# Financial Development, Technology Adoption, and Sectoral Productivity Convergence

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**Job Market Paper**

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# I. Introduction

# Motivation (1/2)

▶ Variations in income per capita across countries are mostly accounted for by differences in productivity.
Klenow & Rodriguez-Clare (1997), Prescott (1998), Caselli (2005) and Jones (2016)

▶ Observed differences in productivity growth are driven by differences in the technologies used in production.
Jerzmanowski (2007), Aghion et al. (2005)

▶ Technologies result from innovation or adoption at the sectoral level.

# Motivation (2/2)

▶ The intensity of use of adopted technologies varies across countries and sectors.

Comin & Mestieri (2018)

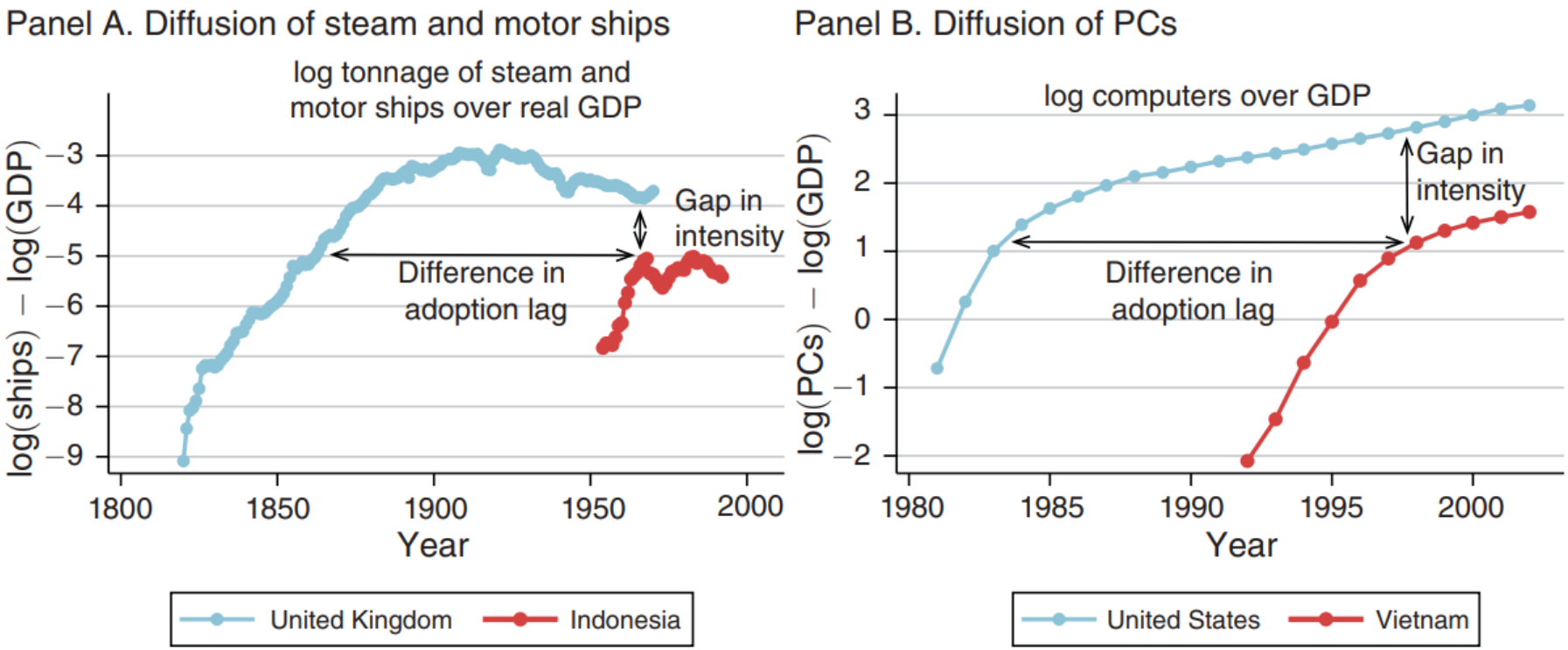


**Figure 1:** Technology diffusion over time

# What I do (1/2)

**Using HCCTAD[1] (Comin &Hobijn (2004)), I show three new observations :**

► *Observation 1*: Across countries, the intensity of use of adopted technologies is positively correlated with the level of Financial Development.

