Technological Differences in Costa Rica

Alberto Vindas & Pablo Slon

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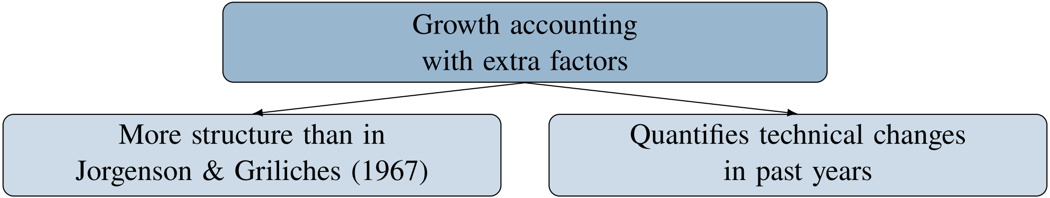
In this project we estimate technological differences

- Use a production model that considers:
  - Different economic activities.
  - Different types of workers.
  - Different types of capital.



- In this context:

Unequal technical change
=
technical bias

- Key variation:

Changes in payments
vs.
changes in inputs

We estimate a value added production function

- We follow Caselli (2005), Caselli (2017), Herrendorf, Herrington & Valentinyi (2015).
- Value added is produced according to:

$$P_{i,t}Y_{i,t} = P_{i,t}\left[\left(A_{\tilde{K},i,t}\tilde{K}_{i,t}\right)^{\rho} + \left(A_{\tilde{L},i,t}\tilde{L}_{i,t}\right)^{\rho}\right]^{1/\rho}$$

  where
  - $P_{i,t}Y_{i,t}$ is the nominal value added in activity i.
  - $\tilde{K}_{i,t}$ and $\tilde{L}_{i,t}$ are *composite* levels of capital and labor.
  - $A_{\tilde{K},i,t}$ and $A_{\tilde{L},i,t}$ are the productivities associated to these inputs.
    - **Do change** among economic activities.
  - $1/(1-\rho)$ is the elasticity of substitution between capital and labor.
    - **Does not change** among economic activities.

Composite capital and labor are also CES

- There are M types of capital (denoted by m) and N types of labor (denoted by n):

$$\tilde{K}_{i,t} = \left[\sum_{m=1}^{M} (A_{K,m,t} K_{i,m,t})^{\xi} \right]^{1/\xi} \qquad \tilde{L}_{i,t} = \left[\sum_{n=1}^{N} (A_{L,n,t} L_{i,n,t})^{\eta} \right]^{1/\eta}$$

in activity i,

- $K_{i,m,t}$ is the amount of m-type capital.
- $A_{K,m,t}$ is its productivity.
  - **Does not change** among economic activities.
- $1/(1-\xi)$ is the elasticity of substitution among types of capital.
  - **Does not change** among economic activities.

- $L_{i,n,t}$ is the amount of n-type labor.
- $A_{L,n,t}$ is its productivity.
  - **Does not change** among economic activities.
- $1/(1-\eta)$ is the elasticity of substitution among types of labor.
  - **Does not change** among economic activities.

Estimation results

Elasticities of substitution

- ρ: composite capital and labor
- ξ: types of capital
- η: types of labor

Relative productivities

- $A_{\tilde{K},i,t}/A_{\tilde{K},I,t}$: composite capital
- $A_{\tilde{L},i,t}/A_{\tilde{L},I,t}$: composite labor
- $A_{K,m,t}/A_{K,M,t}$: types of capital
- $A_{L,n,t}/A_{L,N,t}$: types of labor

- Results so far reveal that:
  - Capital and labor behave closely to a Cobb-Douglas specification (elast. close to 1).
  - Types of capital are substitutes (elast. greater than 1).
  - Types of labor are complements (elast. less than 0).

