On the Investment Network and Development

Lucía Casal
Columbia University & CREI

Julieta Caunedo
Cornell University
CEPR

October 2025

Motivation

Salient features of the process of economic development:

Capital accumulation **Productivity growth** **Sectorial reallocation**

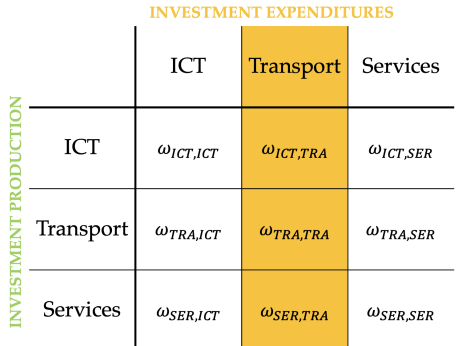
sectors use different capital types → produced by other sectors or imported.

Investment Network

Hirschman ('58)'s hypothesis: investment linkages important for economic development

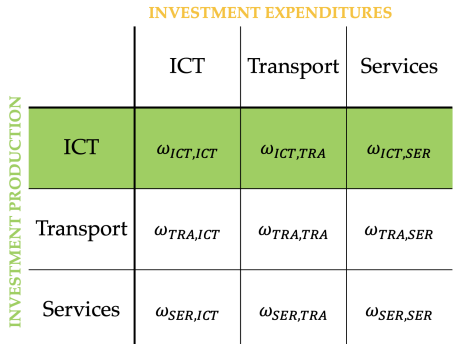
What is the role of investment network for income disparities?

The Investment Network



$$\left(\sum_{j} \omega_{ij} = 1\right)$$

The Investment Network



$$\left(\sum_{j} \omega_{ij} = 1\right)$$

This paper

1. **Dynamic** multisector open economy + **investment network** + intermediates.

2. Constructs harmonized **cross-country measures of the investment network**.
   - Methodology: ≈ BEA in the US
   - Coverage: 58 countries w/income per capita $428 and $81599 constant ppp USD; *9 from sSA; 20 with time series from 1960s.*

3. Document **systematic disparities in the investment network** and output elasticities with development.

4. Infer the role of differences investment network for **income disparities**.

Main findings

Theory:

$$\text{Sectorial Influence} \equiv \frac{\partial \ln(\text{GDP})}{\partial \ln(a_s)} = \underbrace{\tilde{\zeta}}_{\text{VA exp. share}} \overbrace{\tilde{H}\Big(\underbrace{\Omega}_{\text{invest. network}}, \underbrace{M}_{\text{IO}}\Big)}^{\text{augmented Leontief-inverse}}$$

$$\text{Welfare} \equiv \frac{\partial \ln(W)}{\partial \ln(a_s)} = \underbrace{\zeta}_{\text{Domar weight}} H\Big(\underbrace{\frac{x}{k}}_{\text{inv. rate}}, \Omega, M\Big)$$

Quantitatively:

- Differences in Ω explain 28% of s.s. income differences:
  - double the effect of Δ K !
  - 55% of its role from heterogeneity in the uses of investment across sectors.
  - 40% from correlation between sectorial productivity and influence.

- Sectorial influence Δ with income: $\rightarrow$ complementarities with IO and VA shares

Contribution

1. First measures of sectorial investment demand along the development spectrum.
   - Evidence of shifts in the composition of investment Garcia-Santana, et.al. 2021; Herrendorf, et.al. 2021
   - Shifts in the demand for investment and (VA) structural change Caunedo & Keller, 2023

   Available inv. networks in the US and in OECD countries $\longrightarrow$ not harmonized.
   vonLehm & Winberry, 2022 and Ding, 2023

2. Role of the investment network for cross-country income differences: Buera & Trachter (2024)
   IO linkages: Ciccone (2002); Jones (2011); Fadinger, et.al. (2022)

3. Sectorial influence with durable goods: Domar weights depend on investment rates.
   non-durables: Acemoglu et.al. (2012), distortions: Baqaae & Fahri (2020), Liu (2019).

Outline

1. Simple (toy) economy.
2. Measurement of the investment network.
3. Multisector model of investment and intermediate input links.
4. Characterization across the income spectrum.
5. Implications for economic development.

Fixing ideas
A simple economy

A simple economy

Two sectors, no intermediate inputs, no trade, same output elasticities

- GDP

$$\ln(v_t) = \sum_{n=1,2} \eta_{nt} \ln(v_{nt})$$

for η_n the expenditure share of sector n.

- Sectorial technologies

$$v_{nt} = \exp(z_n) K_{nt}^{\alpha} L_{nt}^{1-\alpha} \qquad z_1 \neq z_2$$

$$v_{nt} = c_{nt} + \overbrace{\sum_j \chi_{nit}}^{\chi_{nt}}$$

- Capital accumulation

$$K_{nt+1} = \prod_i \chi_{int}^{\omega_i} + (1-\delta) K_{nt}$$

implication: same investment aggregator $\longrightarrow p_n^k = p_i^k, \longrightarrow \frac{K_n}{L_n} = K$.

