Macroeconomic Data - Sectors

STEG Lecture Series on Data in Macro Development

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Q & A is supported by my colleague Patrick Macnamara

Outline

1. Motivation
2. Sector accounting
3. Macroeconomic Data and Multi-Sector Growth Models
4. Structural Change in Consumption and Investment
5. Conclusion

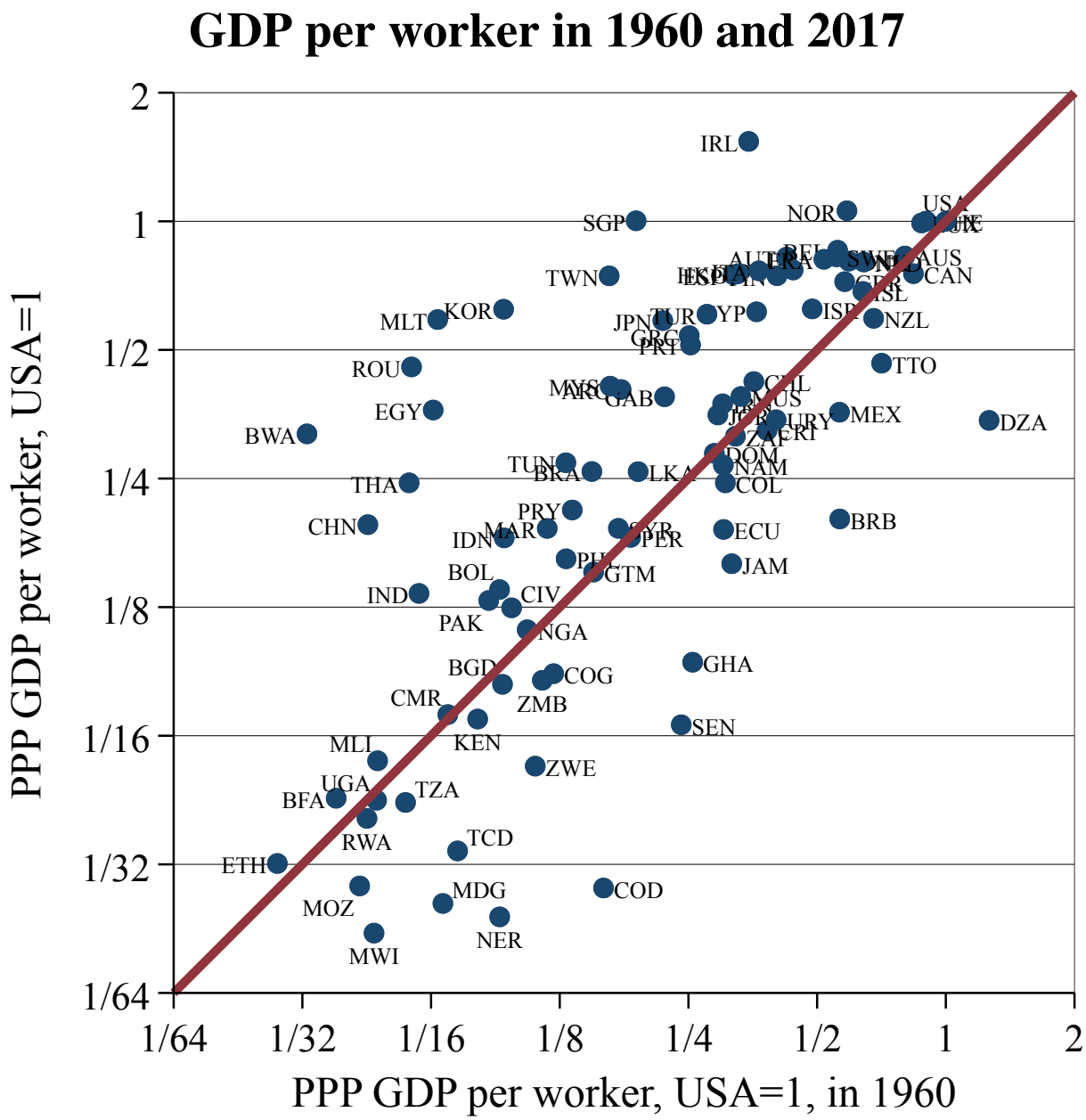
Key Background Paper

- Alder, Boppart & Müller (2022 American Economic Journal: Macroeconomics)
- Boppart (2014 Econometrica)
- Caselli (2005 Handbook of Economic Growth)
- Comin, Lashkari & Mestieri (2022 Econometrica)
- Greenwood, Hercowitz & Krusell (1997 American Economic Review)
- Herrendorf, Rogerson & Valentinyi (2013 American Economic Review)
- Herrendorf, Rogerson & Valentinyi (2014 Handbook of Economic Growth)
- Herrendorf, Rogerson & Valentinyi (2021 Review of Economic Studies)
- Herrendorf, Duernecker & Valentinyi (2021 Journal of Economic Dynamics and Control)
- Herrendorf, Rogerson & Valentinyi (2022 NBER)
- Inklaar, Marapin, & Gräler (2023 GGDC Research Memorandum 195)
- Restuccia, Yang, & Xiaodong Zhu (2008 Journal of Monetary Economics)

1 Motivation

Productivity Gaps and Development

- **One-sector growth model**
  - Aggregate productivity gaps (countries' labor productivities relative to the frontier) are a natural measure of development level.
  - The Penn World Tables (PWT) offers PPPs that allow to express aggregate productivity gaps in international prices.
  - Development accounting gives us key insights about the role of inputs and TFP in accounting for productivity differences



Source: Penn World Tables 10.01

- **Multi-sector growth model**
  - It provides a more nuanced view of productivity gaps
  - Productivity gaps differ across sectors
- **Questions**
  - Which sectors make poor countries so unproductive?
    - Requires data to measure productivity gaps at the sector level
  - What drives the change of sectoral composition along the development path, that is, structural transformation
    - Requires taking sector data to multi-sector growth model

2 Sector Accounting

Background: Some Basic Concepts

- **Industries:** collections of establishments that produce similar goods or services.
  - Establishments produce (gross) output from capital, labor and intermediate inputs.
  - Establishments sell output to final uses, other establishments, or themselves.
- **Sectors:** aggregates of industries with similar characteristics.
- **Value added:** value of gross output minus value of intermediate inputs.
- **Final expenditures:** gross output delivered to final uses.
  - Final expenditures are a composite of value added from different sectors.
  - Input-output tables link final expenditures to gross output and value added.

- **Productivity:** value added in international prices per worker.
- **Productivity gap:** productivity relative to frontier productivity.
- **Frontier productivity** in a sector and year:
  the productivity of the United States in that sector and year.

Data issue

- **Cross-country measurement of aggregate productivity**
  - PWT: covers the expenditure side of NIPA
  - Provides PPPs for GDP and for final *expenditure categories* at purchasers' prices
- **Cross-country measurement of sector productivity**
  - sector value added from the *production side of NIPA* at producers' prices
  - Sector PPPs to convert domestic prices into international prices

Sector PPPs were not available except for a small set of, primarily rich countries.

Groningen Growth and Development Centre (GGDC)

- **Productivity Level Database (PLD) 2023**
  - 84 countries (18 Africa, 21 Asia, 9 Latin-America, 32; Europe, 4 Western Offshoots); it covers 88 percent of the world population
  - Three cross-sections: 2005, 2011, 2017 (ICP benchmark years)
  - 12 sectors

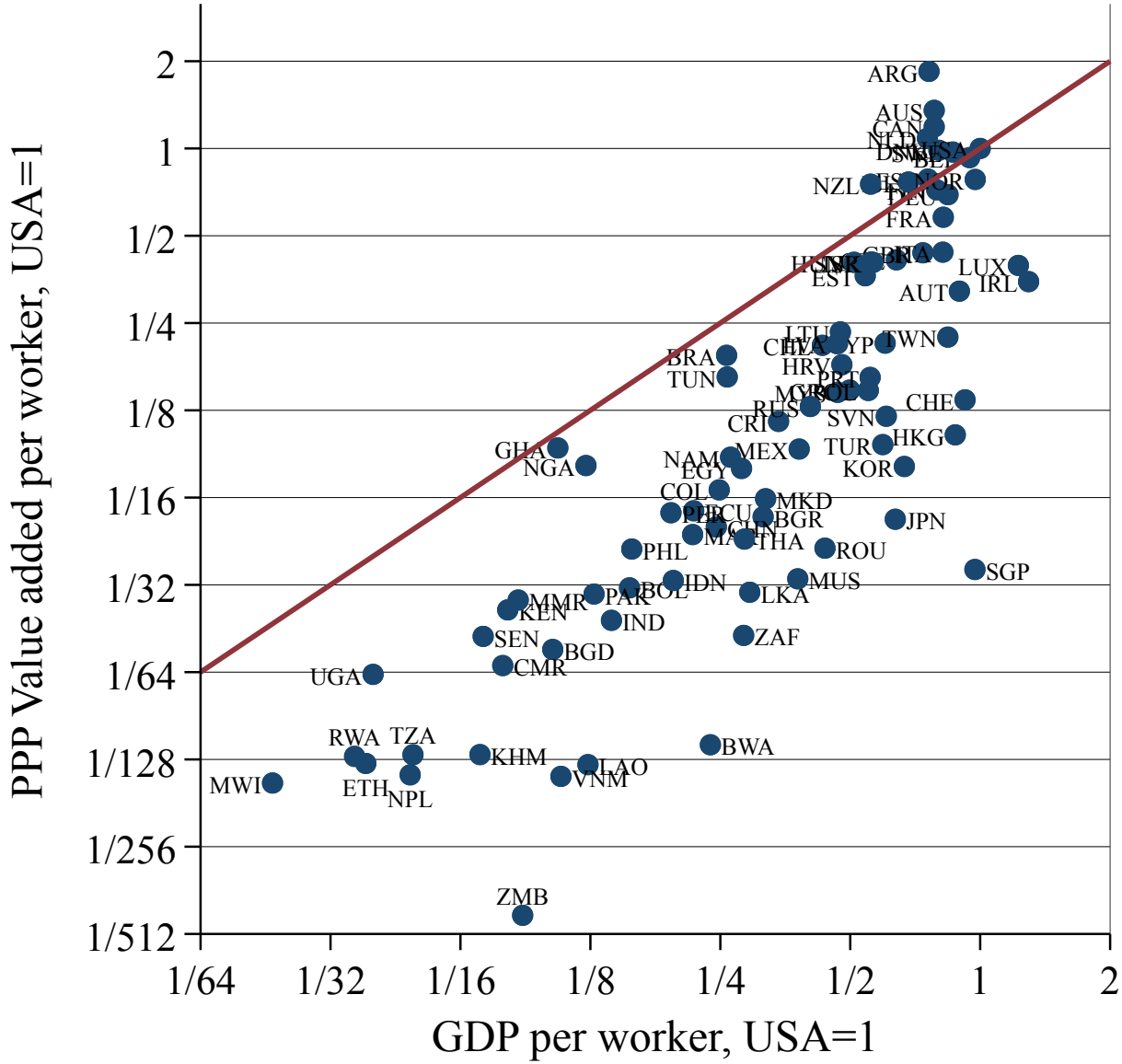
Agriculture	
Mining	
Manufacturing	**Goods**
Public Utilities	
Construction	
Trade	
Transport	
Business Services	
Financial Services	**Services**
Other Services	
Real Estate	
Government Services	

  - Sectoral value added at current prices, value added PPP, and employment
  - We aggregate sector PPPs into goods, services and total value added PPP

- We proceed in two steps
  1. Contrast sector productivity gaps with the aggregate
  2. Gauge the importance sector gaps for the aggregate we review the evidence how sectoral employment shares and value added shares at domestic prices vary with aggregate productivity gaps.