OLS on optimality conditions allows estimation of most parameters

$$\ln\left(\frac{W_{i,n,t}L_{i,n,t}}{P_{i,t}Y_{i,t}}\right) = \sum_{t=1}^{T}\sum_{i=1}^{I}\gamma_{i,t}^{L}\mathbb{I}(i,t) + \sum_{t=1}^{T}\sum_{n\neq N}\gamma_{n,t}^{L}\mathbb{I}(n,t) + \zeta_n \ln\left(L_{i,n,t}\right) + \varepsilon_{i,n,t}$$

- In this context:
  - $\gamma_{i,t}^{L} = \rho \log\left(A_{\tilde{L},i,t}\right) + (\rho-\eta)\log\left(\tilde{L}_{i,t}\right) + \eta\log\left(A_{L,N,t}\right) - \rho\log\left(Y_{i,t}\right)$
  - $\gamma_{j,t}^{L} = \eta\left(\log\left(A_{L,j,t}\right) - \log\left(A_{L,N,t}\right)\right)$
  - $\zeta_n = \eta$
- Results:
  - $A_{L,j,t}/A_{L,J,t}$
  - $A_{\tilde{L},i,t}A_{L,J,t}$
  - η

OLS on optimality conditions allows estimation of most parameters

$$\ln\left(\frac{R_{i,m,t}K_{i,m,t}}{P_{i,t}Y_{i,t}}\right) = \sum_{t=1}^{T}\sum_{i=1}^{I}\gamma_{i,t}^{K}\mathbb{I}(i,t) + \sum_{t=1}^{T}\sum_{m\neq M}\gamma_{m,t}^{K}\mathbb{I}(m,t) + \zeta_K \ln\left(K_{i,m,t}\right) + \varepsilon_{i,m,t}$$

- In this context:
  - $\gamma_{i,t}^{K} = \rho\ln\left(A_{\tilde{K},i,t}\right) + (\rho-\xi)\ln\left(\tilde{K}_{i,t}\right) - \rho\ln\left(Y_{i,t}\right) + \xi\ln\left(A_{K,M,t}\right)$
  - $\gamma_{m,t}^{K} = \xi\ln\left(A_{K,m,t}\right) - \xi\ln\left(A_{K,M,t}\right)$
  - $\zeta_m = \xi$
- Results:
  - $A_{K,m,t}/A_{K,M,t}$
  - $A_{\tilde{K},i,t}A_{K,M,t}$
  - ξ

One normalization is needed do obtain the productivities

- Rewriting the payments to capital:

$$\gamma_{i,t}^{K} = \rho \ln\left(A_{\tilde{K},i,t} A_{K,M,t}\right) + \frac{\rho - \xi}{\xi} \ln\left[\sum_{m=1}^{M} \left(\frac{A_{K,m,t}}{A_{K,M,t}} K_{i,m,t}\right)^{\xi}\right] - \rho \ln\left(Y_{i,t}\right)$$

- If we normalize $A_{\tilde{K},I,t} A_{K,M,t} = 1$ we can:
  - Get an estimate of ρ.
  - Recover the rest of the relative productivities.

Implementation needs decisions

Past versions of the estimates yielded unlikely results.

Improvements in this version:

- WLS instead of OLS:
  - Giving sectors different importance given their shares in overall production.
  - Higher quality in some data collection processes.
- Evaluating the different normalization strategies for ρ, the elasticity of substitution between composite capital and labor.

WLS weighting schemes

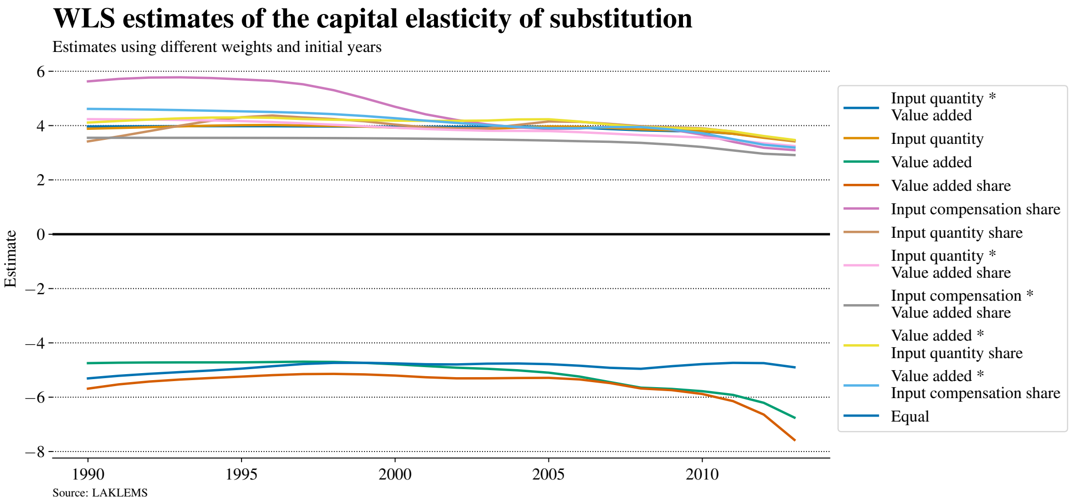
- We considered different alternatives to OLS, where every retribution equation has equal importance:
  - Production input (capital stock or worked hours) $\times$ Value added.
  - Production input.
  - Value added.
  - Value added share.
  - Input compensation share (capital or labor share).
  - Production input share.
  - Production input $\times$ Value added share.
  - Input compensation $\times$ Value added share.
  - Value added $\times$ Production input share.
  - Value added $\times$ Input compensation share.
  - Equal weights.