► *Observation 2*: Across countries, *sectoral proximity*[2] to the frontier is positively associated with more technology adoption.

► *Observation 3*: The coefficient of association between financial development and the intensity of use of adopted technologies vanishes beyond some threshold level of financial development specific to each technology.

[1] HCCTAD : Historical Cross Country Technology Adoption Dataset.
[2] Sectoral productivity relative to US sectoral productivity.

# What I do (2/2)

▶ I consider an endogenous growth model with financing frictions that builds from Aghion et al. (2005).

▶ I incorporate the specificity of each sector based on its degree of advancement and the intensity of use of newly adopted technologies into the technology adoption process.

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► I incorporate the specificity of each sector based on its degree of advancement and the intensity of use of newly adopted technologies into the technology adoption process.

► The model is also extended by introducing the innovator's skills :

- *The more an entrepreneur is skilled in the sector she wishes to innovate the easier it will be.*
- A country's stock of "effective skills" that can be used in technology adoption depends on its level of development in each sector.
  Nelson & Phelps (1996) called this "*absorptive capacity*".

# Results

- The predictions of the model are :
  - Financial development affects positively the intensity of use of adopted technologies for only low financial developed countries and for only sectors/countries far from the frontier.
  - Countries with high level of financial development will grow faster toward the frontier.
  - Sectors that grow faster in developed countries will experience later convergence.

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  - Countries that converge conditionally: moderate levels of financial development and GDP per worker;
  - Countries that converge unconditionally: high levels of financial development and GDP per worker.

# Contribution

▶ This paper documents new evidence on technology adoption, financial development and sectoral proximity to the frontier.

Comin & Nanda (2019), Aghion et al. (2005)

▶ Contribution to the new debate on sectoral productivity convergence :

Rodrik (2013), Rogerson et al. (2022), Kinfemichael & Morshed (2019)

- The role of financial development and aggregate productivity in shaping countries' sectoral productivity convergence;
- The impact of frontier productivity growth and financial development on the speed of convergence.

# II. Technology Adoption: Evidence

# Source and Data Description

**Table 1:** Variables sources

| Variables | Source | Period covered |
|---|---|---|
| Real GDP per capita | World Bank (2021) | 1960-2020 |
| Productivity | World Bank (2021) | 1991-2019 |
| FD[3] | IMF (2015) | 1980-2014 |
| Population | World Bank (2021) | 1960-2020 |
| Human Capital | Penn World Table version 10.0 | 1960-2019 |
| Governance | WGI (2021) | 1996-2020 |
| Geography | Geodata95 (website) | |
| Technology data | HCCTAD[4] | 1750-2004 |

All data are aggregated to average over the period 1991-2004.

[3] Financial Development Index

[4] Historical cross countries technologies adoption data (from NBER)

► **Observation 1**: Across countries, technology adoption is positively correlated with Financial Development index *only for low financial developed countries*.