A simple economy: steady state

Two sectors, no intermediate inputs, no trade, same output elasticities

Output per worker

$$\ln(v) = \frac{1}{1-\alpha} \sum_{n=1,2} \eta_n z_n + \frac{\alpha}{1-\alpha} \ln(\frac{K}{v})$$

where is the investment network?

$$1 = \beta \left[(1-\delta) + \alpha \omega_n \frac{v}{K} \eta_n{}^{\omega_n} \eta_i{}^{\omega_i} \right]$$

for i the numeraire.

- $\frac{K}{v}$ through the equilibrium $\eta_i(z_i, z_n)$, and investment elasticities, ω_i, ω_n.

How does $\omega_{i(j)}$ look empirically? $\rightarrow$ *investment network.*

Cross-Country Investment Networks

Methodology

Methodology

Use Tables (World IO Database): capital produced or imported.

How is capital produced/imported by a sector purchased by other sectors?

- Imputation approach ≈ BEA's methodology in the US:
  1. manual allocation
  2. proportional to occupational composition of the sector
  3. proportional to capital expenditures (handful of sectors w/microdata)

Equipment Sectors

- Tools used on the job (Caunedo et.al.,'23).

Other Sectors

- Assign capital proportional to intermediate inputs.

Methodology: Example

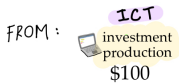
FROM : ICT

investment production

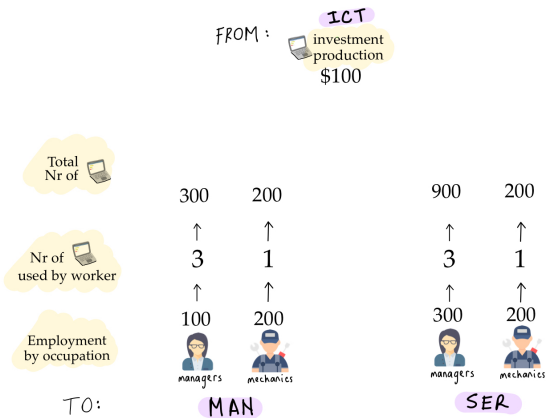
$100

TO: MAN SER

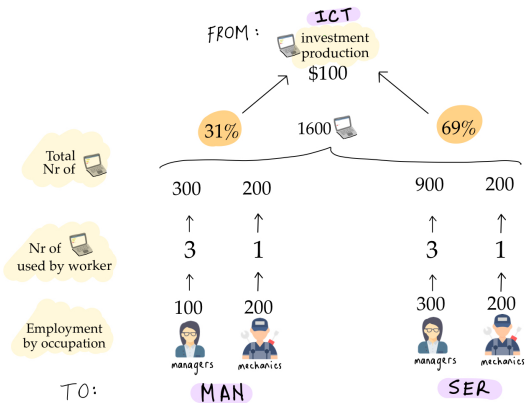
Methodology: Example



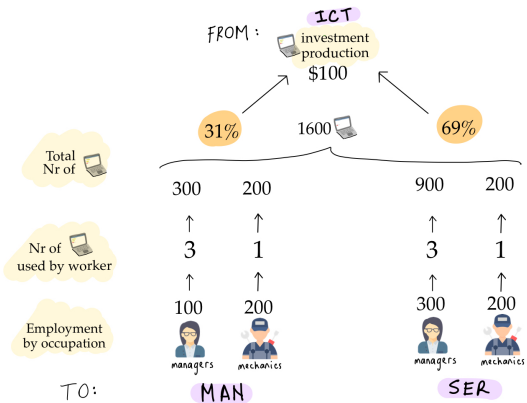
Methodology: Example



Methodology: Example



Methodology: Example



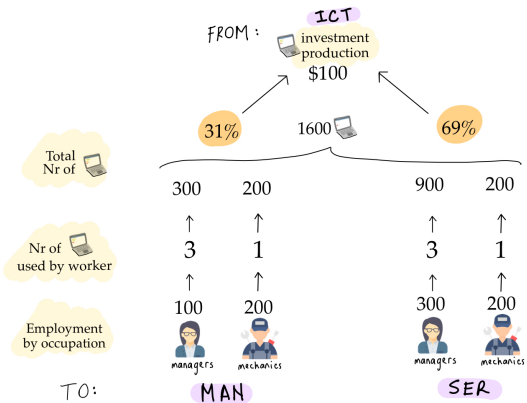
Counterpart in the capital flows table

[values in $]

EXPENDITURES

PRODUCTION	AGRI	MAN	SER	Electronics	ICT	Machinery	Transport	Construc	
AGRI									
MAN									
SER									
Electronics									
ICT		$31	$69						$100
Machinery									
Transport									
Construction									

Methodology: Example



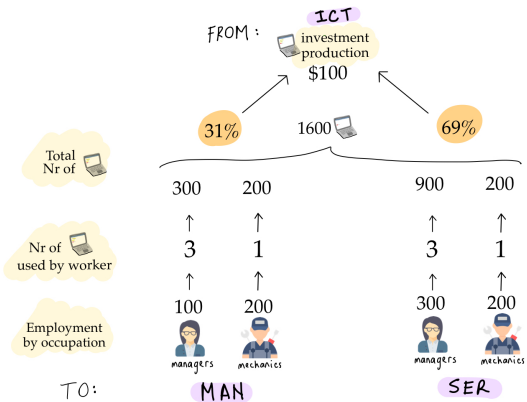
Counterpart in the capital flows table

[values in $]

