpha} H_{N-1}^{1-\alpha} \end{bmatrix} = (I - V)^{-1} \left[(V - \mathbf{v}_{.\mathbf{N}} \mathbf{1}) \mathbf{t} + \mathbf{v}_{.\mathbf{N}} \right] K_N^{\alpha} H_N^{1-\alpha},$$

where

$$V = \begin{bmatrix} v_{11} & \cdots & v_{1N-1} \\ \vdots & \ddots & \\ v_{N-1,1} & & v_{N-1,N-1} \end{bmatrix} \quad \mathbf{v}_{.\mathbf{N}} = \begin{bmatrix} v_{1N} \\ \vdots \\ v_{N-1,N} \end{bmatrix}$$

and we define

- $\mathbf{1}$ as an $N-1$ row vector of ones
- $\mathbf{t} = \left\{ T_1 / K_N^{\alpha} H_N^{1-\alpha}, ..., T_{N-1} / K_N^{\alpha} H_N^{1-\alpha} \right\}'$.

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4 Development Accounting: *success* and *ignorance*

$$\ln y_n = \underbrace{\ln y_n^{ED} + \ln F_n}_{\equiv \ln y_n^{EL}} + \ln A_n \qquad \ln A_n \equiv \ln y_n - \ln y_n^{E\cdot} \qquad Var\left(\ln F_n\right) > 0$$

success:

$$Var\left(\ln y_n^{EL}\right) = Var\left(\ln y_n^{ED}\right) + Var\left(\ln F_n\right) + 2Cov\left(\ln y_n^{ED}, \ln F_n\right)$$

- Including F_n will raise *success*
  - unless $Cov\left(\ln y_n^{ED}, \ln F_n\right)$ is too negative!

ignorance:

$$Var\left(\ln A_n^L\right) = Var\left(\ln y_n\right) + Var\left(\ln y_n^{ED}\right) + Var\left(\ln F_n\right)$$
$$+2Cov\left(\ln y_n^{ED}, \ln F_n\right) - 2Cov\left(\ln y_n, \ln y_n^{ED}\right) - 2Cov\left(\ln y_n, \ln F_n\right)$$

- Including F_n will lower *ignorance* only if:
  - $Cov\left(\ln y_n^{ED}, \ln F_n\right)$ is low
  - $Cov\left(\ln y_n, \ln F_n\right)$ is high

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4 Development Accounting: $\theta \to 0$

Year 1996:

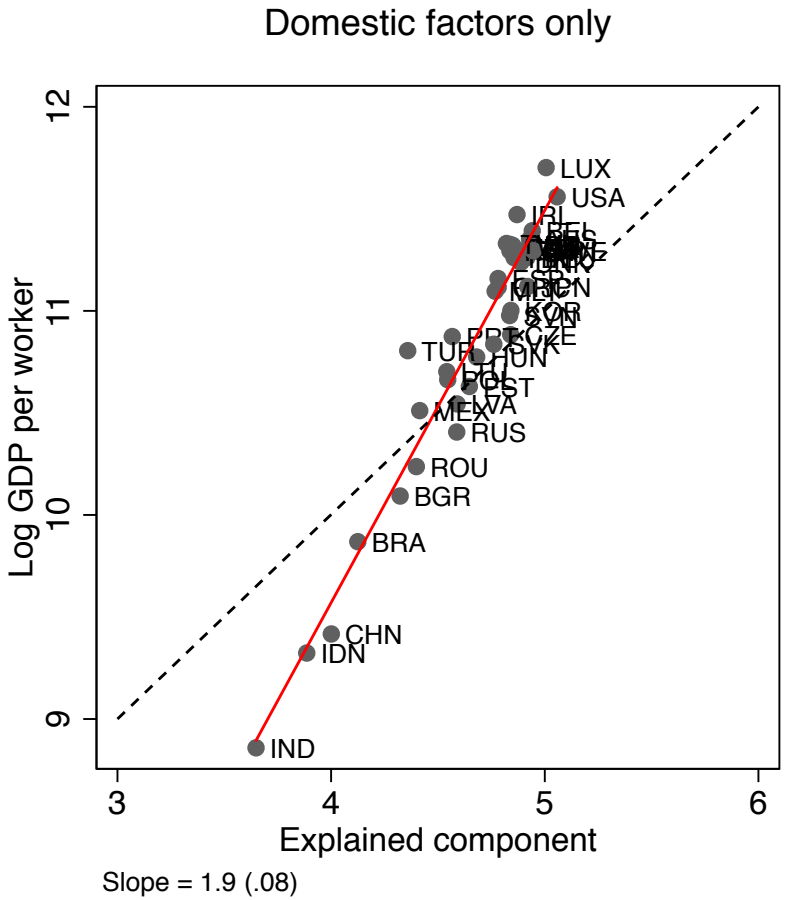
◂ 2006

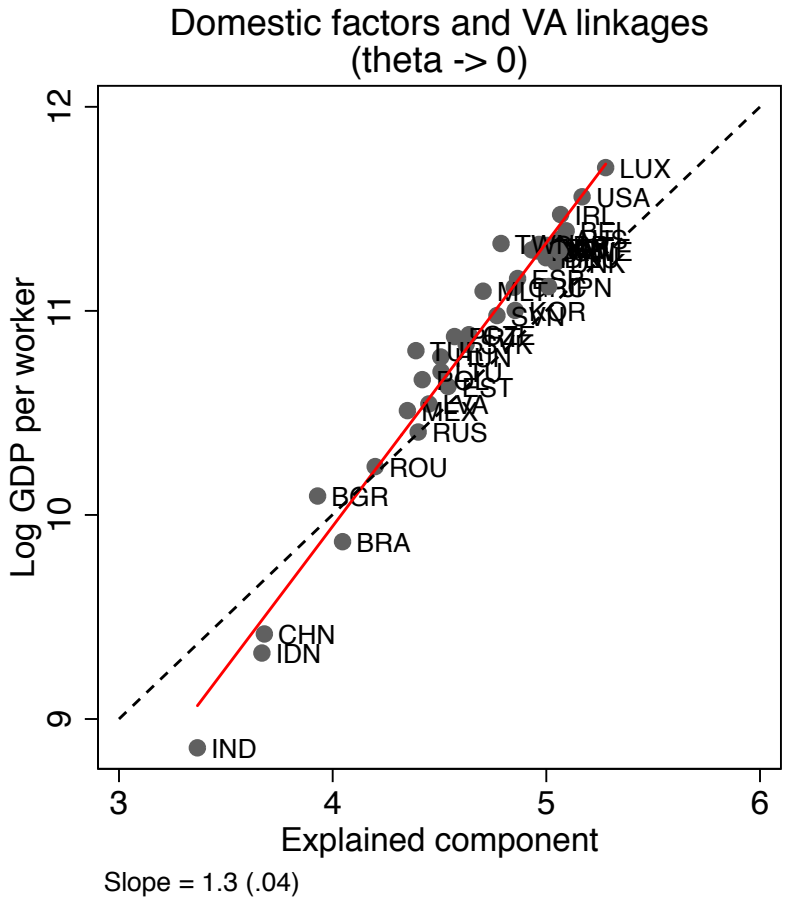
	D	L $(\theta \to 0)$
$Var\left(\ln y_n\right)$	.501	.501
$Var\left(\ln y_n^{E\cdot}\right)$	.130	.244
$Var\left(\ln A_n\right)$	.162	.070
success	.26	.49
ignorance	.32	.14

Caselli (2005) finds values of "success" ranging from .23 (Europe) to .47 (Americas) in different subsamples for the year 1996.

Magnitudes are similar for other years between 1995 and 2011.