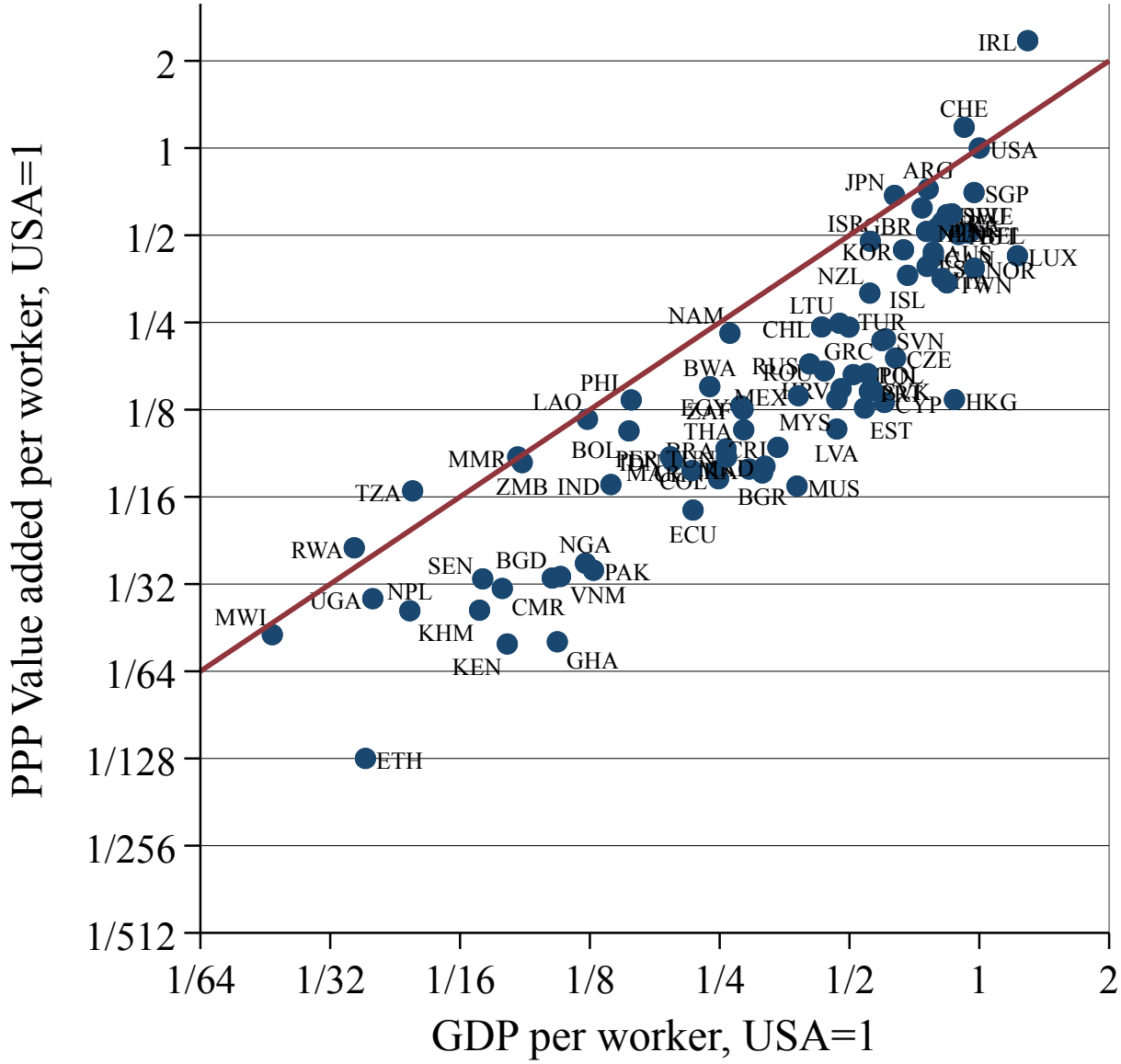
Productivity Gaps

Productivity Gaps in Agriculture vs. Aggregate in 2017



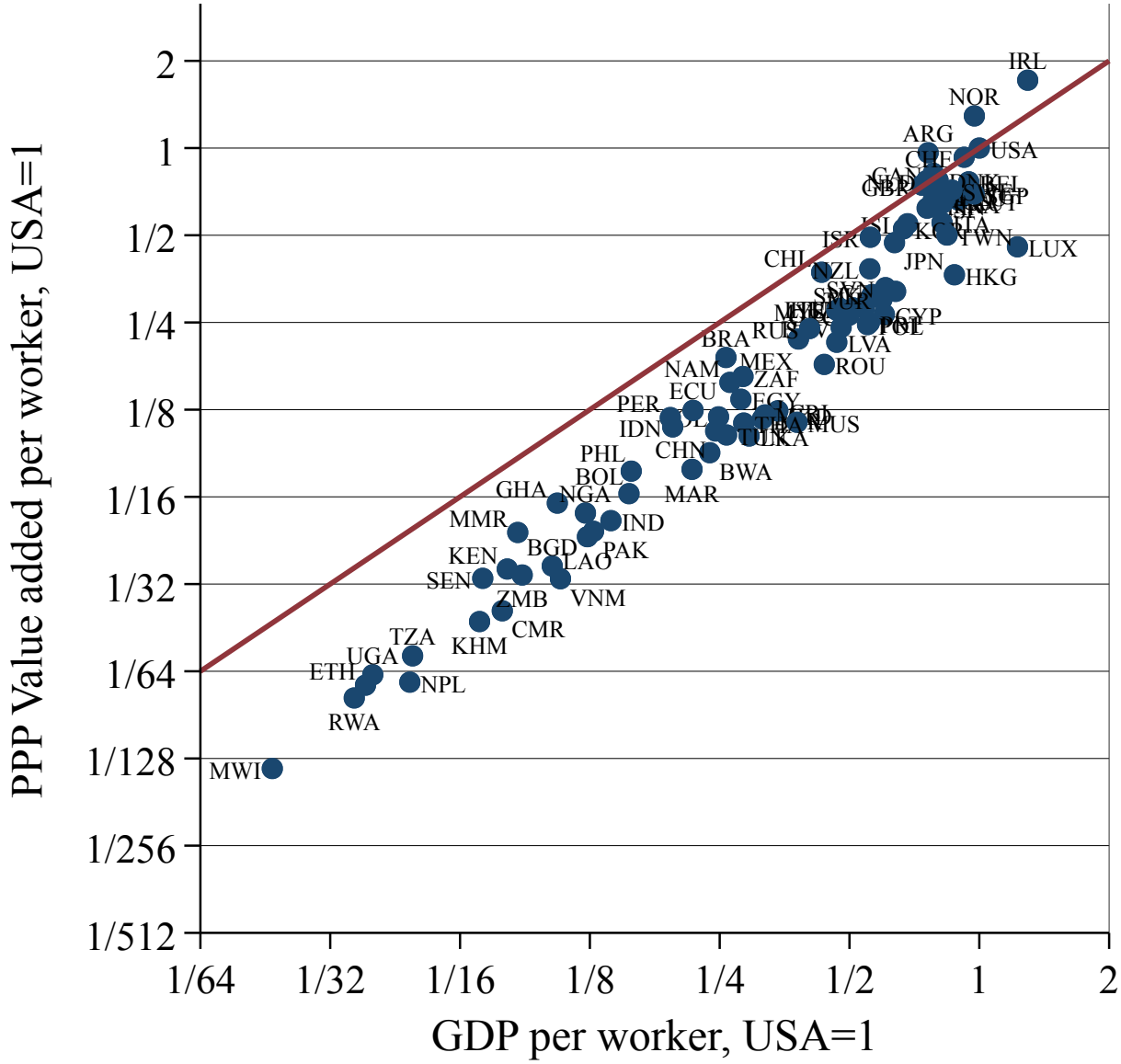
Source: Productivity Level Database, 2023, GGDC