WLS weighting schemes: additional robustness

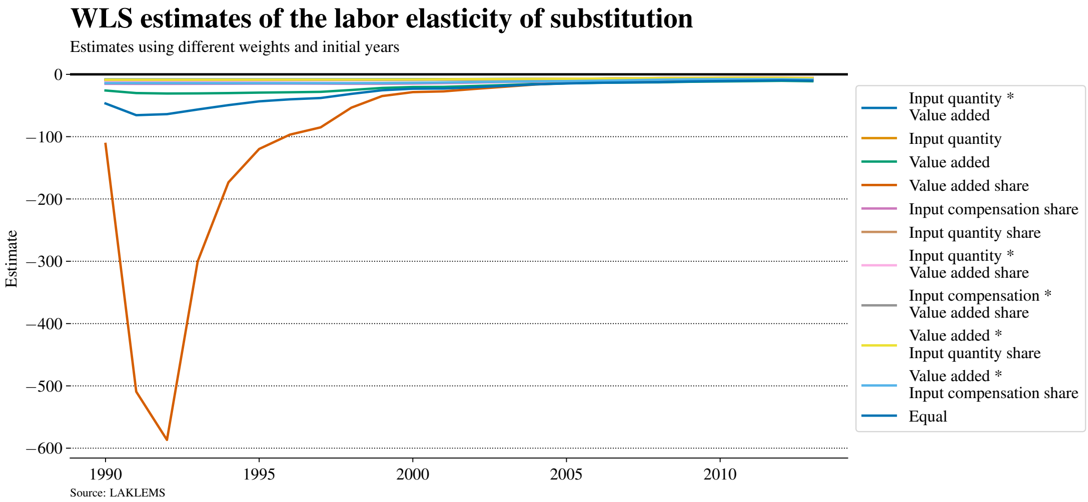
- Using real quantities (that grow over time) give more weight to recent observations.
- However, data collection has had important improvements over time.
- Disaggregated data lends itself to higher measurement errors.

- Additional test: **are elasticity estimates stable over time?**
  - Consider several estimation windows:
    - 1991-2016.
    - 1992-2016.
    - ...
    - 2015-2016.
  - Evaluate the sensitivity to these changes.

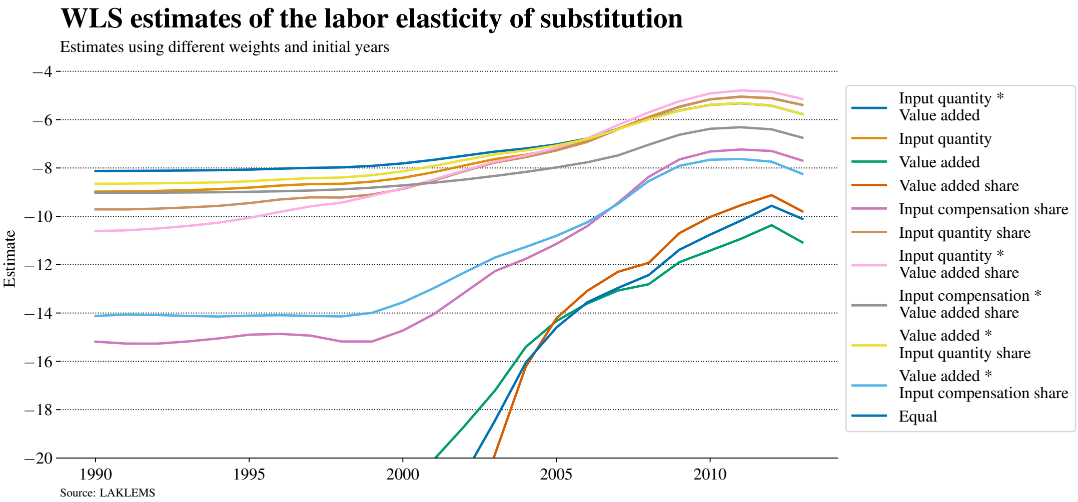
Most capital elasticity estimates are stable and around 4