4 Development Accounting: $\theta \to 0$





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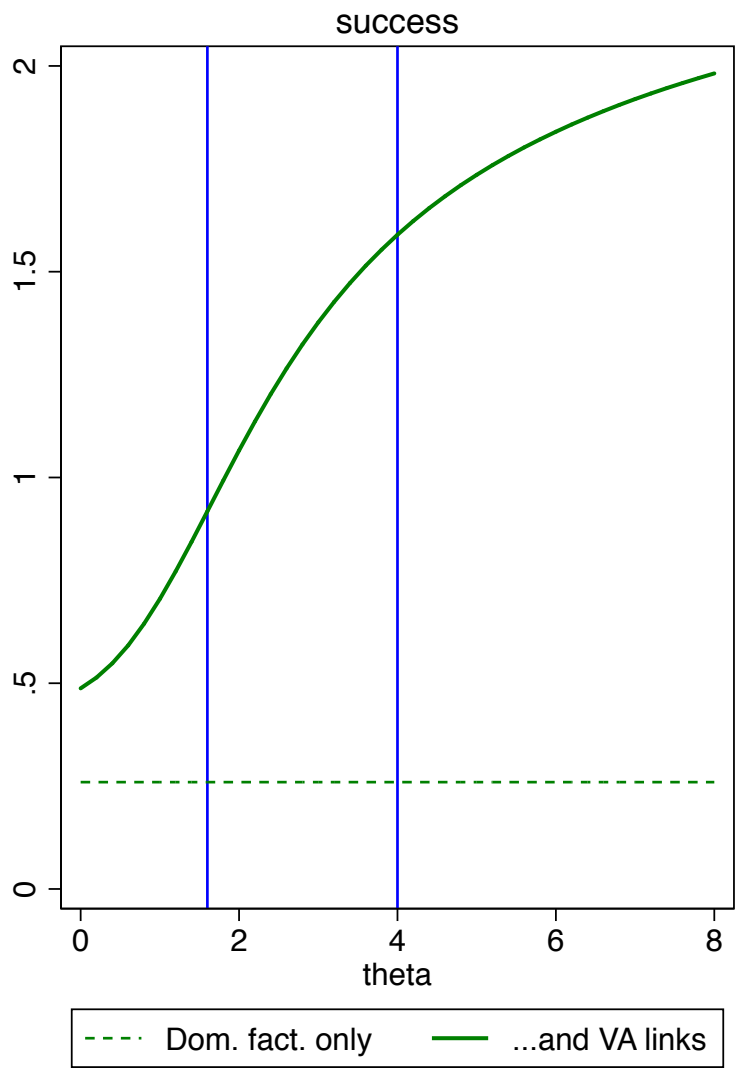
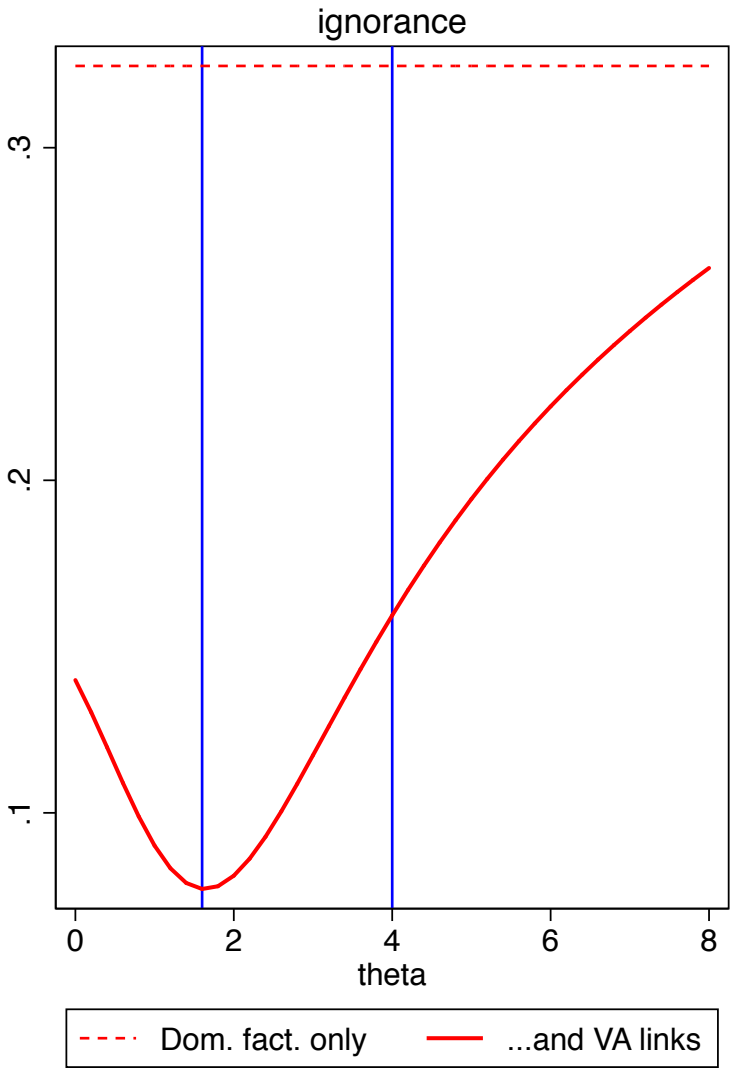
4 Development Accounting: $\theta > 0$