Productivity Gaps in Manufacturing vs. Aggregate in 2017



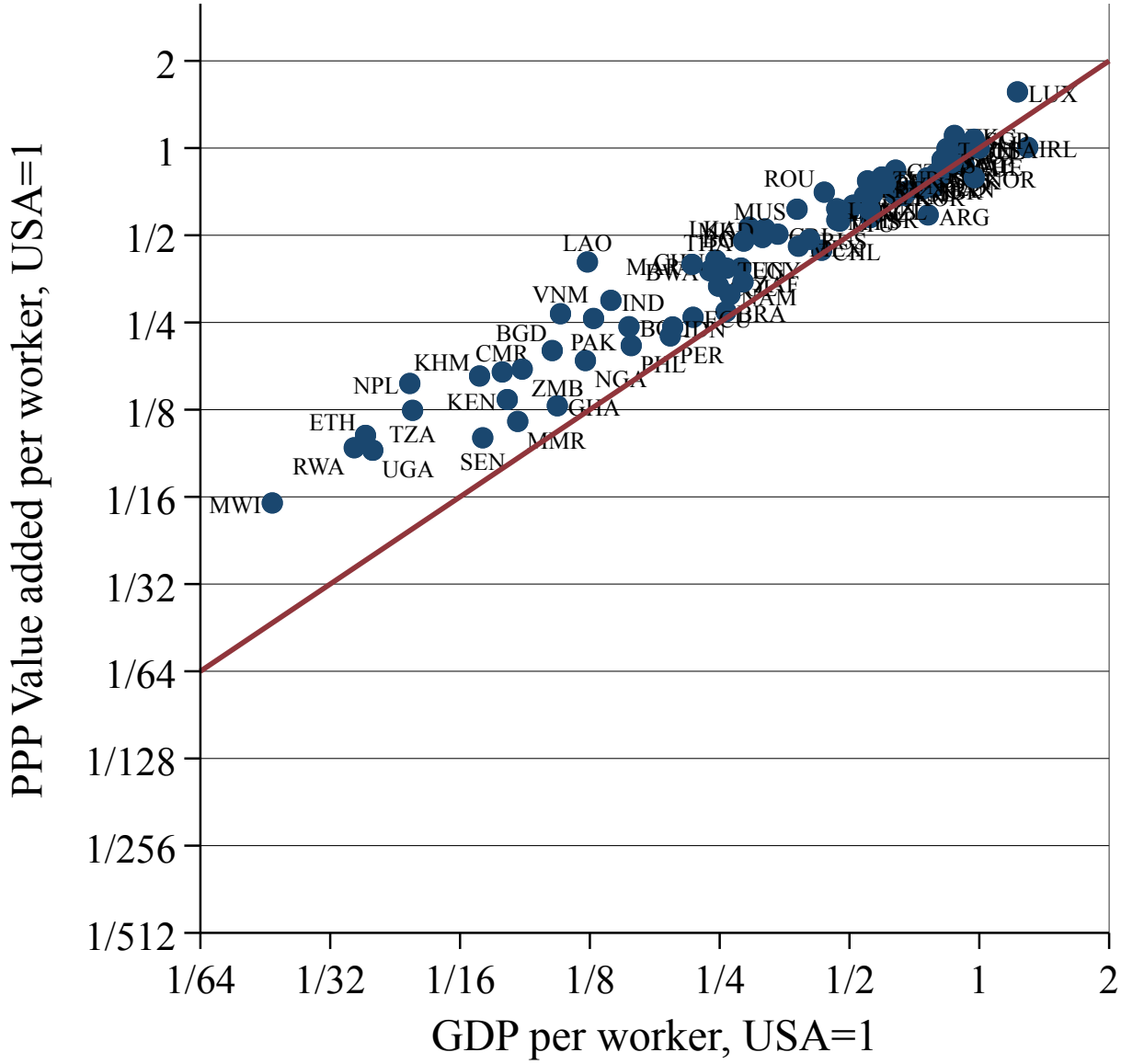
Source: Productivity Level Database, 2023, GGDC