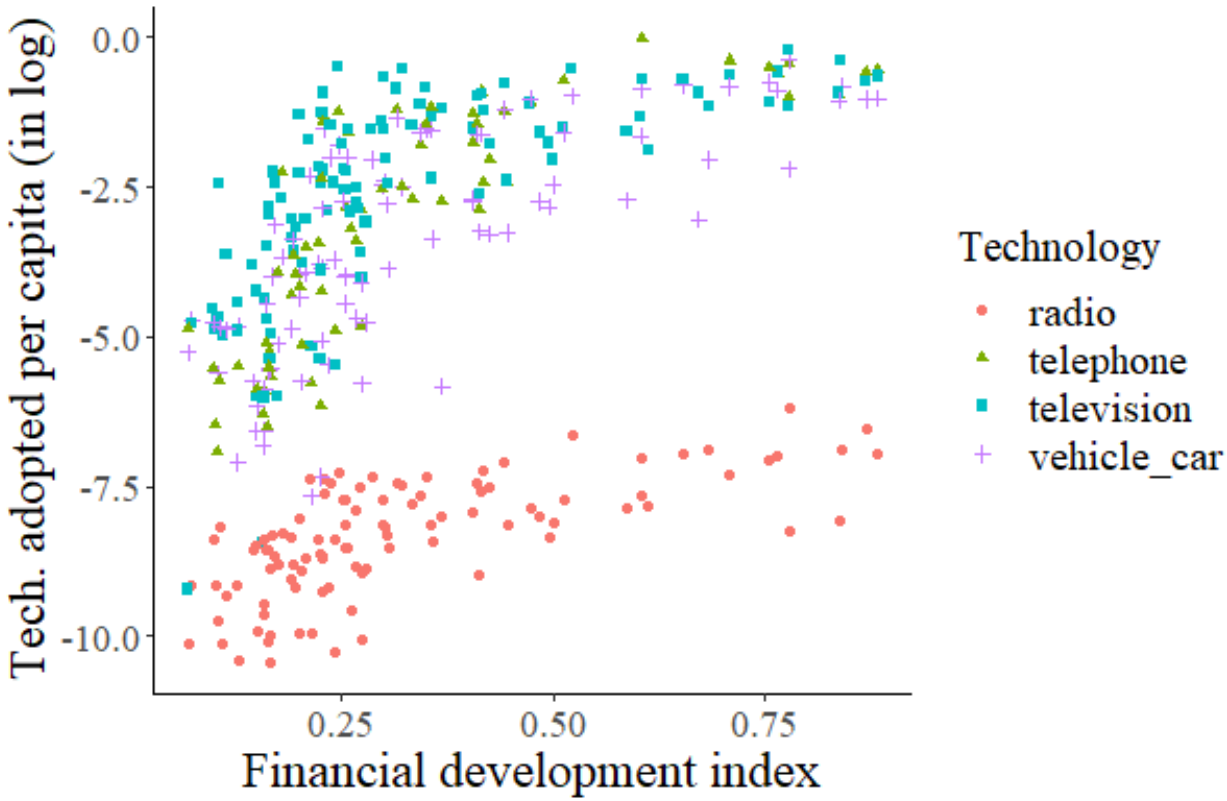


**Figure 2:** Average levels of financial development and log technology adoption per capita, 1980-2003

▸▸ More graphs

► **Observation 2**: Across countries, *sectoral proximity* to the frontier is positively associated with more technology adoption.