Year 1996:

◂ 2006





4 Development Accounting: $CGDP_n^e / CGDP_n^o$

Corr.		PWT/FIT	CZ ($\theta = 4.0$)	
		lnG_n	lnF_n	lnG_n
PWT/FIT	lnG_n	1.00		
CZ ($\theta = 4.0$)	lnF_n	.18 (.26)	1.00	
	lnG_n	.52*** (.00)	.03 (.85)	1.00

Dev. Acc.	ln G_n		ln F_n
	PWT/FIT	CZ ($\theta = 4.0$)	CZ ($\theta = 4.0$)
$Var\left(\ln y_n\right)$	.401	.401	.401
$Var\left(\ln y_n^{E\cdot}\right)$	.121	.107	.614
$Var\left(\ln A_n^{E\cdot}\right)$	.106	.111	.041
success	.30	.27	1.53
ignorance	.26	.28	.10

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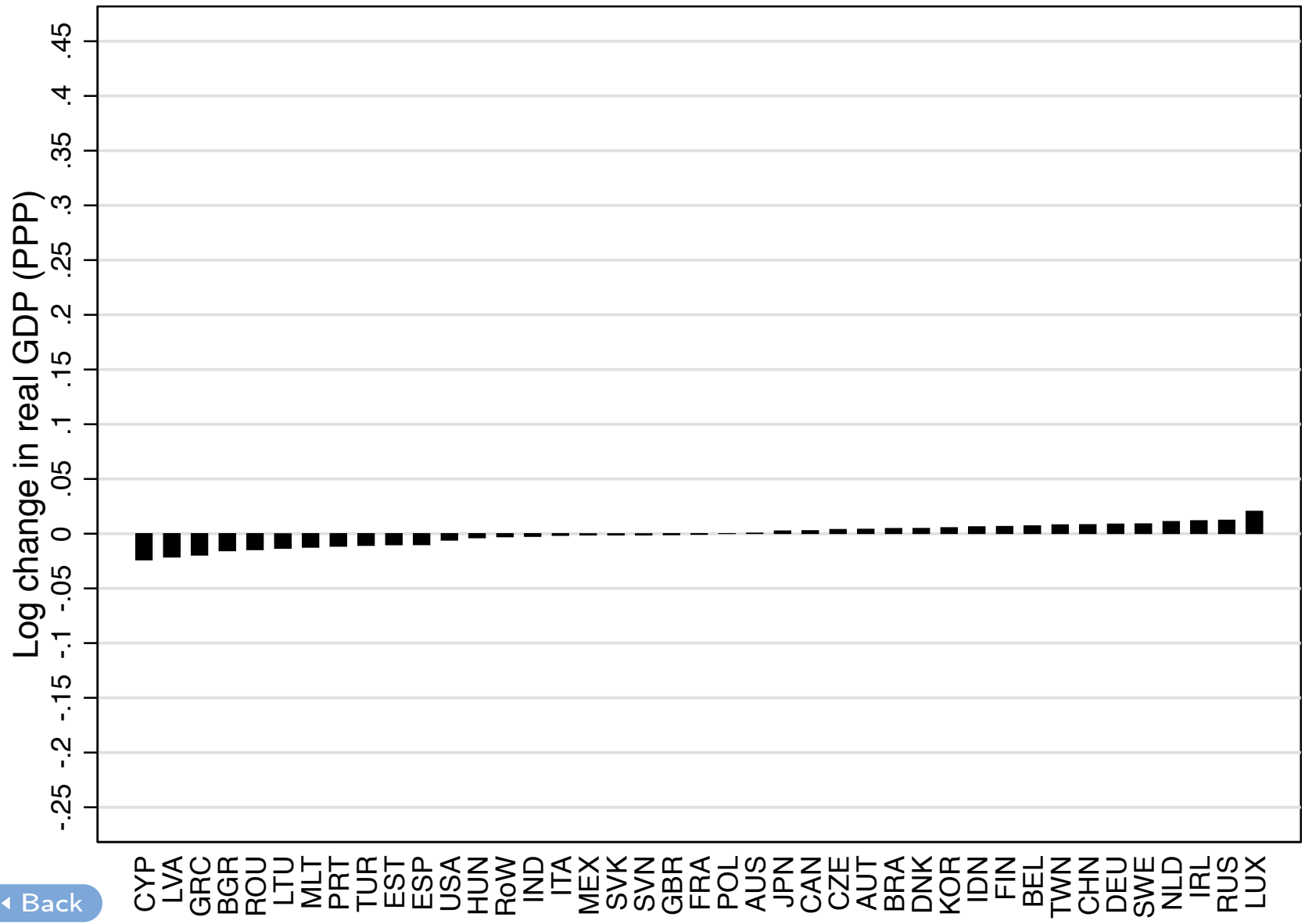
5 Counterfactuals: No Trade Imbalances ($\theta = 4.0$)