Productivity Gaps in Goods vs. Aggregate in 2017



Source: Productivity Level Database, 2023, GGDC

Productivity Gaps in Services vs. Aggregate in 2017

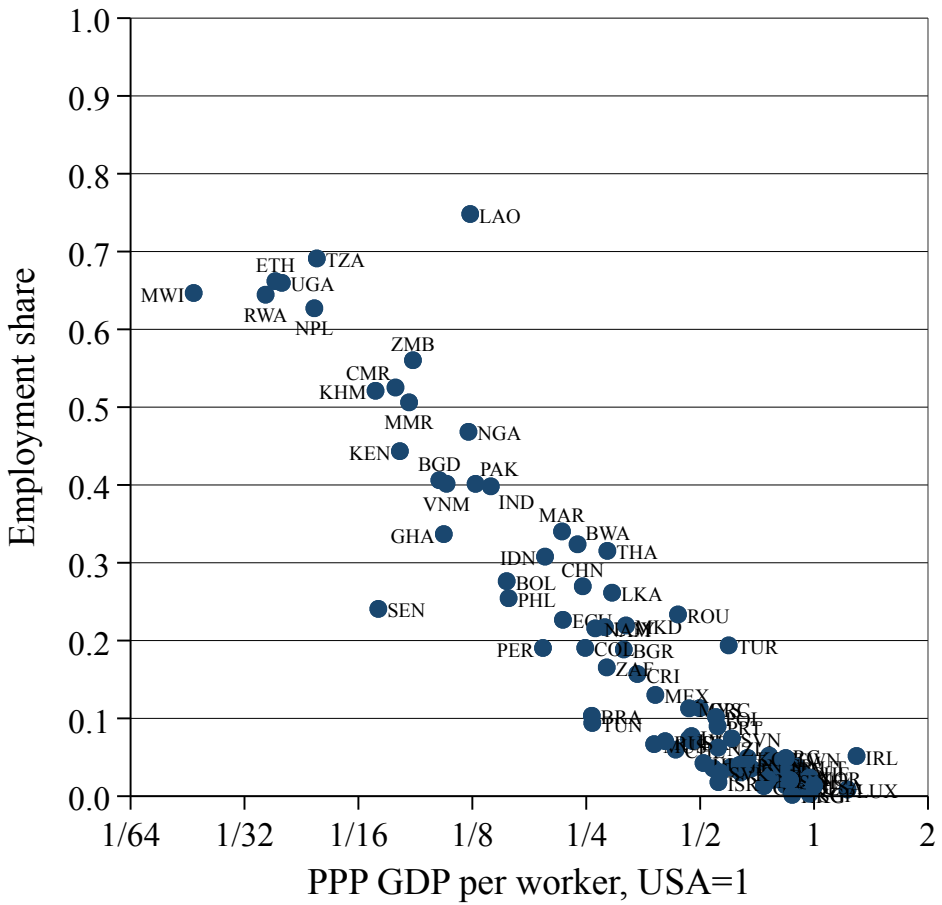


Source: Productivity Level Database, 2023, GGDC

Employment and Value Added Shares

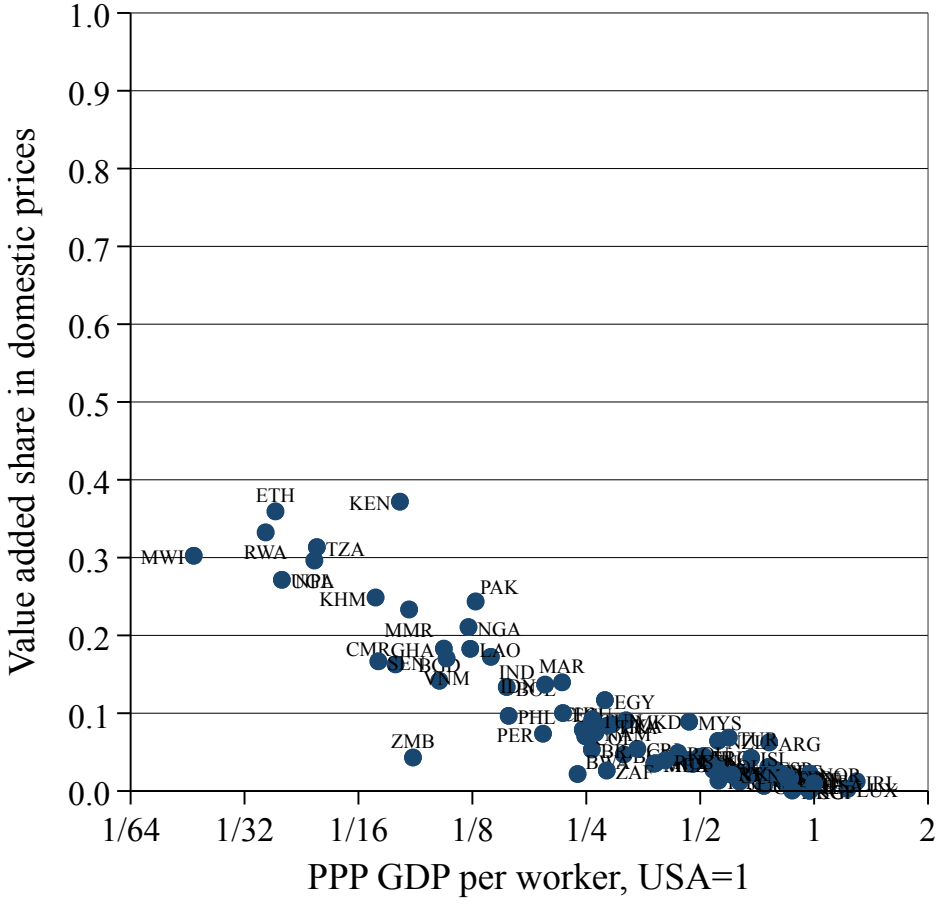
Agriculture

Employment Share in 2017



Source: Productivity Level Database, 2023, GGDC

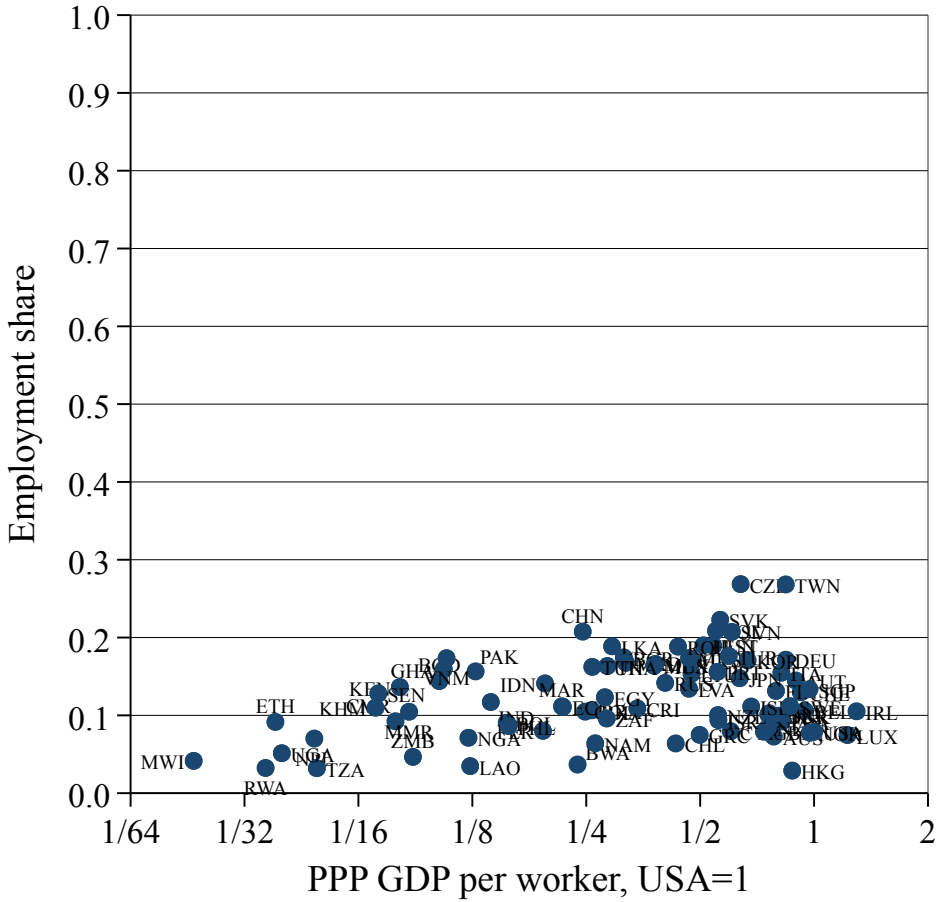
Value Added share in 2017



Source: Productivity Level Database, 2023, GGDC

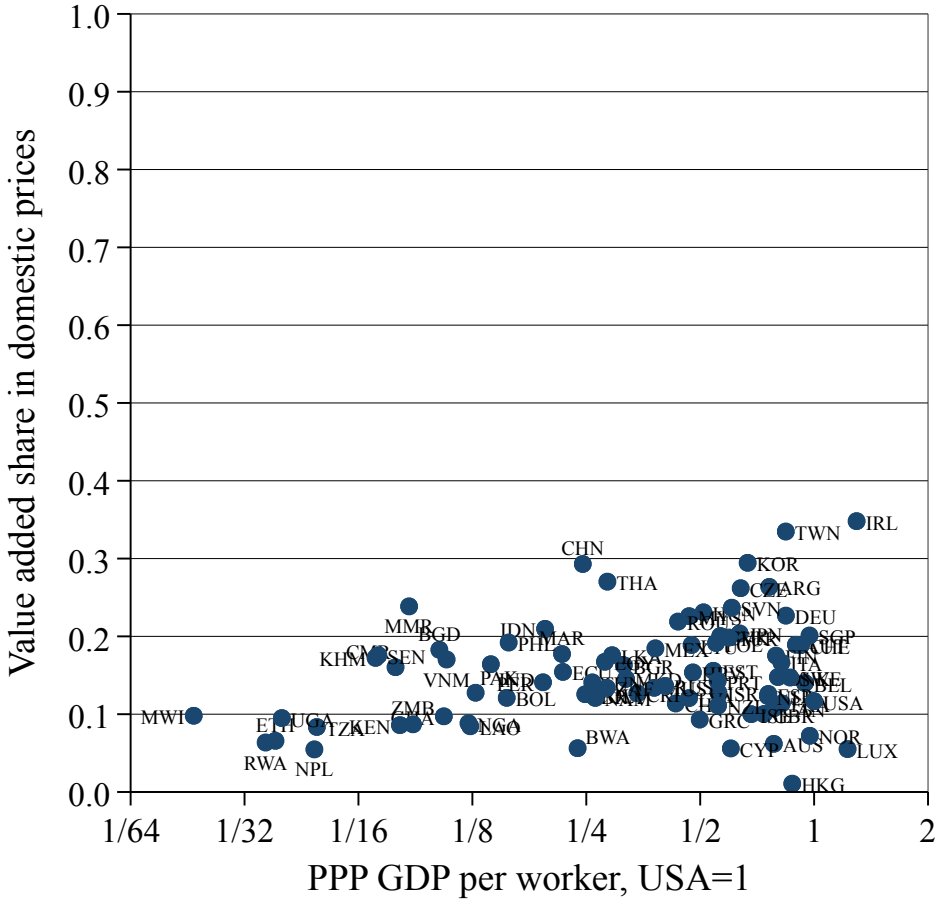
Manufacturing

Employment Share in 2017



Source: Productivity Level Database, 2023, GGDC

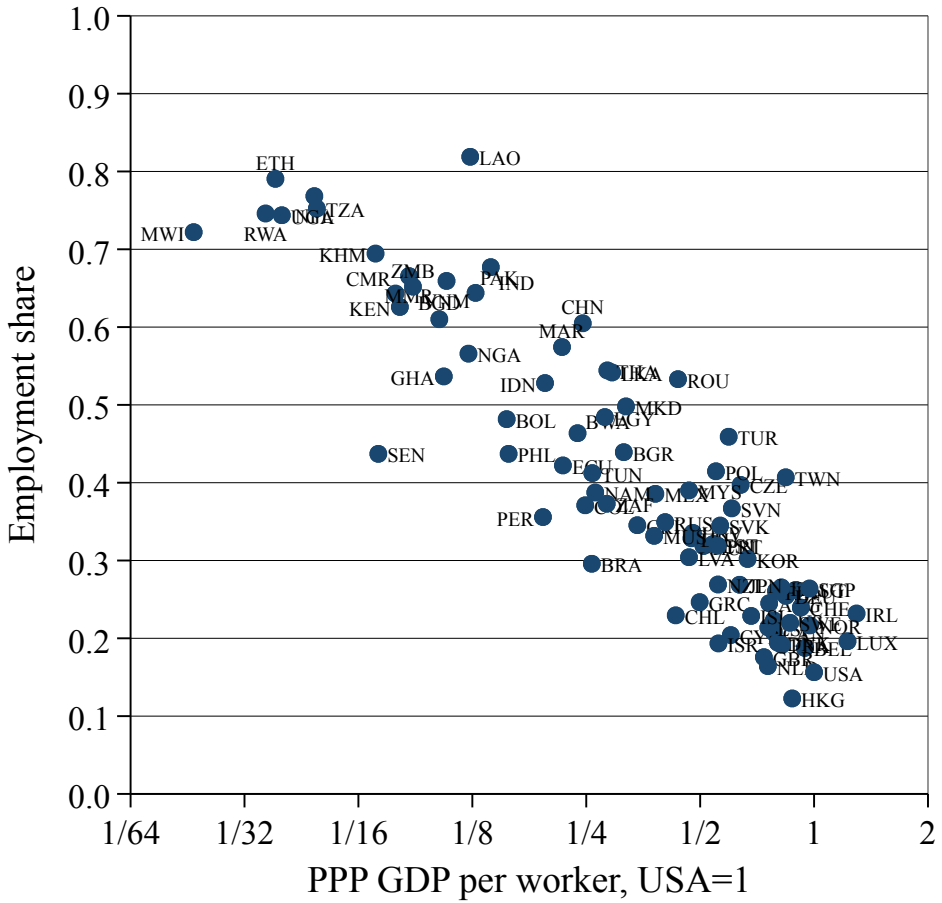
Value Added share in 2017



Source: Productivity Level Database, 2023, GGDC

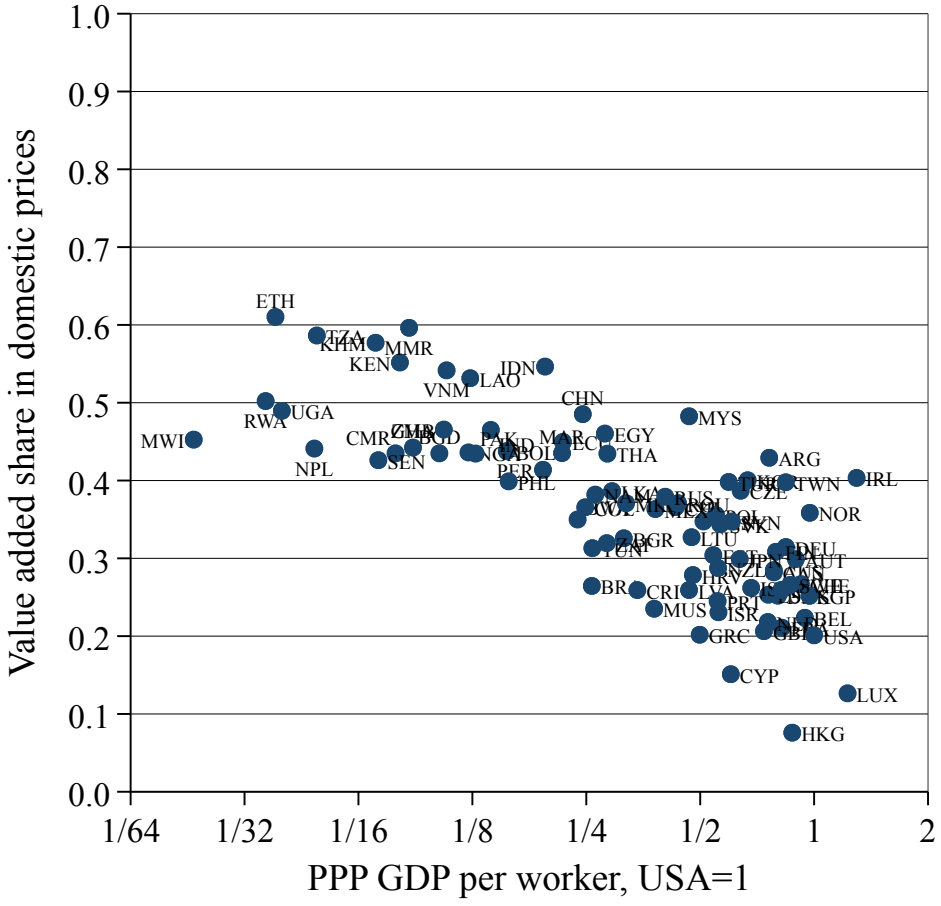
Goods

Employment Share in 2017



Source: Productivity Level Database, 2023, GGDC

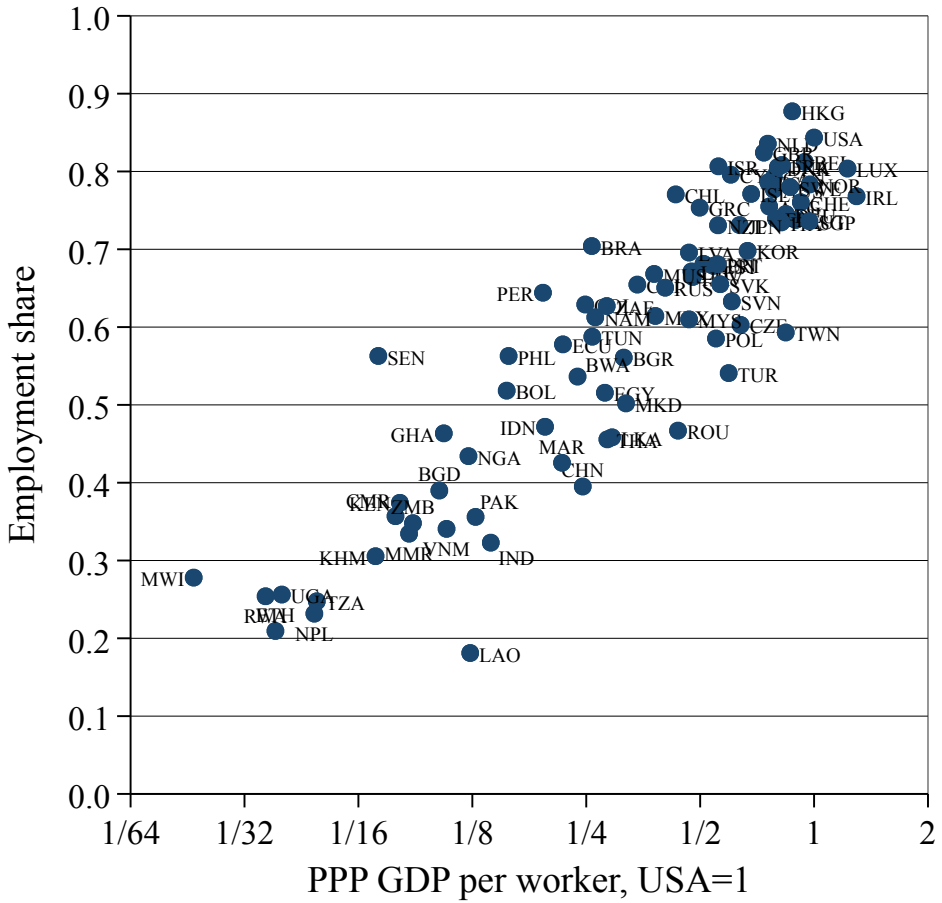
Value Added share in 2017



Source: Productivity Level Database, 2023, GGDC

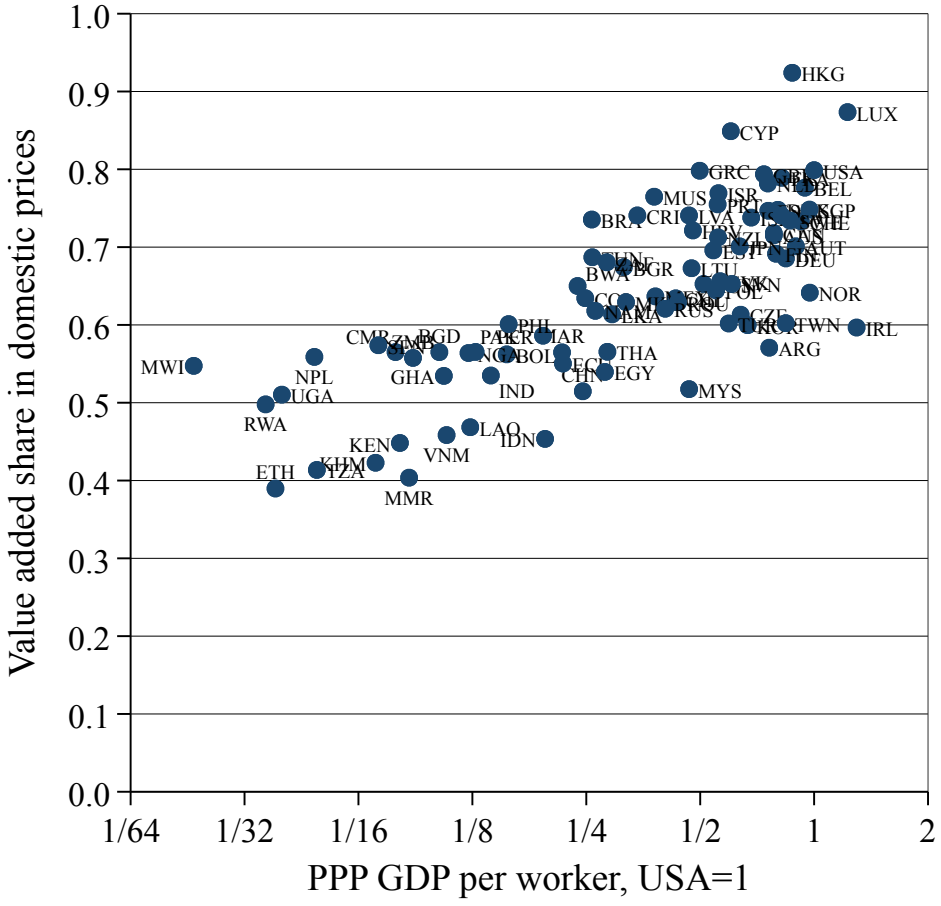
Services

Employment Share in 2017



Source: Productivity Level Database, 2023, GGDC

Value Added share in 2017



Source: Productivity Level Database, 2023, GGDC

Take Away From Sector Accounting

- **Productivity gaps**

The 90 and 10 percentile ratio of

Aggregate	15
Agriculture	92
Manufacturing	16
Goods	35
Services	7

- **Poor countries**
  - employ a large share of workers in the least productive sectors
  - produce a large share of their value added in the least productive sectors

3 Macroeconomic Data and Multi-Sector Growth Models

Complications of using multi–sector growth models

- Mapping model into the data is more complex than mapping the one sector model.
- Relative price movements
- Model GDP and data GDP are defined differently
- “Real” quantities in the model are different from real quantities in the data

Two-sector Growth Model

- **Utility**

$$\sum_{t=0}^{\infty} \beta^t \log(C_t).$$

- **Production functions**

$$C_t = K_{ct}^{\theta}(A_{ct}L_{ct})^{1-\theta}, \qquad X_t = K_{xt}^{\theta}(A_{xt}L_{xt})^{1-\theta}.$$

- **Growth factors**

$$\widehat{A}_{it+1} \equiv \frac{A_{it+1}}{A_{it}}$$

- **Feasibility**

$$K_{ct} + K_{xt} \leq K_t, \qquad L_{ct} + L_{xt} \leq L_t = 1.$$

- **Capital accumulation**

$$K_{t+1} = (1-\delta)K_t + X_t.$$

Competitive Equilibrium