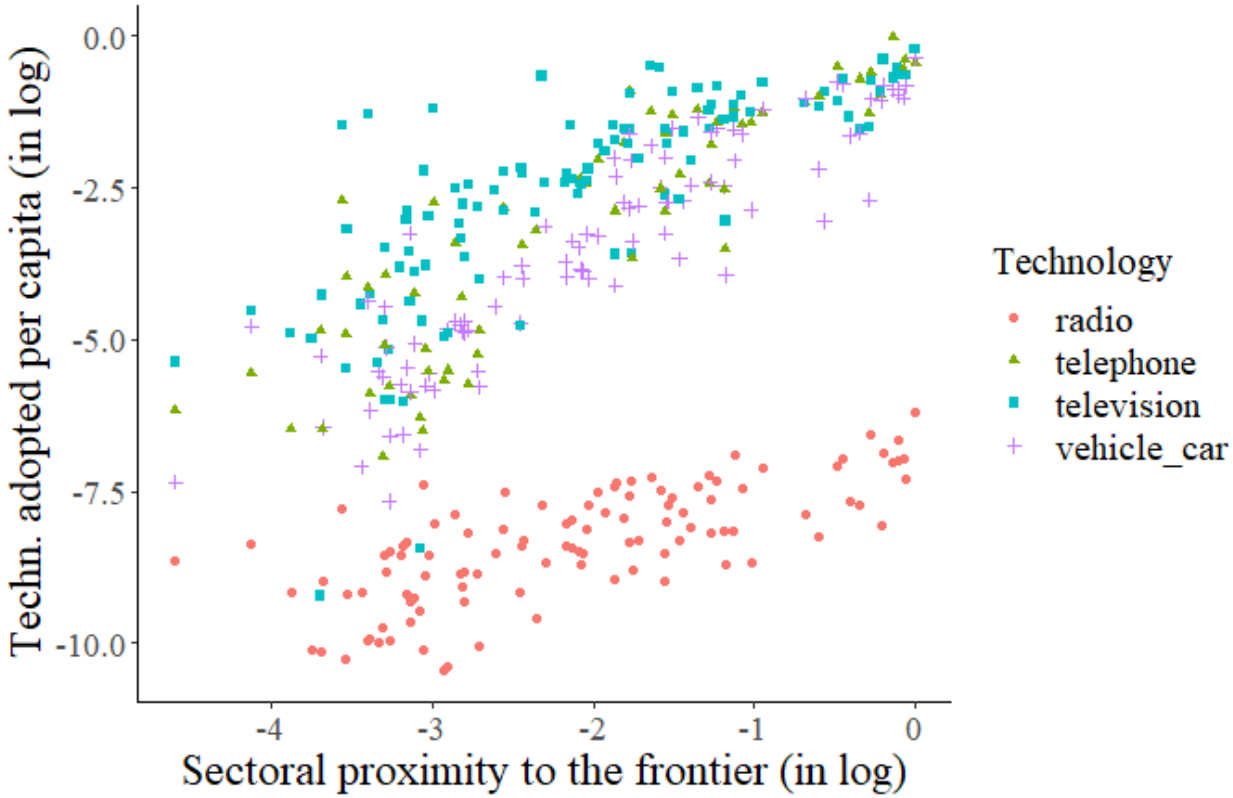


**Figure 3:** Average levels of log technology adoption per capita and log sectoral productivity relative to US, 1991-2003

▸▸ More graphs

# Plan

# Econometric specification

$$\theta_{cjt} = \eta_{jt} + \delta_c + \beta_1 FD_{ct-1} + \beta_2 dist_{cjt-1} + \beta_3 \left( FD_{ct-1} \times dist_{cjt-1} \right) + \beta_4 \mathbf{X}_{ct} + \varepsilon_{cjt}$$

- $\theta_{cjt}$ is the measure of technology j in country c at time t;
- $\eta_{jt}$ is technology-year-fixed effect;
- $\delta_c$ is country fixed effect;
- $FD_{ct-1}$ is financial developement level at period t-1;
- $dist_{cjt-1}$ is the country $c$ productivity in the sector of technology $j$ divided by US productivity in the same sector at time t-1;
- $\mathbf{X}_{ct}$ are control variables such as GDP, human capital, governance, and their interactions with FD.

▶ The association between financial development and technology adoption is higher for countries that are far from the technological frontier. ⏩ More controls

| | Intensity of use of adopted technologies | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| FD | 0.442 | 0.253 | 0.510 | 0.783 | 3.641 | 4.045 |
| dist | 0.205** | 0.202** | 0.156* | 0.228** | 0.278*** | 0.227** |
| FD×dist | -0.573** | -0.545** | -0.550* | -0.777** | -0.841*** | -0.772** |
| GDP | | 0.732 | 0.258 | 0.412 | 0.478 | 0.463 |
| GDP×FD | | | | | -0.500 | -0.679 |
| hc | | | 0.707 | 0.845 | | 0.794 |
| hc× FD | | | | | | 0.371 |
| Geog. | | | | 0.031 | 0.012 | 0.004 |
| Geog.× FD | | | | | 0.052 | 0.061 |
| Tech. FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1,871 | 1,871 | 1,757 | 1,438 | 1,485 | 1,438 |
| R-squared | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |

# Impact of Financial Development on Technology Adoption

► Both Lithuania and Ethiopia had almost the same level of financial development in 1995 (around 0.12 on a scale of 0 to 1). Let's increase their financial development to the level of USA (0.69) in 1995:

| | **Agriculture** | **Industry** | **Services** |
|---|---|---|---|
| Lithuania | 197% | 134% | 117% |
| Ethiopia | 540% | 192% | 475% |