All labor elasticity estimates are negative, some unstable



Zooming in suggests an interval between -11 and -5



Stability statistics for WLS elasticity estimates

	Labor elasticity of substitution		Capital elasticity of substitution	
	Standard deviation	Coefficient of variation	Standard deviation	Coefficient of variation
Production input × Value added	0.14	0.04	1.02	0.14
Production input	0.14	0.04	1.43	0.19
Value added	0.56	0.11	7.41	0.37
Value added share	0.55	0.10	152.37	1.60
Input comp. share	0.92	0.20	3.13	0.26
Production input share	0.25	0.06	1.70	0.22
Production input × Value added share	0.28	0.07	2.06	0.26
Input comp. × Value added share	0.19	0.05	0.98	0.12
Value added × Production input share	0.21	0.05	1.21	0.16
Value added × Input comp. share	0.41	0.10	2.55	0.22
Equal weights	0.16	0.03	17.74	0.64

One normalization is needed do obtain the productivities

- Rewriting the payments to capital:

$$\gamma_{i,t}^{K} = \rho \ln\left(A_{\tilde{K},i,t} A_{K,M,t}\right) + \frac{\rho - \xi}{\xi} \ln\left[\sum_{m=1}^{M}\left(\frac{A_{K,m,t}}{A_{K,M,t}} K_{i,m,t}\right)^{\xi}\right] - \rho \ln\left(Y_{i,t}\right)$$

- If we normalize $A_{\tilde{K},I,t} A_{K,M,t} = 1$ we can:
  - Get an estimate of ρ.
  - Recover the rest of the relative productivities.
- This can be done with any industry as base category in the capital or labor retribution equations.

Simple average is 0.9175, closest is manufacturing in capital equation

Capital-labor elasticity estimates by normalization equation

	Compensation equation	
	Capital	Labor
Agriculture, hunting, forestry and fishing	0.8630	0.9833
Mining and quarrying	0.9601	0.8649
Manufacturing	0.9290	0.9645
Electricity, gas and water supply	0.9760	0.9073
Construction	0.7073	0.9993
Wholesale and retail trade; repairs; hotels and rests.	0.8968	0.9748
Transport, storage and communications	0.9498	0.9554
Fin. intermediation; real estate, renting and business acts.	0.9677	0.9376
Public admin.; soc. security; social and pers. servs.	0.6786	0.9990

Capital and labor substitute with relative ease

- By normalizing manufacturing's productivity, we get $\rho = -0.0765$.
  - The elasticity of substitutions is 0.9290, in line with some of the findings in Caselli (2005).

- The optimality conditions between capital and labor imply:

$$\frac{\tilde{W}_{i,t}}{\tilde{R}_{i,t}} = \left(\frac{A_{\tilde{L},i,t}}{A_{\tilde{K},i,t}}\right)^{\rho} \left(\frac{\tilde{K}_{i,t}}{\tilde{L}_{i,t}}\right)^{1-\rho}$$

- When prices change, $1 - \rho$ determines changes in relative demands.
- If $\rho = -0.0765$, it's close to a Cobb-Douglas production function.
  - Increases in prices cause reductions in relative demand, but less than proportionally.