Household problem

- Euler equation governs consumption growth: $\dfrac{C_{t+1}p_{ct+1}/p_{xt+1}}{C_t p_{ct}/p_{xt}} = \beta(1-\delta+R_{t+1})$

Firm problem

- First-order conditions imply:

$$\frac{p_{xt}}{p_{ct}} = \left(\frac{A_{ct}}{A_{xt}}\right)^{1-\theta}.$$

- Empirically relevant case: $p_{xt}/p_{ct} \downarrow$.

Assumption for rest of the two-sector model: $\widehat{A}_{ct} < \widehat{A}_{xt}$.

Equalization of capital-labor ratios

- First-order conditions of firm problem imply:

$$\frac{K_{ct}}{L_{ct}} = \frac{K_{xt}}{L_{xt}} = \frac{K_t}{L_t} = K_t.$$

- Sectoral production functions:

$$C_t = K_t^{\theta} A_{ct}^{1-\theta} L_{ct}, \qquad X_t = K_t^{\theta} A_{xt}^{1-\theta} L_{xt}.$$

- Expenditure ratios equal labor ratios:

$$\frac{p_{ct} C_t}{p_{xt} X_t} = \frac{L_{ct}}{L_{xt}}.$$

Production side aggregation

- GDP in units of numeraires (from current period):

$$Y_t^C \equiv C_t + P_{xt}X_t, \qquad Y_t^X \equiv P_{ct}C_t + X_t,$$

where

$$P_{xt} \equiv \frac{p_{xt}}{p_{ct}}, \qquad P_{ct} \equiv \frac{p_{ct}}{p_{xt}}.$$

- Aggregate production functions:

$$Y_t^C = K_t^\theta A_{ct}^{1-\theta}, \qquad Y_t^X = K_t^\theta A_{xt}^{1-\theta}.$$

- Wage in units of numeraires (from current period)

$$w_t^C = (1-\theta)\left(\frac{K_t}{A_{ct}}\right)^\theta, \qquad w_t^X = (1-\theta)\left(\frac{K_t}{A_{xt}}\right)^\theta.$$

Aggregation and GDP measures

GDP growth

- With the numeraires:

$$\widehat{Y}_t^C \equiv \frac{C_t + P_{xt}X_t}{C_{t-1} + P_{xt-1}X_{t-1}}, \qquad \widehat{Y}_t^X \equiv \frac{P_{ct}C_t + X_t}{P_{ct-1}C_{t-1} + X_{t-1}}.$$

- With Fisher quantity index:

$$\widehat{Y}_t^F \equiv \sqrt{\underbrace{\frac{C_t + P_{xt-1}X_t}{C_{t-1} + P_{xt-1}X_{t-1}}}_{\text{Laspeyres Index}} \cdot \underbrace{\frac{C_t + P_{xt}X_t}{C_{t-1} + P_{xt}X_{t-1}}}_{\text{Paasche Index}}} = \sqrt{\underbrace{\frac{P_{ct-1}C_t + X_t}{P_{ct-1}C_{t-1} + X_{t-1}}}_{\text{Laspeyres Index}} \cdot \underbrace{\frac{P_{ct}C_t + X_t}{P_{ct}C_{t-1} + X_{t-1}}}_{\text{Paasche Index}}}.$$

GDP Per Worker in the U.S. during 1947–2018

	Average annual growth rates (in %)				Levels in
	1947–2018	1947–1970	1970–1994	1994–2018	2018
Investment units	2.61	2.81	2.03	2.99	2.49
Chained Fischer index	1.68	2.42	1.21	1.44	1.28
Consumption units	1.33	2.26	0.89	0.87	1.00

Source: NIPA, Bureau of Economic Analysis, Bureau of Labour Statistics, own calculations.