**Table 2:** Impact of an increase in the financial development on the technology adoption

# III. The Theoretical Model

# The Model : Environment

- The model economy follows *Aghion et al. (2005)*
- Countries do not exchange goods or factors, but do make use of others' technological ideas ;
- The model economy is populated by risk-neutral agents, a final good production sector, a continuum of intermediate goods sectors $j \in [0,1]$.
- Each individual lives two periods and is endowed with two units of labor in the first period and none in the second : $U(c_1, c_2) = c_1 + \beta c_2$;
- At the end of the first period, households obtains a skill level and invest their savings $sw_t$ in technology adoption project as entrepreneurs.

# Financial intermediaries

- The amount invested in sector $j$ at date $t$ for technology adoption is $z_{jt}$ and the amount borrowed is $z_{jt} - s\,w_t$.
- There is imperfection linked to the presence of moral hazard. A borrower can not repay her loan by hiding the profits made.
- The borrower is prompted to choose to stay honest if :

$$\underbrace{h\,z_{jt}}_{\text{cost of hiding}} + q\,\underbrace{(1+r)\,(z_{jt} - s\,w_t)}_{\text{Repayment of the loan}} \geq (1+r)(z_{jt} - s\,w_t)$$

which implies : $z_{jt} \leq \dfrac{(1-q)(1+r)}{(1-q)(1+r)-h}\,s\,w_t$ i.e. $z_{jt} \leq \kappa\,w_t$

- $\kappa$ is the credit multiplier which is increasing with $h$ and decreasing with $q$.

# Goods production sectors

## ▶ Final good

The final good is produced competitively using labor and a continuum of intermediate goods as inputs. The problem of the firm in the final sector is

$$\max_{\{L_t,[x_{jt}]_{j\in[0,1]}\}} L_t^{1-\alpha}\int_0^1 A_{jt}^{1-\alpha}x_{jt}^{\alpha}dj-\int_0^1 p_{jt}x_{jt}dj-w_tL_t \tag{1}$$

$$\Rightarrow\begin{cases} p_{jt}=\alpha x_{jt}^{\alpha-1}A_{jt}^{1-\alpha}L_t^{1-\alpha} & \forall j\in[0,1] \\ w_t=(1-\alpha)L_t^{-\alpha}\int_0^1 A_{jt}^{1-\alpha}x_{jt}^{\alpha}dj \end{cases}$$

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## ▶ Intermediate good sectors

$$\max_{\{x_{jt}\}} \pi_{jt}=p_{jt}x_{jt}-x_{jt} \tag{2}$$

$$\text{s.t.} \qquad p_{jt}=\alpha x_{jt}^{\alpha-1}A_{jt}^{1-\alpha}L_t^{1-\alpha}$$

# Equilibrium in goods and labor markets

In equilibrium, the profit $\pi_{jt}$, the production $Y_{jt}$, the wage rate $w_t$, and the total gross domestic product $GDP_t$ can be expressed as follows:

- $\pi_{jt} = \pi A_{jt} L_t$ where $\pi := (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}$.
- $Y_t = \alpha^{\frac{2\alpha}{1-\alpha}} A_t L_t$ where $A_t = \int_0^1 A_{jt} dj$ is the aggregate productivity.
- $w_t = \omega A_t$, with $\omega = (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}$
- $GDP_t = \zeta A_t L_t$ where $\zeta := (1-\alpha^2)\alpha^{\frac{2\alpha}{1-\alpha}}$

# Technological Progress and Productivity Growth (1/2)

▶ Productivity grows as the result of technology adoption that allow the monopolists to access an existing technology frontier :

$$A_{jt+1} = \theta_{jt+1}\bar{A}_{jt} + (1 - \theta_{jt+1})A_{jt}$$

- $A_{jt+1}$ : The country's sector $j$ productivity at period $t+1$.
- $\theta_{jt+1}$ : The intensity of use of the adopted technology in sector $j$ at period $t+1$.
- $\bar{A}_{jt+1}$ : The frontier's sector $j$ productivity at period $t+1$.