EXPENDITURES

PRODUCTION	AGRI	MAN	SER	Electronics	ICT	Machinery	Transport	Construction	
AGRI		:	:						
MAN		:	:						
SER		:	:						
Electronics		$20	$50						$70
ICT		$31	$69						$100
Machinery		:	:						
Transport		$80	$30						$110
Construction		:	:						
		$300	$500						

Methodology: Example



data sources

Counterpart in the investment network

[values in % share]

EXPENDITURES

PRODUCTION	AGRI	MAN	SER	Electronics	ICT	Machinery	Transport	Construction
AGRI		:	:					
MAN		:	:					
SER		:	:					
Electronics		7%	10%					
ICT		10%	14%					
Machinery		:	:					
Transport		27%	6%					
Construction		:	:					
		100%	100%					

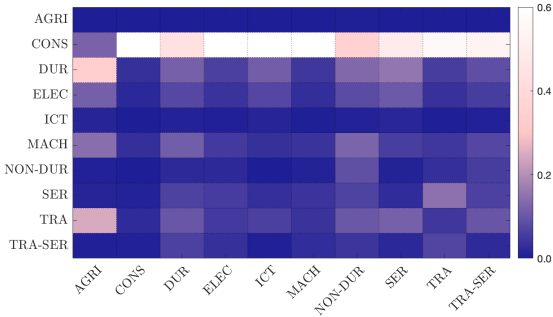
Dataset Coverage

Country	Investment Network	Country	Investment Network	Country	Investment Network
Ethiopia	1990-2019	Thailand	2005-2015	Lithuania	2000-2014
Rwanda	1990-2019	South Africa	2005-2015	Slovakia	2000-2014
Tanzania	1990-2019	Costa Rica	2005-2015	Hungary	2000-2014
Zambia	1990-2019	Turkey	2000-2014	Czechia	2000-2014
Kenya	1990-2019	Argentina	2005-2015	Portugal	1965-2014
Cambodia	2005-2015	Mauritius	1990-2019	Slovenia	2000-2014
Senegal	1990-2019	Chile	2005-2015	Greece	1965-2014
India	1965-2014	Mexico	1965-2014	South Korea	1965-2014
Vietnam	2005-2015	Russia	2000-2014	New Zealand	2005-2015
Ghana	1990-2019	Poland	2000-2014	Israel	2005-2015
Nigeria	1990-2019	Malaysia	2005-2015	Spain	1965-2014
Philippines	2005-2015	Indonesia	2005-2015	Cyprus	2005-2015
Morocco	2005-2015	Brazil	1965-2014	Italy	1965-2014
Tunisia	2005-2015	China	2005-2015	France	1965-2014
		Peru	2005-2015	Japan	1965-2014
		Colombia	2005-2015	Germany	1965-2014
				Belgium	1965-2014
				United Kingdom	1965-2014
				Denmark	1965-2014
				Sweden	1965-2014
				Austria	1965-2014
				Australia	1965-2014
				Netherlands	1965-2014
				Ireland	1965-2014
				Switzerland	2005-2015
				Norway	2000-2014
				United States	1965-2014
				Singapore	2005-2015

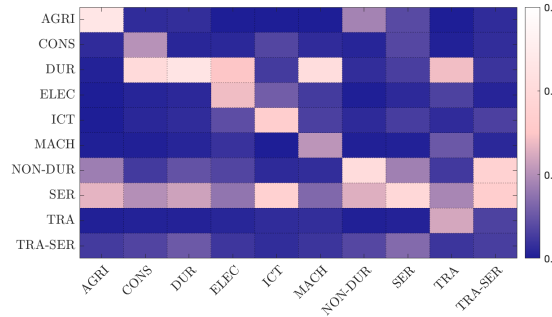
Investment Networks along the Development Spectrum