Facts about the Productivity Growth Slowdown

Consumer durables

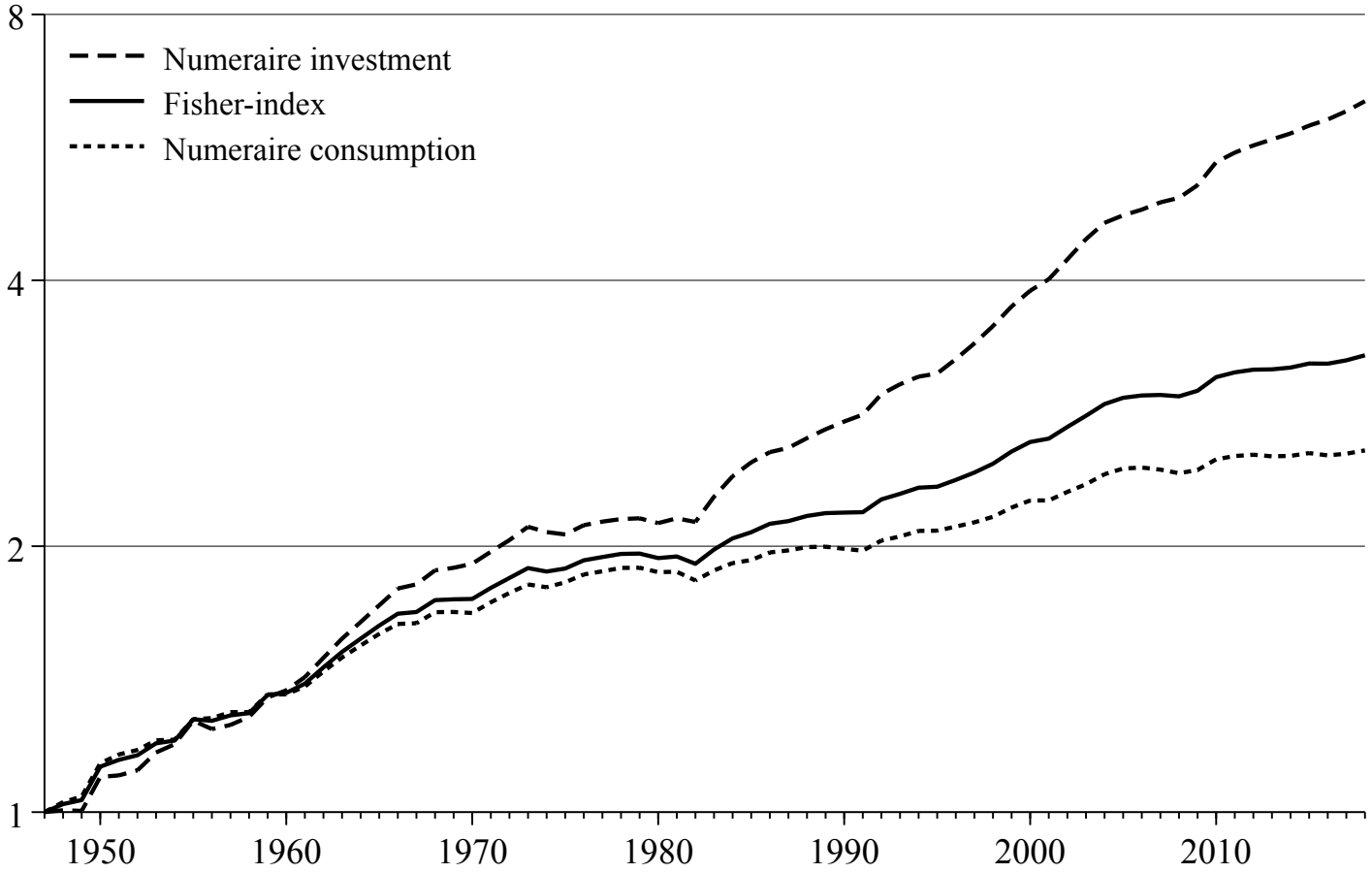
- The BEA treats the purchases of consumer durables as personal consumption expenditure.
- We treat the purchases of consumer durables as investment expenditures.
- We follow the methodology of Cooley and Prescott (1995):

(i) reassign the flow of purchases of consumer durables from consumption to investment;

(ii) add an imputed services flow from the stock of consumer durables to consumption.

Real GDP per Worker in the Postwar U.S.

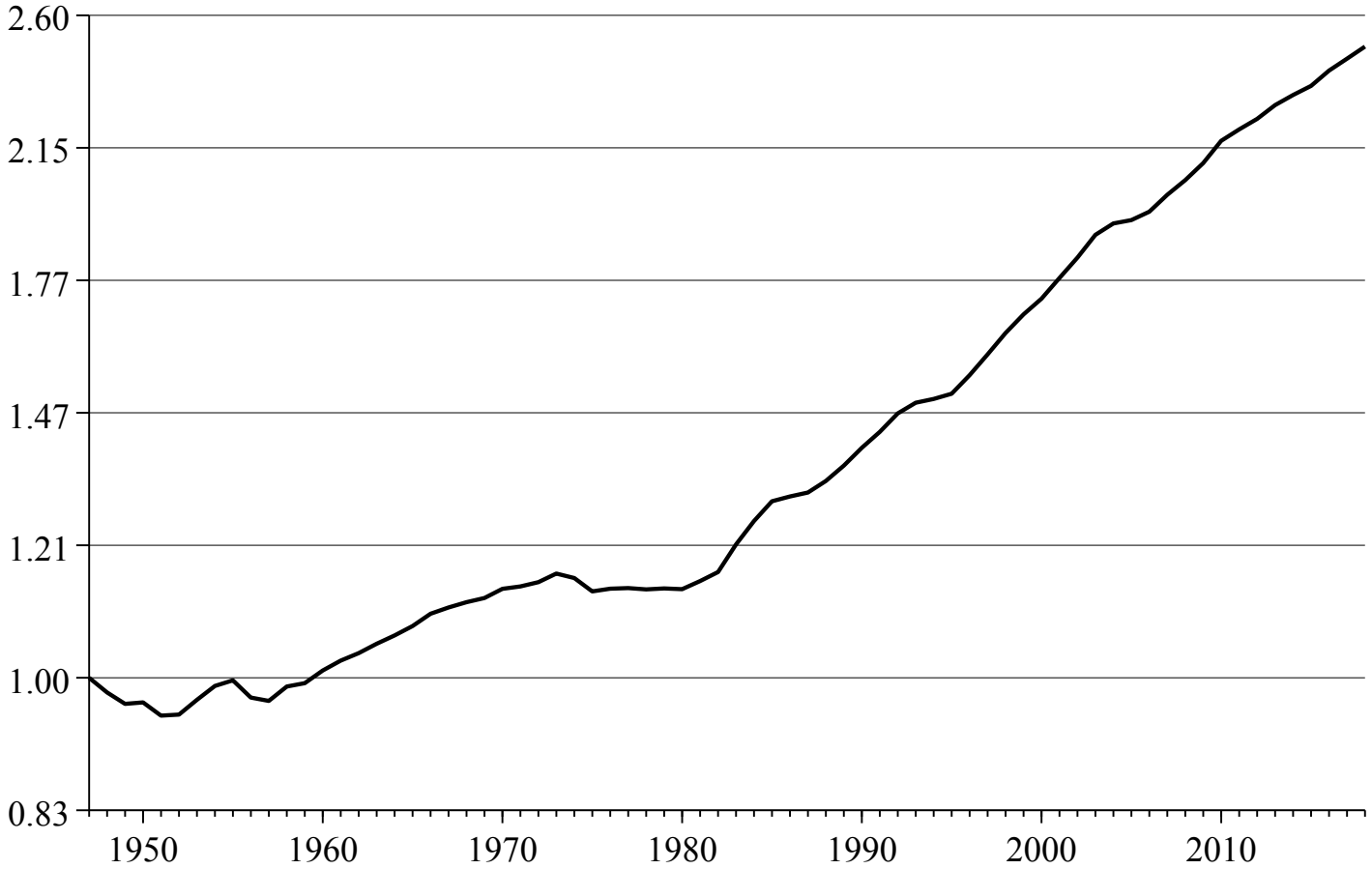
(log scale, 1947=1)



Source: NIPA, Bureau of Economic Analysis, Bureau of Labour Statistics, own calculations.

Price of Consumption relative to Investment in the Postwar U.S.

(Levels in log scale, 1947=1)



Source: NIPA, Bureau of Economic Analysis, Bureau of Labour Statistics, own calculatio

Implications for how to connect the model with the data

- Construct a BGP in the model using the numeraire investment.
- Construct model GDP by applying the Fisher index to the BGP.
- Connect model GDP calculated in this way to NIPA GDP.