Types of capital and types of labor are substitutes and complements

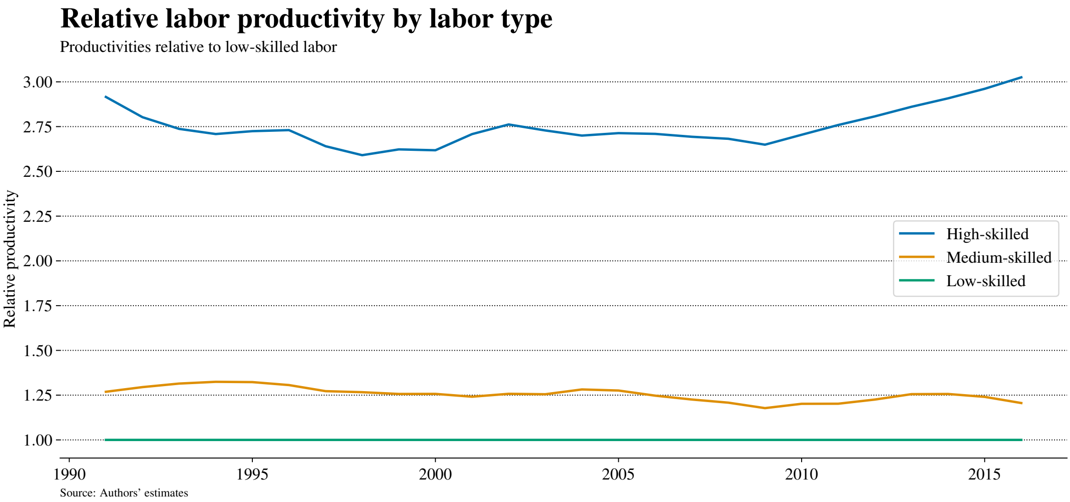
Types of capital

- Estimation yields $\hat{\xi} = 0.75$.
- Elasticity of substitution is larger than one.
  - Point estimate is 3.97.
- Types of capital behave as substitutes.

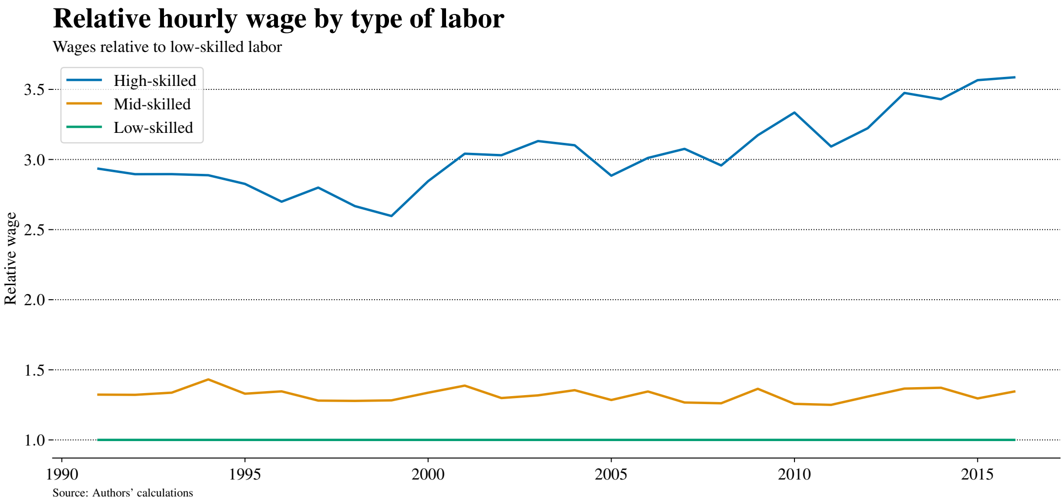
Types of labor

- Estimation yields $\hat{\eta} = 1.12$.
- Elasticity of substitution is lower.
  - Point estimate is -8.12.
- Types of labor work as complements.

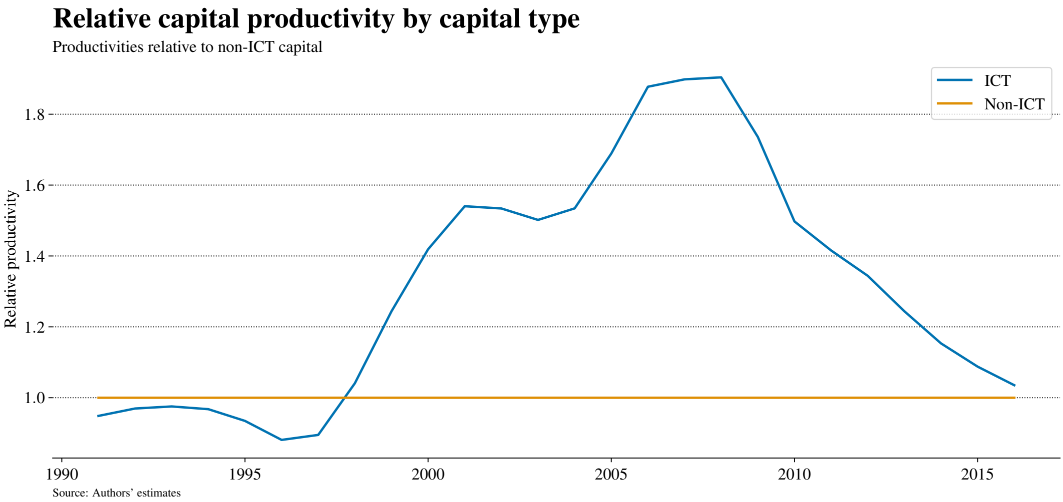
Labor productivities explain most of wage gap