Investment Network vs IO Network 2014

INV Network: India



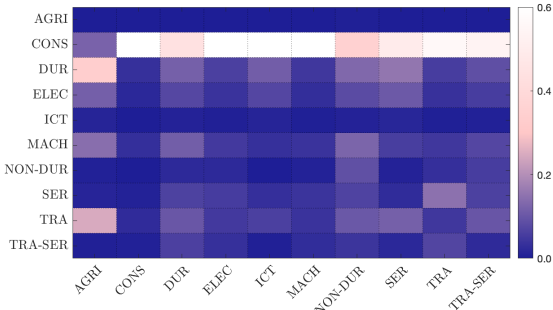
IO Network: India



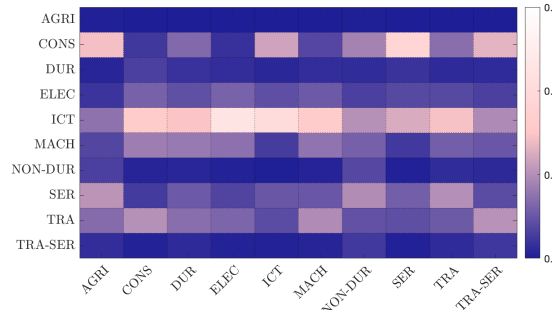
details

Investment Network vs IO Network 2014

INV Network: India

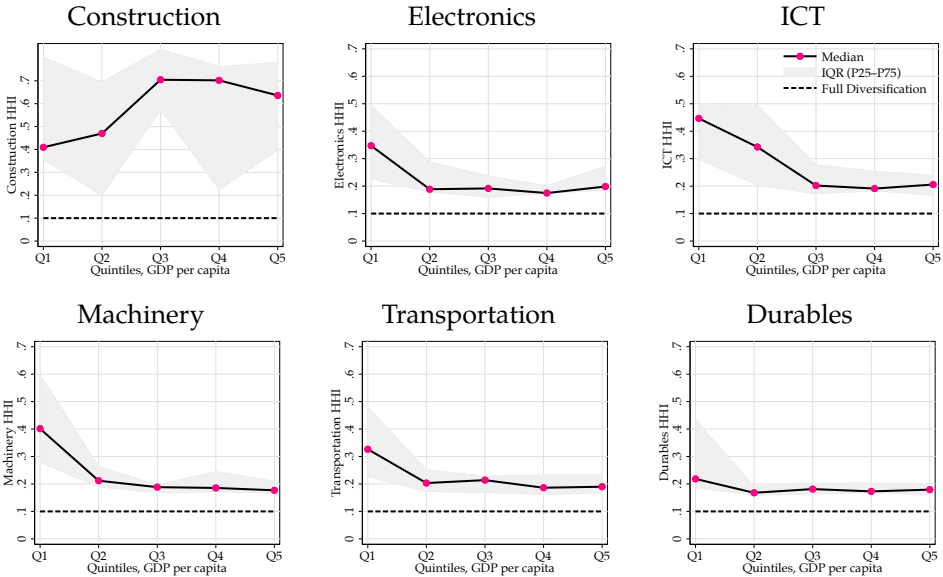


INV Network: USA



validation USA | validation Chile | outdegrees

Investment network HHI



Multisector Model of Investment Linkages

The model

- N Cobb-Douglas technologies in capital k, labor l and intermediate inputs m.

$$y_{nt} = \underbrace{\nu_n(z_{nt}, k_{nt}, l_{nt})}_{\text{value added}}^{\gamma_{nt}} \left(\frac{m_{nt}}{1-\gamma_{nt}}\right)^{1-\gamma_{nt}},$$

$$m_{nt} = \prod_{i=1}^{N} \left(\frac{m_{int}}{\mu_{in}}\right)^{\mu_{in}} \quad \rightarrow \quad \text{IO matrix, } M\text{, with elements } \mu_{in}.$$

- Sectors produce for consumption or exports c, intermediates m and investment, x,

$$y_{nt} = c_{nt} + x_{nt} + m_{nt}.$$

- Homothetic final output aggregator,

$$Y_t = \prod_{n=1}^{N} \left(\frac{c_{nt}}{\theta_{nt}}\right)^{\theta_n} = C_t + \underbrace{\epsilon_t}_{\text{exports}}.$$

- Trade in final and investment goods.

The model

- Sector-specific capital services k with standard law of motion.

$$k_{nt+1} = x_{nt} + (1 - \delta_n)k_{nt}$$

- Sector-specific investment aggregator for services x w/ time varying factor shares

$$x_{nt} = \left(\sum_{i=1}^{N} \omega_{in}^{1-\sigma_n} \chi_{int}^{\sigma_n}\right)^{\frac{1}{\sigma_n}} \quad \rightarrow \quad \text{Investment network, } \Omega, \text{ w/ elements } \left(\frac{\chi_{int}}{x_{nt}}^{\sigma_n} \omega_{in}^{1-\sigma_n}\right)$$

as $\sigma_n \to 0, \omega_{in}$

where investment services,

$$\chi_{int} = \underbrace{\left(\frac{\chi_{int}^{d}}{1-\phi_n}\right)^{1-\phi_n}}_{\text{domestic}} \underbrace{\left(\frac{\chi_{int}^{f}}{\phi_n}\right)^{\phi_n}}_{\text{imported}}.$$

Trade balance: $p_Y \epsilon_t - p_x^f \epsilon_t^f = 0$.

Impact of productivity on GDP

Proposition (GDP)

$$\longrightarrow \textit{Sectorial influence} \equiv \frac{\partial \ln(GDP)}{\partial \ln(a)} = \Phi \eta^{GDP}$$

$$\eta^{GDP} = \underbrace{\tilde{\zeta}'}_{\textit{exp share in VA}} \underbrace{[I - \Gamma\alpha(1-\phi)\Omega - (1-\Gamma)M]^{-1}}_{\textit{augmented Leontief inverse}}$$

for a_n *sectorial productivity,* α *capital share,* Γ *value added share,* $(1-\phi)$ *domestic investment share;*

$$\ln(GDP) \equiv \ln(\nu) = \Phi \eta^{GDP} \ln(\mathbf{a}) \qquad \mathbf{a} \equiv \Gamma(\overbrace{z}^{TFP} + \overbrace{\alpha\phi\Omega'\tau}^{terms\ of\ trade})$$

welfare

Implications for Development

Quantitative Exercises

1. Infer sectoral productivities to match observed sectoral value added, $\mathbf{a} = (\mathbf{\Phi}\boldsymbol{\eta}^{GDP})^{-1} \ln(\nu)$.