$$\bar{A}_{jt+1} = (1 + \bar{g}_j)\bar{A}_{jt}.$$

▶ The investment in technology adoption costs $z_{jt}$ which is convex in $\theta_{jt+1}$ and increasing in $\bar{A}_{jt}$ :

$$\lambda_{jt}\frac{z_{jt}}{\bar{A}_{jt}} = \eta\,\theta_{jt+1} + \frac{\psi}{2}\theta^2_{jt+1} \quad \text{with } \eta,\ \psi > 0$$

▶ $\lambda_{jt} = \lambda A_{jt}$ : the skills of the entrepreneur in sector $j$.

# Technological Progress and Productivity Growth (2/2)

► In equilibrium an entrepreneur chooses $z_{jt}$ (or $\theta_{jt+1}$) in order to maximize the expected net payoff :

$$\max_{0\leq z_{jt}\leq 1} \beta\pi\left[\theta_{jt+1}\bar{A}_{jt} + (1-\theta_{jt+1})A_{jt}\right] - z_{jt} \tag{3}$$

$$\text{s.t. } z_{jt} \leq \kappa w_t \text{ and } z_{jt} = \frac{\frac{\psi}{2}\theta_{jt+1}^2 + \eta\theta_{jt+1}}{\lambda a_{jt}}$$

where $a_{jt} := A_{jt}/\bar{A}_{jt+1}$ is the sectoral proximity to the frontier.
The problem (3) is equivalent to (4):

$$\max_{0\leq\theta_{jt+1}\leq 1} \beta\pi\left[\theta_{jt+1}\bar{A}_{jt} + \left(1-\theta_{jt+1}\right)A_{jt}\right] - \left(\lambda a_{jt}\right)^{-1}\left(\frac{\psi}{2}\theta_{jt+1}^2 + \eta\theta_{jt+1}\right) \tag{4}$$

$$\text{s.t. } \theta_{jt+1} \leq -\frac{\eta}{\psi} + \left[\left(\frac{\eta}{\psi}\right)^2 + \frac{2\lambda\kappa w_t a_{jt}}{\psi}\right]^{\frac{1}{2}}$$