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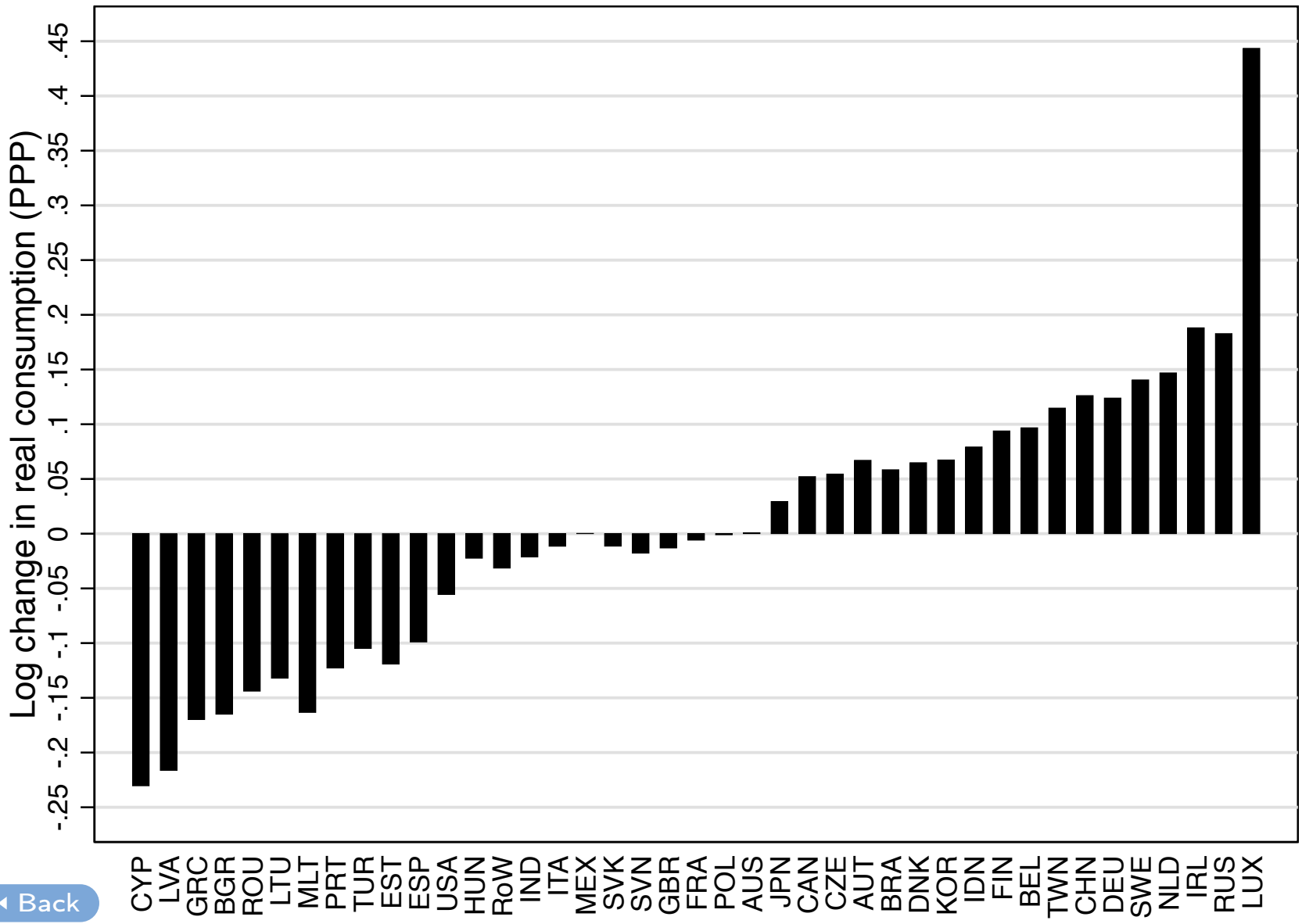
5 Counterfactuals: No Trade Imbalances ($\theta = 4.0$)