2. How much of the disparities in income per capita come from Ω?

   - when model-predicted output disparities come only from Ω.
   - when sectorial productivity interact with Ω
     fix sectorial $\mathbf{a}$ to US.
   - when sectorial investment demand is the same across sectors.
   - when only domestic investment flows are considered.

What is the role of Ω for income variance?

Table 1: Development Accounting

	Income Variance	Contribution of Ω
Baseline	1	
Only Investment Links	0.37	37%
Only Intermediate Inputs Links	0.81	19%

$$\ln(\text{GDP}) = \underbrace{\Phi}_{\substack{\text{trade} \\ \text{amplification}}} \underbrace{\tilde{\zeta}'}_{\text{exp share in VA}} \underbrace{(I - \Gamma(1-\phi)\alpha\Omega - (1-\Gamma)M)^{-1}}_{\substack{\text{augmented} \\ \text{Leontief inverse}}} \Gamma \ln(a)$$

What is the role of Ω for income variance?

Table 2: Development Accounting

	Income Variance	Contribution of Ω
Baseline	1	
Only Investment Links	0.37	37%
Only Intermediate Inputs Links	0.82	18%

$$\eta^{GDP}z = \underbrace{\Phi}_{\text{trade amplification}} \quad \underbrace{\tilde{\zeta}'}_{\text{exp share in VA}} \quad \underbrace{(I - \Gamma(1-\phi)\alpha\Omega - (1-\Gamma)M)^{-1}}_{\text{augmented Leontief inverse}} \Gamma \ln(a)$$

What is the role of Ω for income variance?

Table 3: Development Accounting

	Income Variance	Contribution of Ω
Baseline	1	
Only Investment Links	0.37	37%
Only Intermediate Inputs Links	0.82	18%
Average		28%

$$\eta^{GDP} z = \underbrace{\Phi}_{\substack{\text{trade} \\ \text{amplification}}} \quad \underbrace{\tilde{\zeta}'}_{\text{exp share in VA}} \quad \underbrace{(I - \Gamma(1-\phi)\alpha\Omega - (1-\Gamma)M)^{-1}}_{\substack{\text{augmented} \\ \text{Leontief inverse}}} \Gamma \ln(a)$$

$\rightarrow$ **28%** of GDP p/cap. differences explained by $\neq$ in the investment network.

How much of the role of Ω depends on sectorial productivity?

Table 4: Development Accounting

	Income Variance	Contribution of Ω
Baseline	1	
Investment Links	0.37	37%
Investment Links + TFP_{US}	0.22	22%

$$\eta^{\text{GDP}}_{z} = \underbrace{\Phi}_{\substack{\text{trade} \\ \text{amplification}}} \quad \underbrace{\tilde{\zeta}'}_{\text{exp share in VA}} \quad \underbrace{(I - \Gamma(1-\phi)\alpha\Omega - (1-\Gamma)M)^{-1}}_{\substack{\text{augmented} \\ \text{Leontief inverse}}} \Gamma \ln(a)$$

$\rightarrow$ **40%** of the role of Ω for GDP p/cap. differences explained by $\mathbf{a}$.

What is the role of heterogeneity in Ω for income variance?

Table 5: Development Accounting

	Income Variance	Contribution of Ω
Baseline	1	
Only Intermediate Inputs Links	0.82	18%
Ω with columns of VA shares	0.85	15%

$$\eta^{GDP} z = \underbrace{\Phi}_{\text{trade amplification}} \underbrace{\tilde{\zeta}'}_{\text{exp share in VA}} \underbrace{(I - \Gamma(1-\phi)\alpha\tilde{\Omega} - (1-\Gamma)M)^{-1}}_{\text{augmented Leontief inverse}} \Gamma \ln(a)$$

where $\tilde{\Omega}$ has columns equal to sectorial VA shares

→ **55%** of the contribution of Ω explained by heterogeneity in the investment network.

Development Accounting: the Impact of Trade

Table 6: Development Accounting

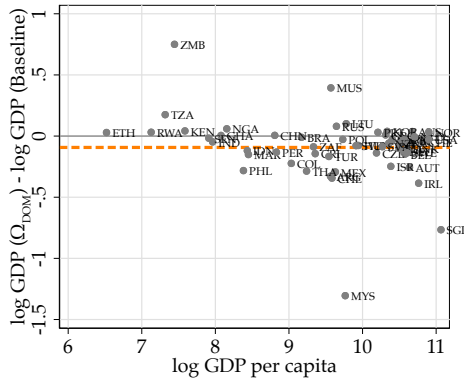
	Income Variance	Contribution of Ω
Baseline	1	
Only Domestic Inputs Links	0.93	7%

$$\eta^{GDP} z = \underbrace{\Phi}_{\substack{\text{trade} \\ \text{amplification}}} \underbrace{\tilde{\zeta}'}_{\text{exp share in VA}} \underbrace{(I - \Gamma\alpha\Omega^{DOM} - (1-\Gamma)M)^{-1}}_{\substack{\text{augmented} \\ \text{Leontief inverse}}} \Gamma \ln(a)$$

→ Trade in Investment goods 7% of income variance.