This can be generalised to other multi-sector models

- Choose a numeraire which allows for a constant interest rate

Balanced Growth and Productivity Growth Slowdown in Multi-sector Growth Models

- Generalized balanced growth path (GBGP) along which real interest rate is constant
  - Balanced growth only at the aggregate level.
  - Changes in relative prices and sector shares permitted to happen underneath GBGP.
- Suppose that $\widehat{A_x}$ is constant.
- There is a GBGP along which $\left\{K_t, X_t, C_t, Y_t^X, Y_t^C\right\}_{t=0}^{\infty}$ grow at the following factors:

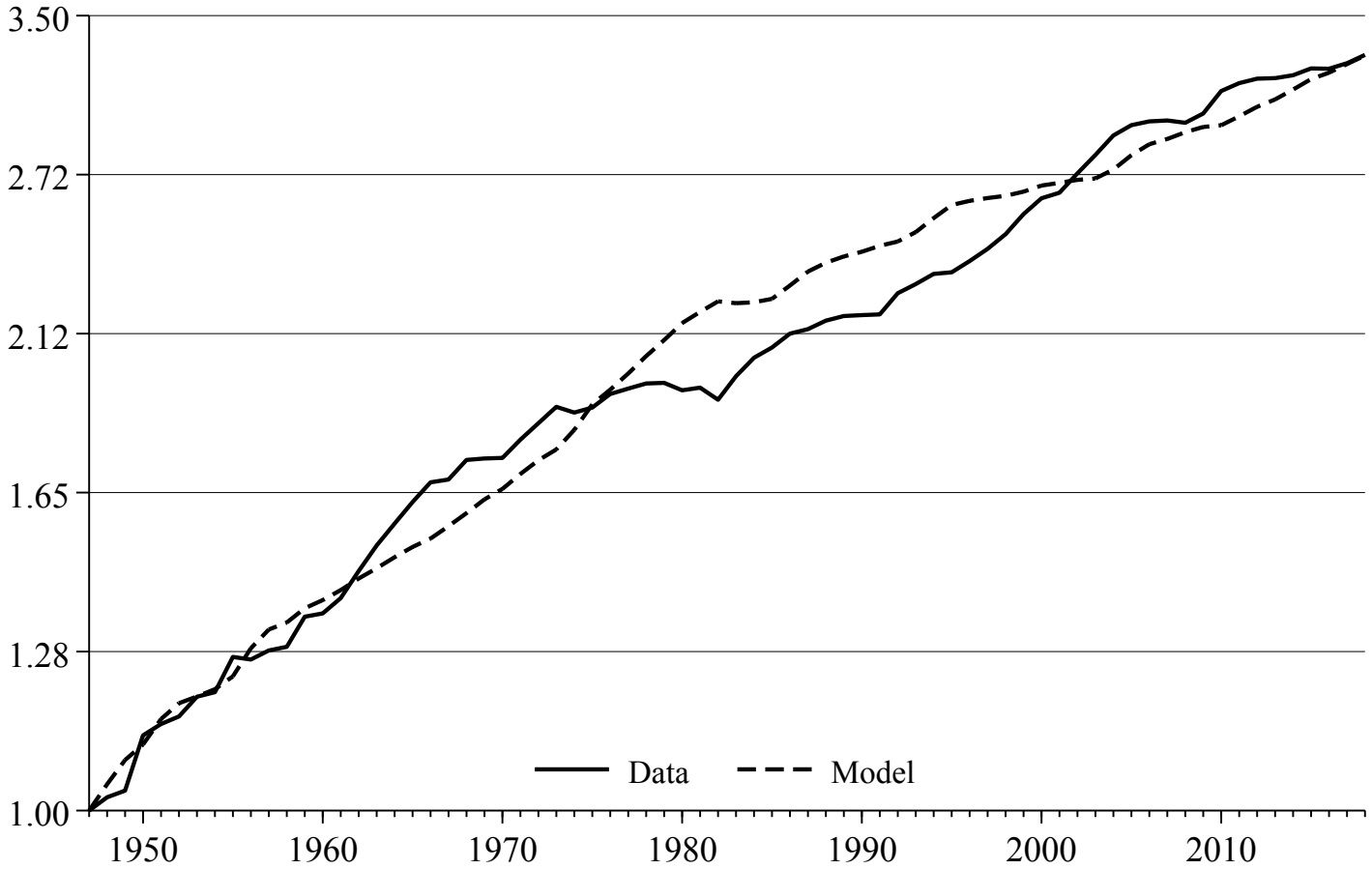
$$\widehat{K_t} = \widehat{X_t} = \widehat{Y_t^X} = \widehat{A_x}, \quad \widehat{C_t} = \widehat{Y_t^C} = \widehat{A_x^\theta} \widehat{A_{ct}^{1-\theta}}.$$

In addition, if $p_{xt} = 1$, then r_t and R_t are constant and $\{w_t, p_{ct}\}_{t=0}^{\infty}$ grow:

$$r = \theta \left(\frac{K_t}{A_{xt}}\right)^{\theta-1}, \qquad R = 1 - \delta + \theta \left(\frac{K_0}{A_{x0}}\right)^{\theta-1},$$

$$w_t = (1-\theta)\left(\frac{K_t}{A_{xt}}\right)^{\theta} A_{xt}, \quad p_{ct} = \left(\frac{A_x}{A_{ct}}\right)^{1-\theta}.$$

Data versus model of GDP per worker measured with the Fisher index (log scale, 1947=1)



Source: NIPA, Bureau of Economic Analysis, Bureau of Labour Statistics, own calculatio

4 Structural Change in Consumption and Investment

Expenditure and Production Side of NIPA

- **Expenditure side of NIPA**
  - Detailed information about final expenditure categories (consumption and investment)
  - No information of production factors
- **Production side of NIPA**
  - No information of final expenditure categories
  - Information about outputs and production factors at the sector level

Input-output Structure of the Economy

- It connects the two sides of the NIPA
  - Final expenditures are a composite of value added from different sectors.
  - Annual input-output tables for the US available post 1947

How to Proceed?

- Write down a model with full fledged input-output structure
  - It might be an overkill
- Use input-output tables to brake down final expenditures into their sectoral value added components
  - The so called total requirement matrix allows to do it.
  - The sectoral value added representation of final expenditures we can be combined with sector production factors

Estimating Stone-Geary Preferences on US data

- Consider the utility function

$$C_t = \left(\omega_c^{\frac{1}{\varepsilon_c}} C_{gt}^{\frac{\varepsilon_c - 1}{\varepsilon_c}} + (1-\omega_c)^{\frac{1}{\varepsilon_c}} (C_{st} + \bar{C}_s)^{\frac{\varepsilon_c - 1}{\varepsilon_c}} \right)^{\frac{\varepsilon_c}{\varepsilon_c - 1}},$$

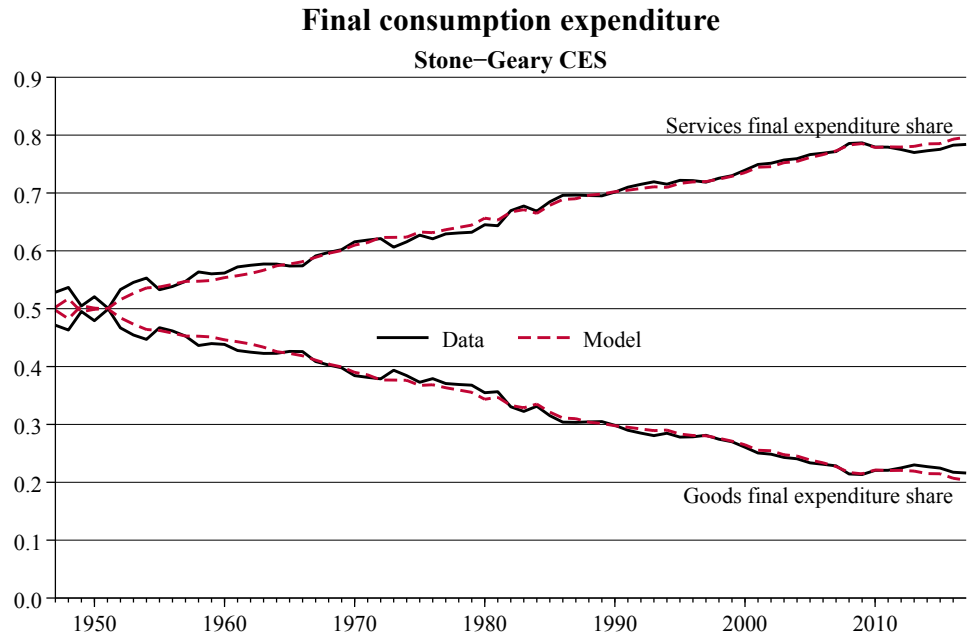
  which implies the demand function

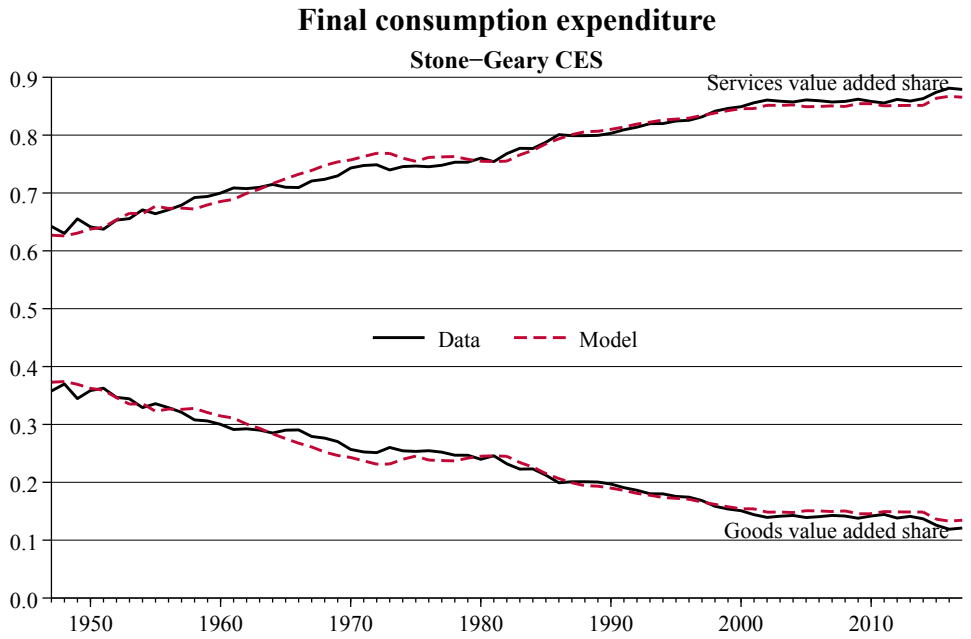
$$\frac{P_{gt} C_{gt}}{E_t} = \frac{\omega_c P_{it}^{1-\varepsilon_c}}{\omega_c P_{gt}^{1-\varepsilon_c} + (1-\omega_c) P_{st}^{1-\varepsilon_c}} \left(1 + \frac{P_{st} \bar{C}_s}{E_t} \right) \tag{1}$$

  with

$$E_t = P_{gt} C_{gt} + P_{st} C_{st}.$$

  where E_t is per capita expenditure.