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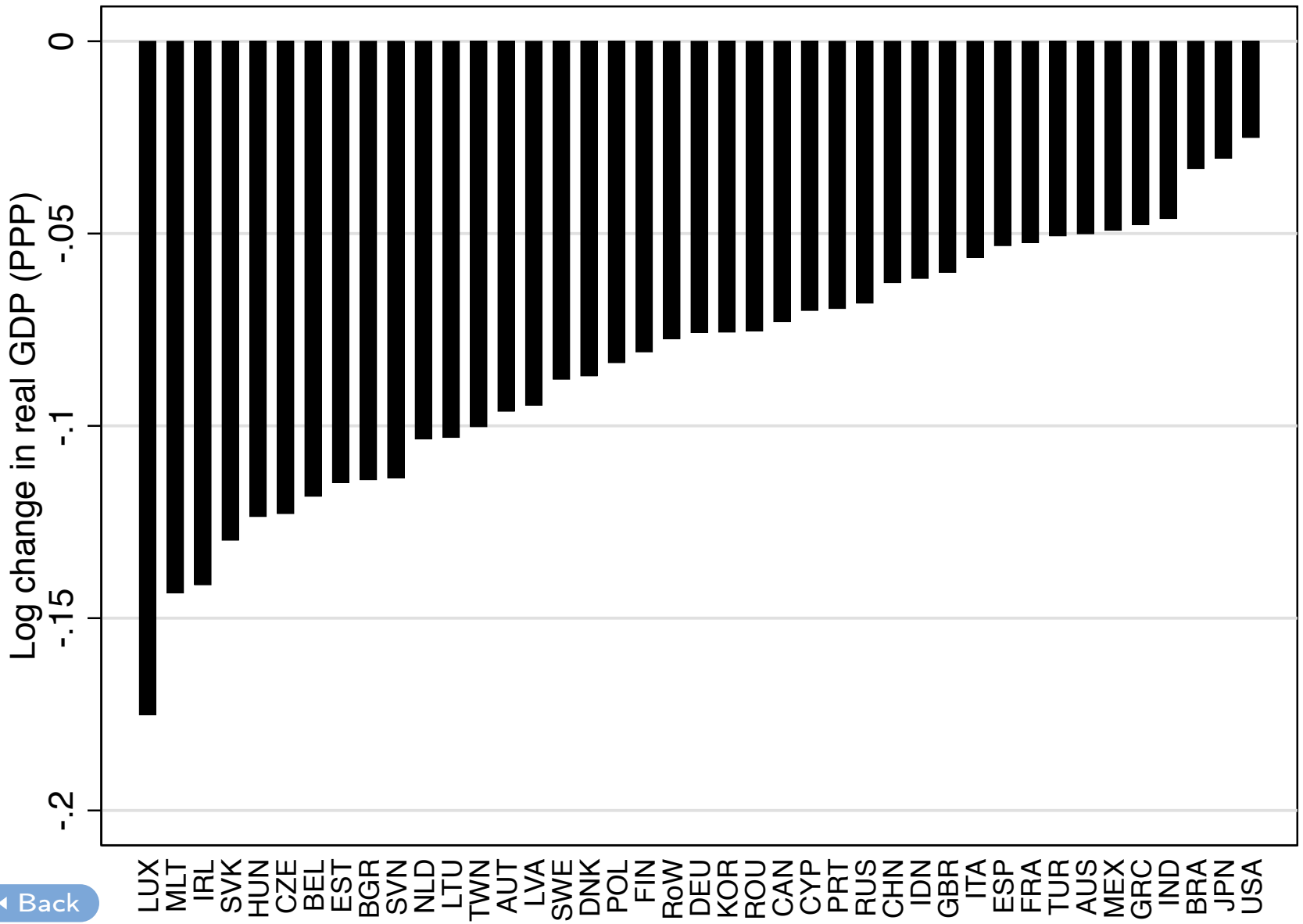
5 Counterfactuals: Autarky ($\theta = 4.0$)