...and average income per capita levels falls by 9%.

Development Accounting: the Impact of Trade

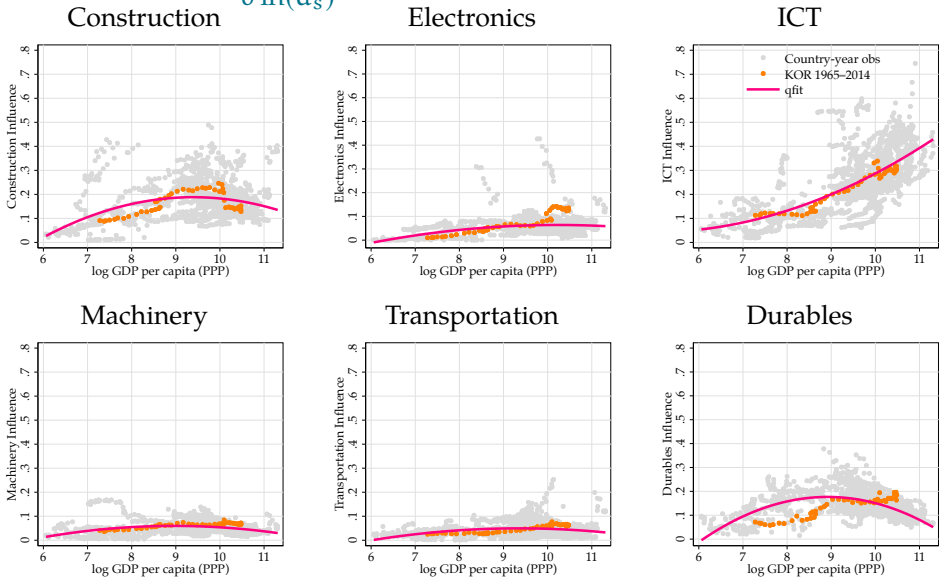


$$\eta^{GDP} z = \underbrace{\Phi}_{\text{trade amplification}} \underbrace{\tilde{\zeta}'}_{\text{exp share in VA}} \underbrace{(I - \Gamma\alpha\Omega^{DOM} - (1-\Gamma)M)^{-1}}_{\text{augmented Leontief inverse}} \Gamma z$$

investment imported share

Which sectors' productivity growth matters for income?

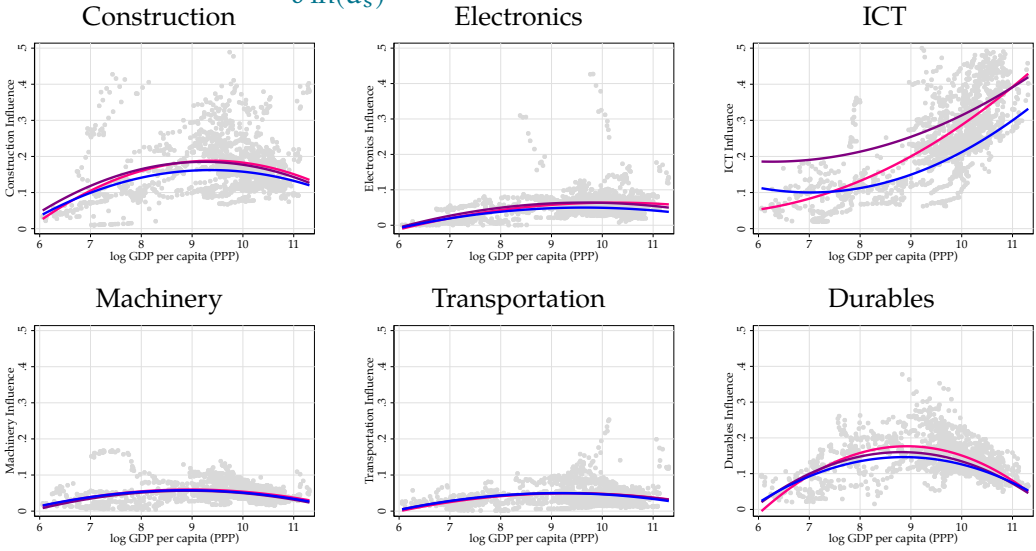
Sectorial Influence: $\frac{\partial \ln(\text{GDP})}{\partial \ln(a_s)}$



sectorial influence by income group

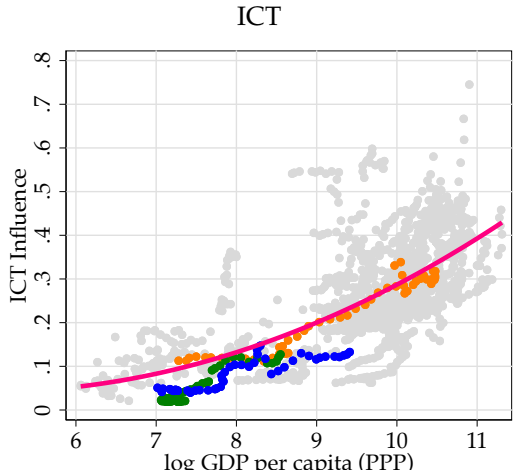
Sectorial Influence: $\frac{\partial \ln(\text{GDP})}{\partial \ln(a_s)}$