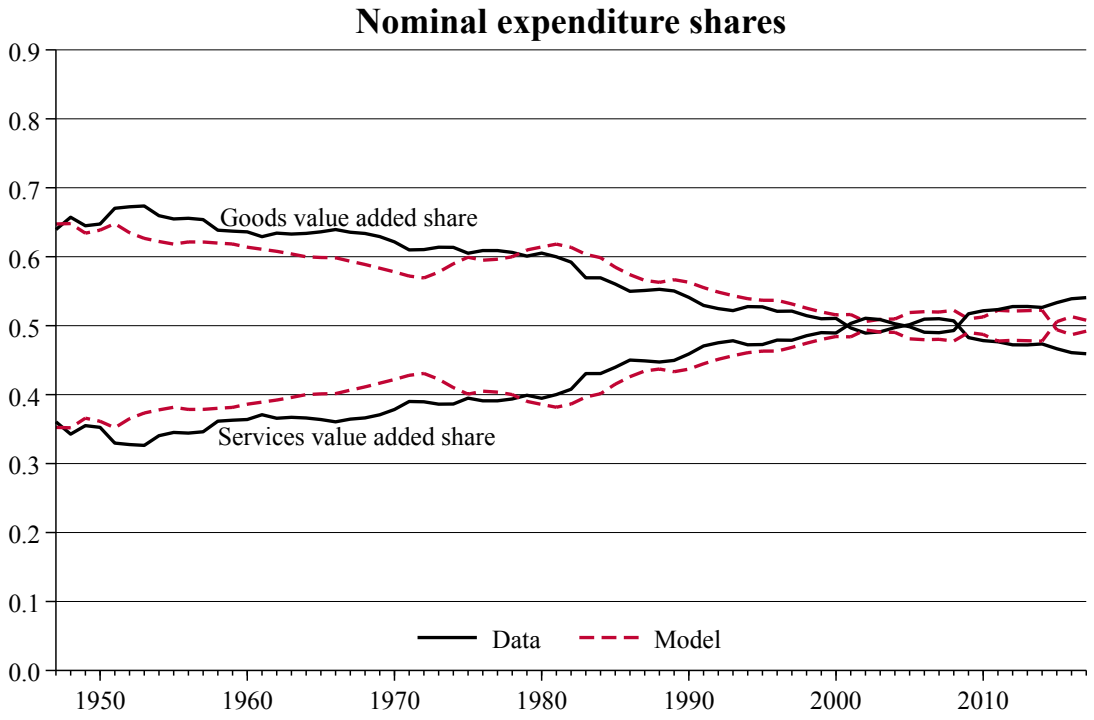


- Estimated
  - $0 < \sigma_c(VA) < \sigma_c(FE) < 1$
  - $\bar{C}_s > 0$, preferences are non–homothetic, hence income effects matter for reallocation

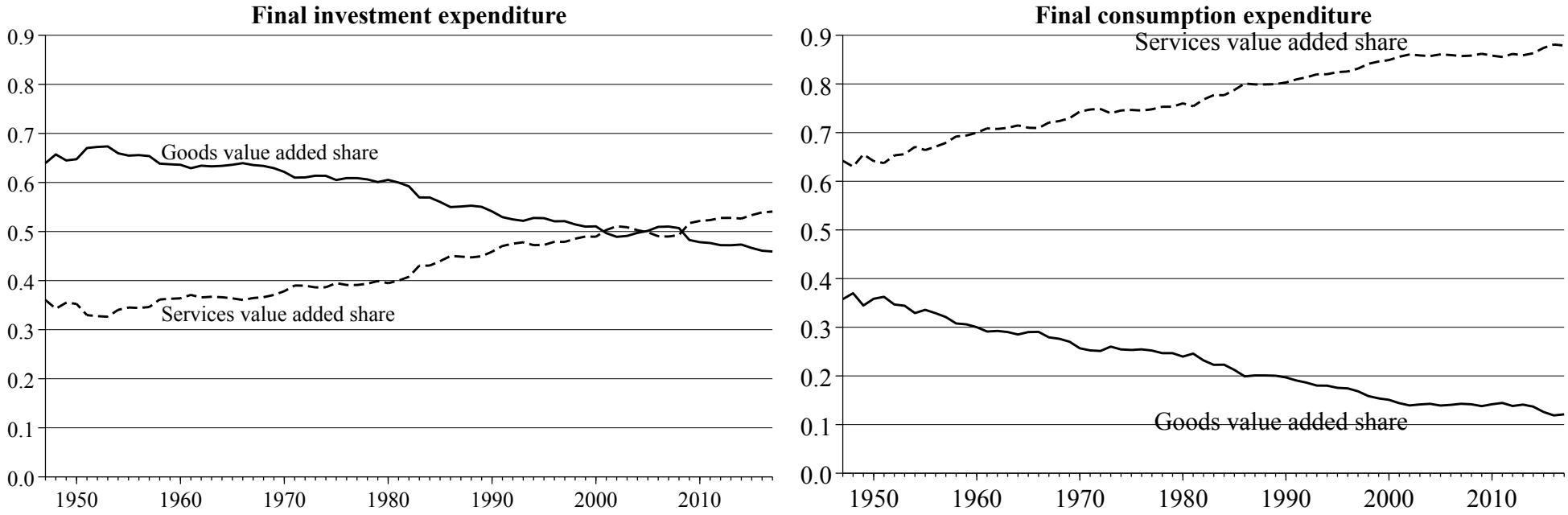
Estimating Investment Technology on US data

- Consider the investment technology

$$X_t = A_{xt}\left(\omega_x^{\frac{1}{\varepsilon_x}} X_{gt}^{\frac{\varepsilon_x-1}{\varepsilon_x}} + (1-\omega_x)^{\frac{1}{\varepsilon_x}} X_{st}^{\frac{\varepsilon_x-1}{\varepsilon_x}}\right)^{\frac{\varepsilon_x}{\varepsilon_x-1}}.$$

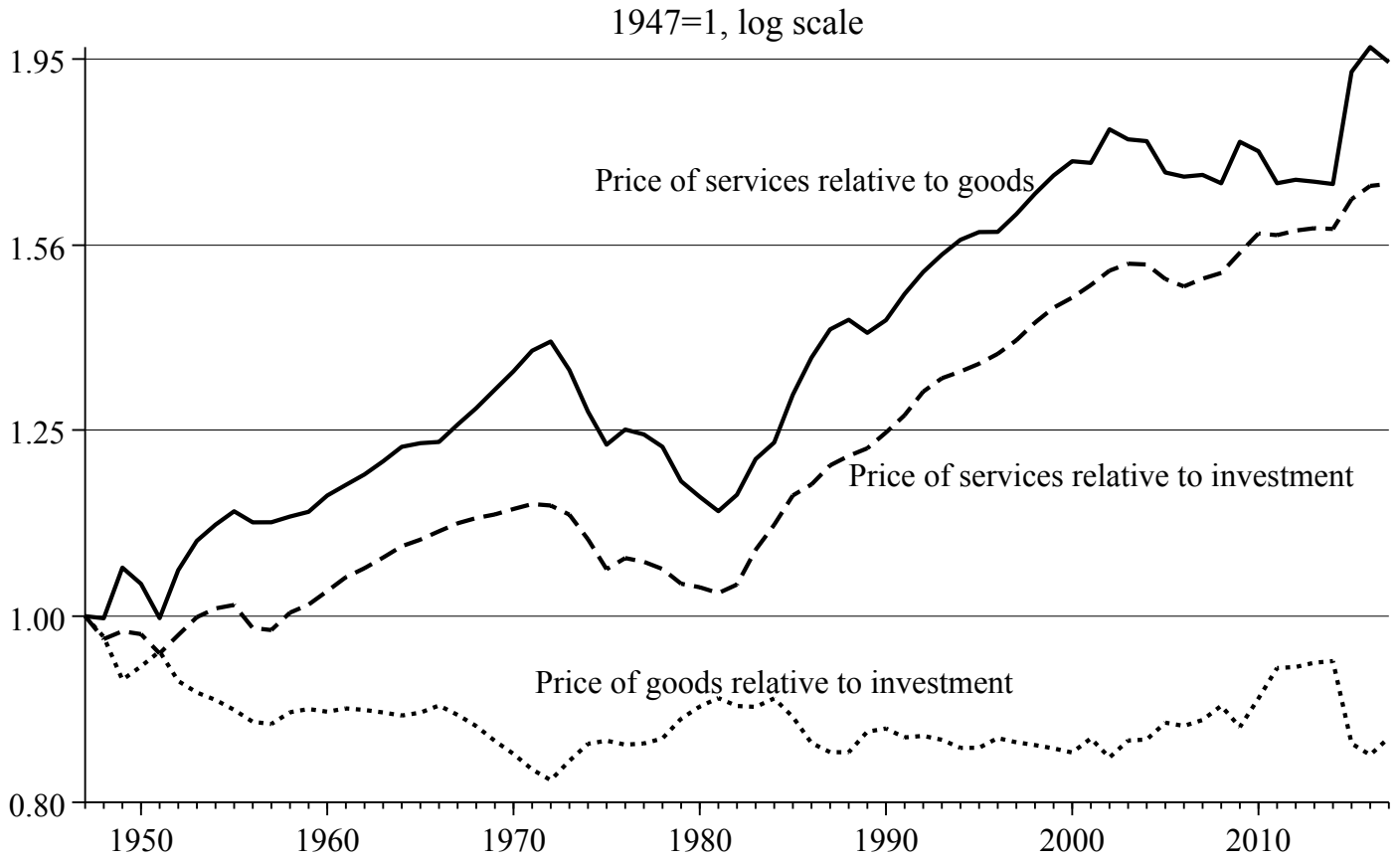


Estimated $\varepsilon_x = 0$



Investment is more goods intensive than consumption, $\omega_c < \omega_x$

Relative prices on US data



5. Conclusion

- Sector productivity gaps are large
  - Goods sector gaps tend to be larger and service gaps smaller the the aggregate gap
  - Poor countries employ a large share of their workforce in unproductive sectors
  - Agriculture is one of the key unproductive sector in poor countries
- Taking data to multi-sector models is more complex than taking them to one sector model
  - When solve a multi-sector model we chose a numeraire
  - Official statistics do not use a numeraire.
- Reallocation is driven both
  - by income effects, and
  - by price effects