# Plan

# Effect of Financial Development on Technology Adoption

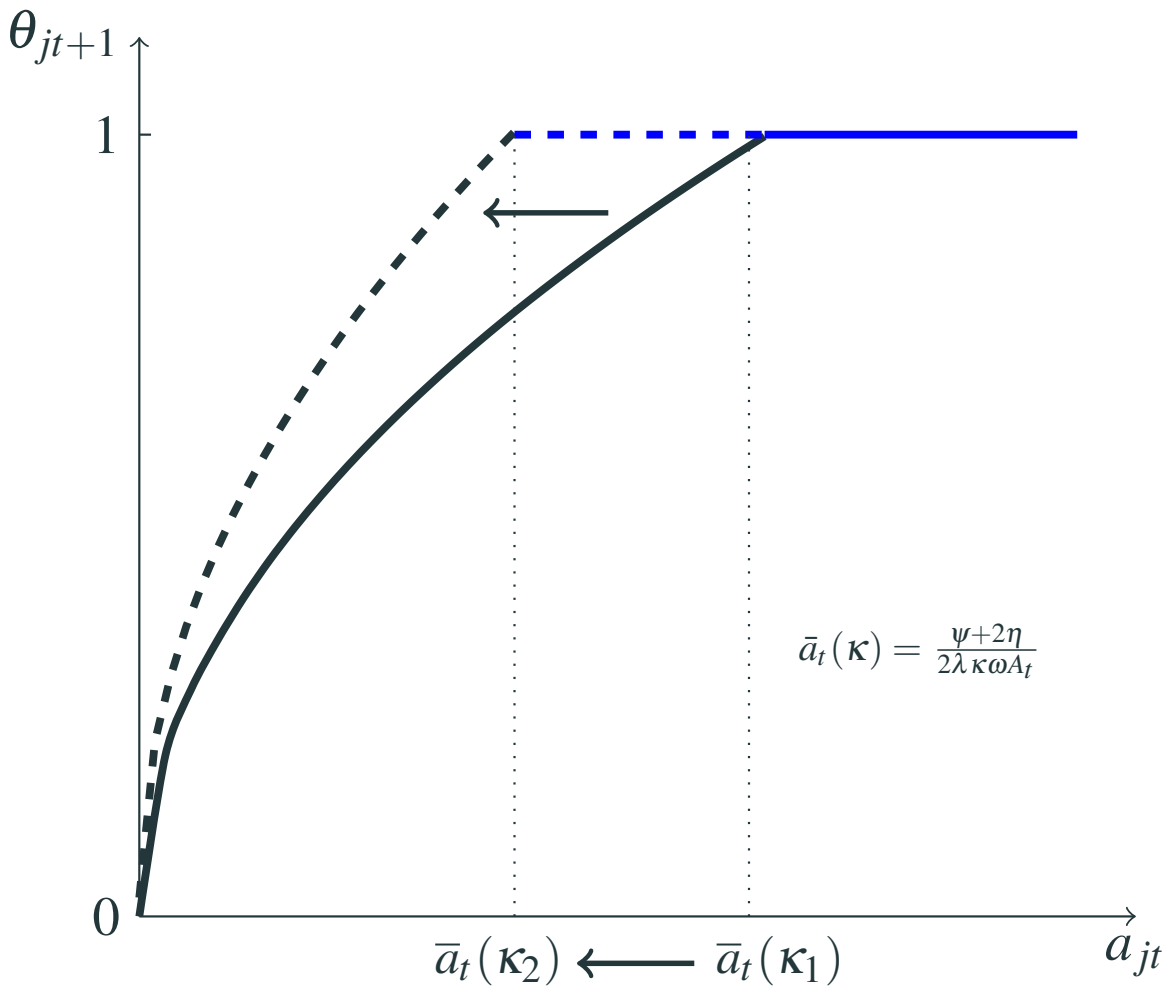



**Figure 4:** Effect of financial development on the intensity of use of adopted technology :

$\kappa_1 < \kappa_2 < \underline{\kappa}_{jt} = \frac{2\eta+\psi}{2\lambda w_t a_{jt}}$

▸▸ Observations

# Dynamic Transitions of Countries

- The model classifies countries into three groups within each sector.