VA shares, $\zeta_{it} = \zeta_{\text{Korea2014}}$ $\zeta_{it} = \zeta_{\text{Korea1965}}$



Influence vector by income group

Sectorial Influence (cross-country): $\frac{\partial \ln(GDP)}{\partial \ln(a_s)}$



Final Remarks

- Build first **harmonized cross-country measures** of the investment network.
- Role for income disparities, $\approx 1/3 \rightarrow$ **doubles** $\Delta K/Y$.
- Interaction with trade important for the role of the investment network.
- Moving forward
  - **Transition dynamics? Sectorial bottlenecks?** $\rightarrow$ ongoing!
  - **Systematic shifts with development**

    Why do we observe these patterns? Distortions? Comparative advantage? $\rightarrow$ jointly determined?

Appendix

Investment network in Chile, firm-to-firm VAT data

only domestic transactions, back

	Outdegree		Homophily	
Sector	This Paper	Gillmore et al. (2025)	This Paper	Gillmore et al. (2025)
Agriculture	0.32	0.07	0.13	0.04
Construction	4.22	5.13	0.68	0.86
Durables	0.44	0.46	0.07	0.07
Electronics	0.06	0.11	0.01	0.05
ICT	2.73	0.15	0.33	0.03
Machinery	0.49	0.28	0.07	0.11
Nondurables	0.34	0.15	0.09	0.04
Services	1.08	4.47	0.06	0.36
Transportation	0.13	0.04	0.01	0.01
TrptServices	0.20	0.11	0.06	0.04

Investment Network Outdegrees & Development

Sector	Low income	Middle income	High income
Agriculture	0.45 (0.06 0.48)	0.22 (0.05 0.32)	0.13 (0.05 0.21)
Construction	3.18 (2.69 3.89)	3.39 (3.07 3.63)	2.98 (2.55 3.35)
Durables	0.90 (0.24 0.97)	0.39 (0.31 0.48)	0.49 (0.30 0.70)
Electronics	0.69 (0.20 0.96)	0.97 (0.64 1.13)	0.78 (0.57 0.95)
ICT	0.41 (0.01 0.90)	0.46 (0.28 0.58)	1.21 (0.84 1.38)
Machinery	1.42 (0.36 1.80)	1.31 (1.08 1.68)	1.29 (0.99 1.64)
Nondurables	0.32 (0.08 0.43)	0.16 (0.05 0.26)	0.18 (0.14 0.22)
Services	1.75 (1.26 2.38)	1.61 (1.28 1.76)	1.58 (1.16 1.95)
Transportation	0.72 (0.55 1.01)	1.08 (0.92 1.24)	1.20 (0.84 1.53)
TrptServices	0.14 (0.00 0.12)	0.41 (0.15 0.44)	0.16 (0.08 0.18)

Notes: Data for 2005, for low-, middle-, and high-income countries (World Bank classification). Outdegrees are sectoral row sums in the investment network. Entries report means; values in parentheses are the 25th and 75th percentiles.

back

Equilibrium Characterization

Proposition (Welfare changes, $\Delta\mathcal{C}$)

$$\textit{Welfare influence} \equiv \frac{\partial \ln(\mathcal{C})}{\partial \ln(a)} = \overbrace{\underbrace{\frac{\nu_t}{C_t}}_{\textit{cons.}}}^{\textit{GDP}} \eta^C$$

$$\eta^C \equiv \overbrace{\underbrace{\theta}_{\textit{exp share in consump.}} \underbrace{\left[I - \tilde{\beta}\Gamma\alpha(1-\phi)\Omega - (1-\Gamma)M\right]^{-1}}_{\textit{augmented Leontief inverse}}}^{\textit{Domar weight}}$$

for a_n sectorial productivity, α capital share, Γ value added share in production.

$$\text{dynamics} \rightarrow \tilde{\beta} = \frac{\hat{\delta}}{\frac{1}{\beta} - (1-\hat{\delta})} \qquad \text{for } \hat{\delta}_i \equiv \frac{1-\delta_i}{1+g_i^k} - 1 = \frac{x_i^s s}{k_i^s s} \qquad \text{and } g^k = \Omega g^z$$