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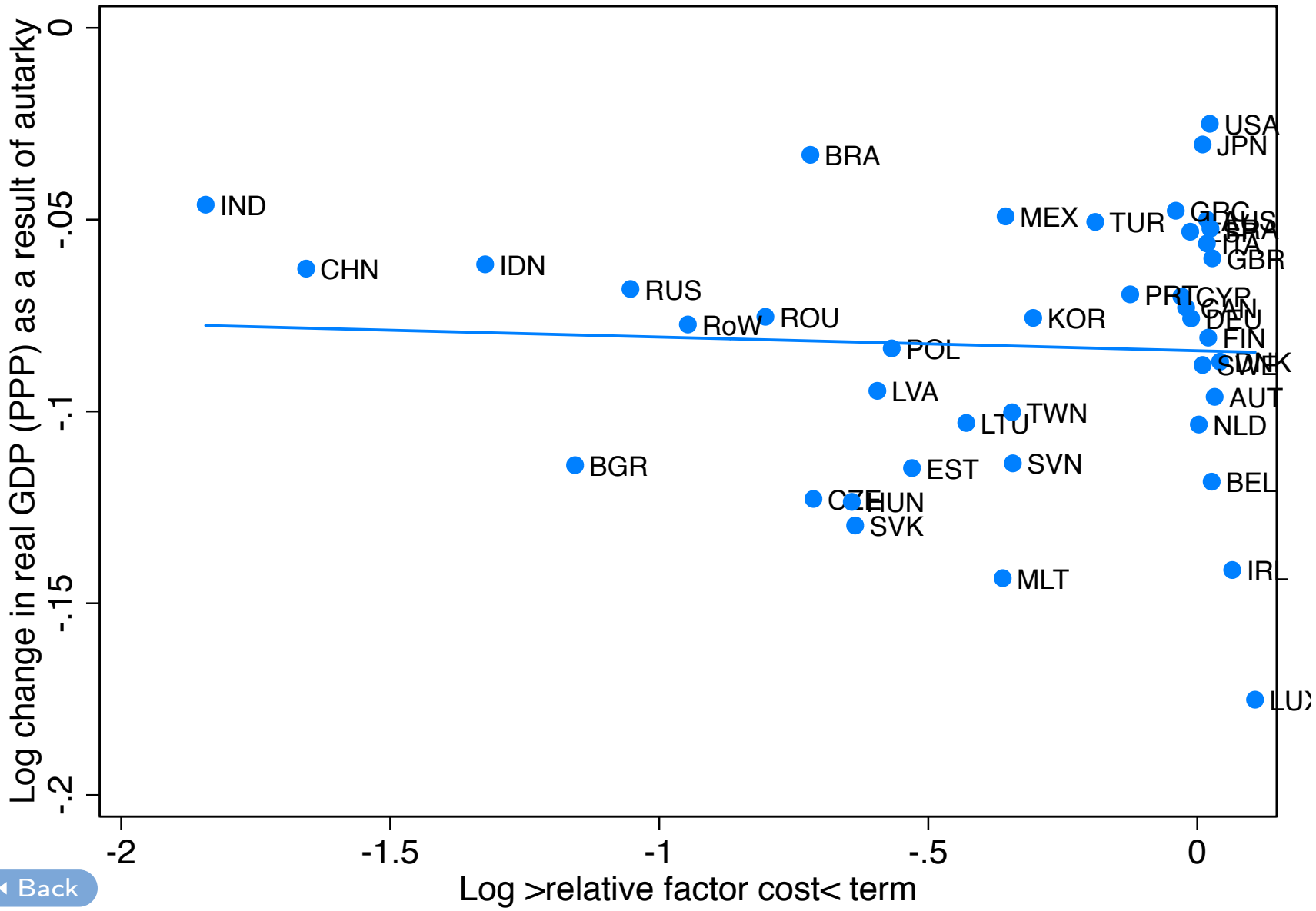
5 Counterfactuals: Autarky ($\theta = 4.0$)



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