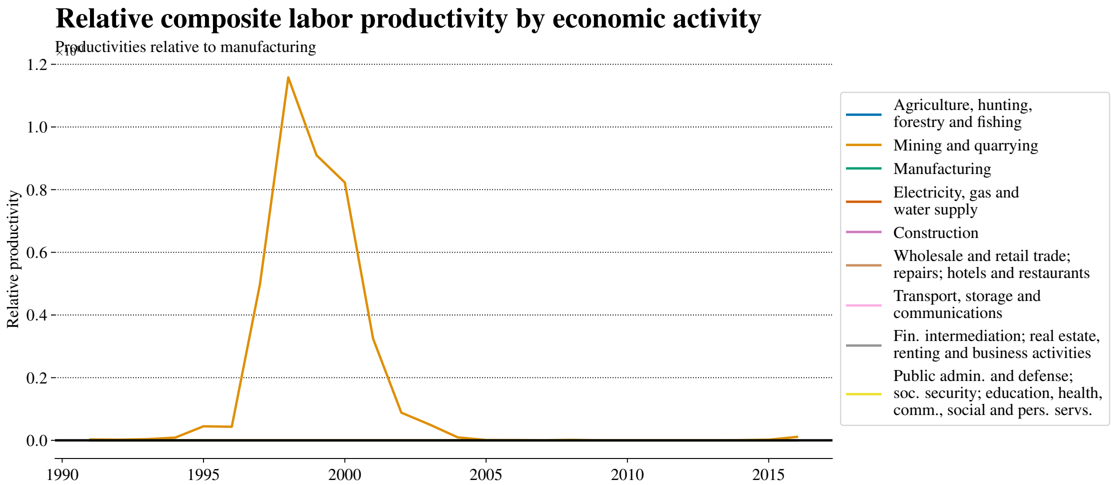
Labor productivities explain most of wage gap