back

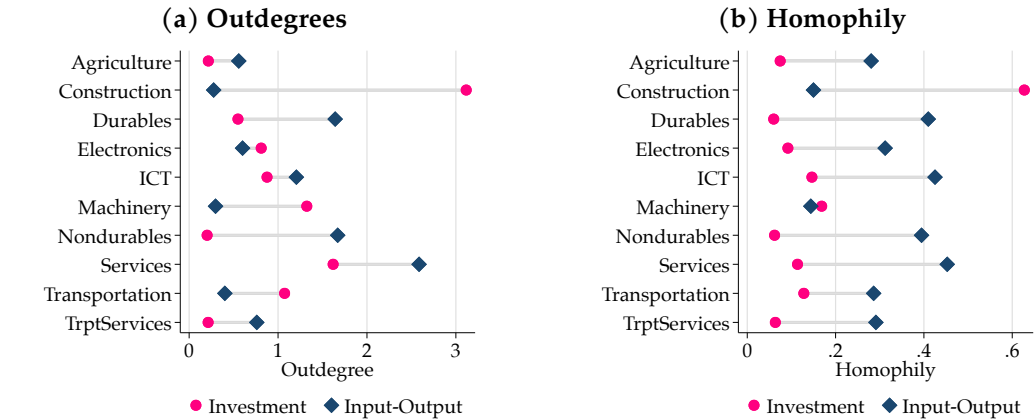
Methodology: Data Sources

Sector-equipment bridge	*US Bridge Tables* (*BEA*)
Investment production by sector	*Mensah and de Vries* (2023), *WIOD*, *OECD*
Nr of tools by worker in each occupation	*Caunedo et al.* (2023) for US Identification assumption: intensity of equipment use between occupations same across countries
Employment by occupation and sector	*IPUMS*, *ILOSTAT*, *PIAAC*
IO structure	*Mensah and de Vries* (2023), *WIOD*, *OECD*

- Country coverage: 58 countries 9 sSA countries (1990-2019); 20 countries (1965-2014); 29 countries (2000-2014)

back

Investment Network vs. Input-Output



Notes: Data for 2005, averaged across countries. Circles denote the investment network; diamonds denote the input–output network. Panel (a) reports sectorial outdegrees (row sums); panel (b) reports sectorial homophily (diagonal elements of each network).

back

Sectorial Influence & Development

Sector	Low income	Middle income	High income
Agriculture	0.38 (0.28 0.51)	0.15 (0.08 0.20)	0.04 (0.02 0.06)
Construction	0.17 (0.07 0.26)	0.25 (0.21 0.33)	0.19 (0.13 0.21)
Durables	0.13 (0.05 0.18)	0.20 (0.13 0.21)	0.13 (0.10 0.16)
Electronics	0.05 (0.01 0.05)	0.10 (0.05 0.10)	0.06 (0.04 0.07)
ICT	0.14 (0.10 0.15)	0.23 (0.16 0.29)	0.31 (0.25 0.37)
Machinery	0.03 (0.01 0.04)	0.07 (0.05 0.08)	0.04 (0.03 0.06)
Nondurables	0.20 (0.10 0.31)	0.34 (0.23 0.44)	0.13 (0.09 0.15)
Services	0.67 (0.59 0.80)	0.69 (0.51 0.84)	0.75 (0.69 0.81)
Transportation	0.03 (0.01 0.05)	0.07 (0.05 0.08)	0.04 (0.03 0.06)
TrptServices	0.10 (0.07 0.13)	0.14 (0.09 0.15)	0.11 (0.08 0.12)

Notes: Data for 2005, for Low, Middle and High income countries per the World Bank classification. Entries report means; values in parentheses are the 25th and 75th percentiles.

back

Comparison with BEA US Investment Network (2012)

Own sector share ω_{ii} (Homophily)

Sector	This Paper	VLW
Agriculture	0.00	0.00
Construction	0.04	0.03
Durables	0.04	0.05
Electronics	0.12	0.07
ICT	0.43	0.61
Machinery	0.18	0.26
Nondurables	0.01	0.005
Services	0.11	0.12
Transportation	0.11	0.06
Transportation Services	0.03	0.01

"vLW" = vom Lehn and Winberry (2022) back

Comparison with BEA US Investment Network (2012)

Sector's outdegree

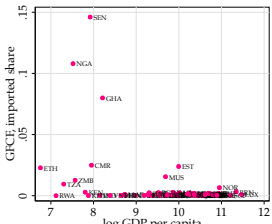
Sector	This Paper	VLW
Agriculture	0.00	0.00
Construction	1.65	1.31
Durables	0.30	0.24
Electronics	0.90	0.64
ICT	3.02	3.57
Machinery	1.42	1.94
Nondurables	0.04	0.03
Services	1.16	1.06
Transportation	1.35	1.10
Transportation Services	0.16	0.10

"vLW" = vom Lehn and Winberry (2022) back

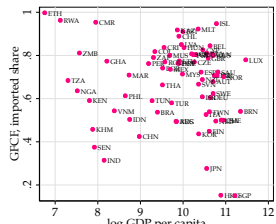
Sectorial Investment, Imported Share

back

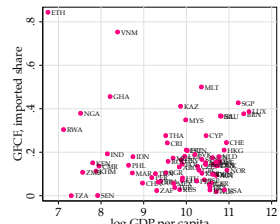
Construction



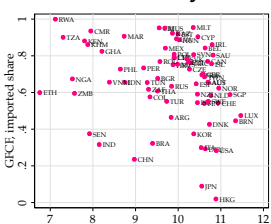
Electronics



ICT



Machinery



Transportation

Durables