ICT capital more productive, gap closes in later years

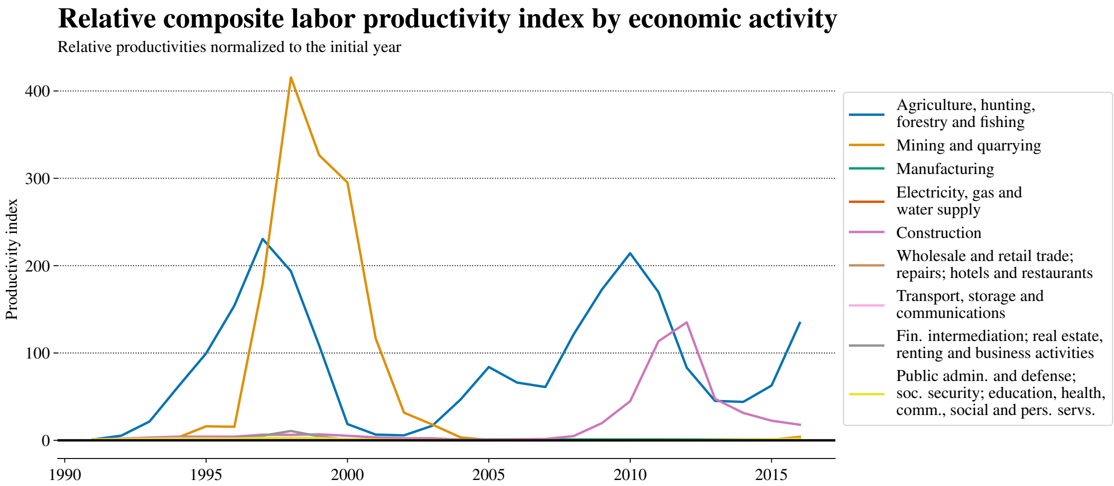


Composite labor productivity: attempt 1



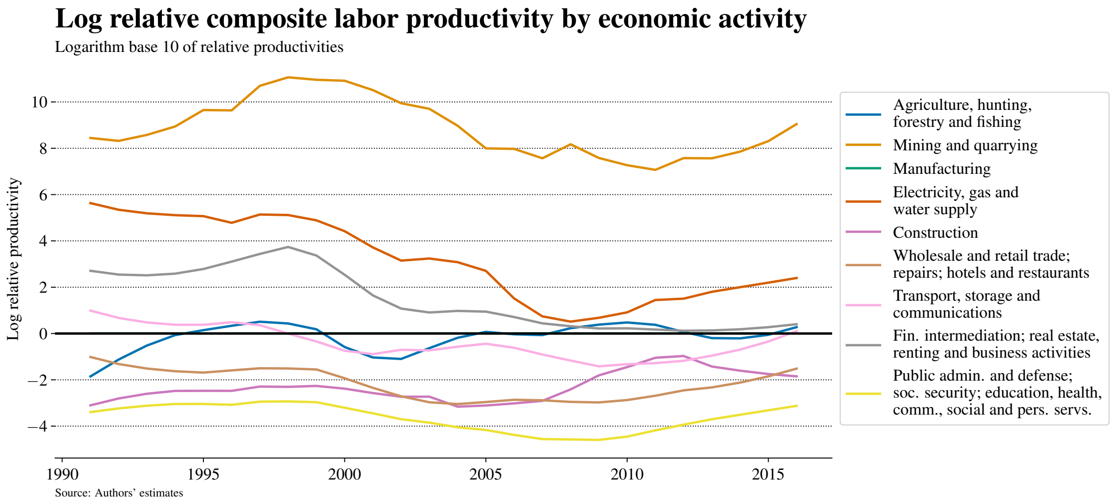
Source: Authors' estimates

Composite labor productivity: attempt 2

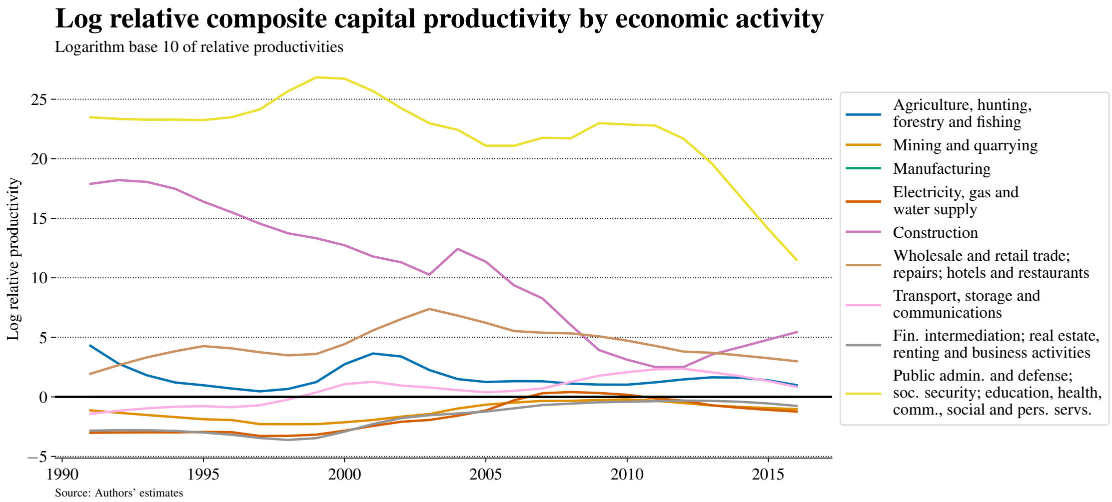


Source: Authors' estimates

Composite labor productivity: attempt 3



Composite capital productivities also need a logarithmic scale



Pending: proper interpretation of non-linearities

- The CES production functions are highly non-linear.
  - Productivity accounting would require more than accouting for changes in productivities.
- Comparison to log-linear productivity estimates.
- Comparison to average productivity indicators.

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