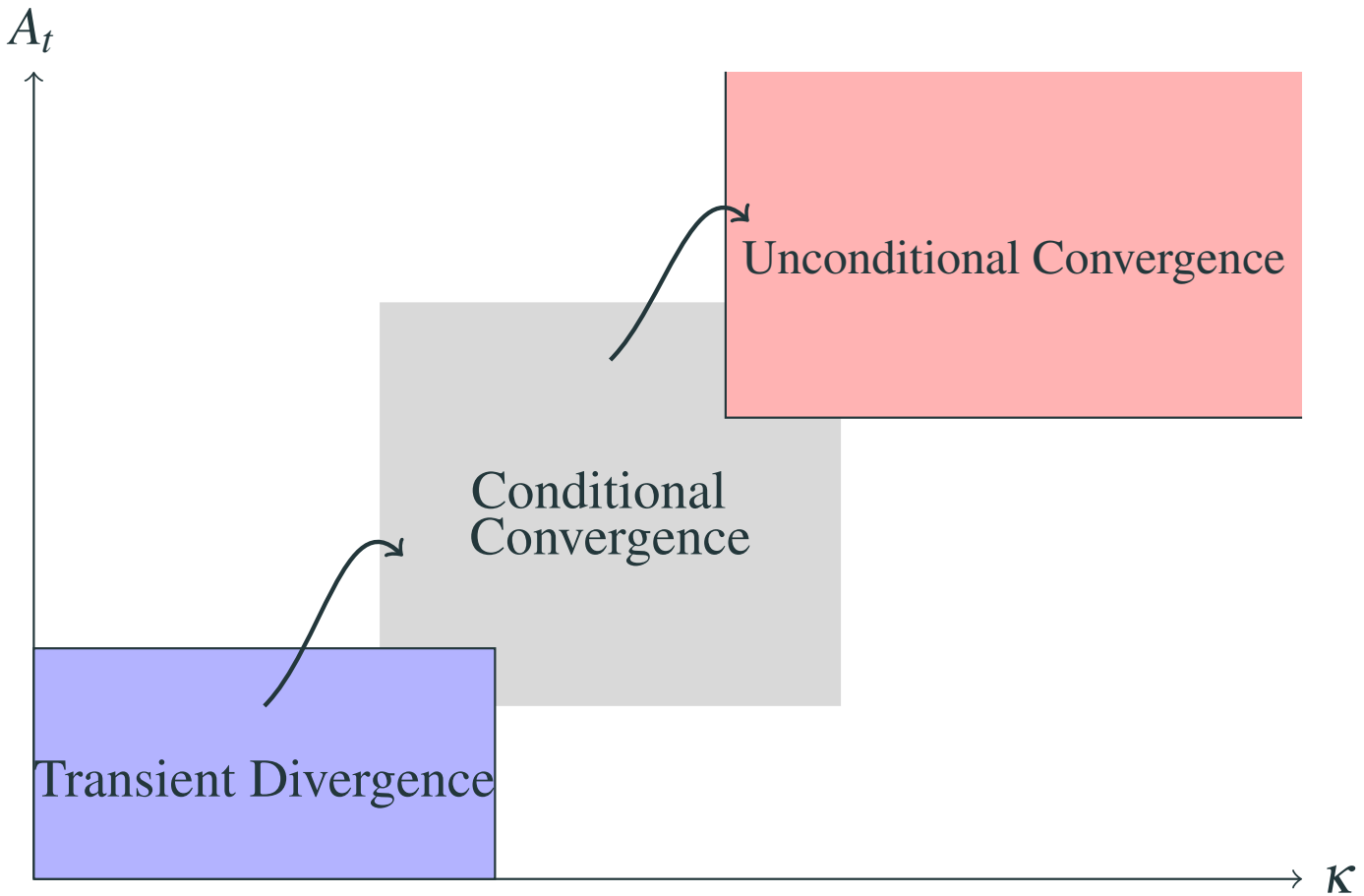
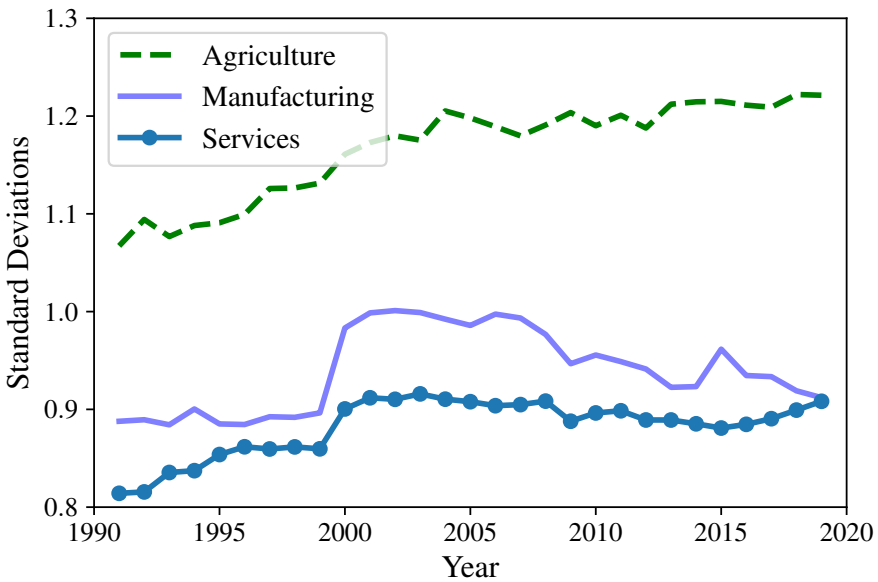



**Figure 5:** Dynamic Transitions of Countries Across Financial Development and Aggregate Productivity Groups

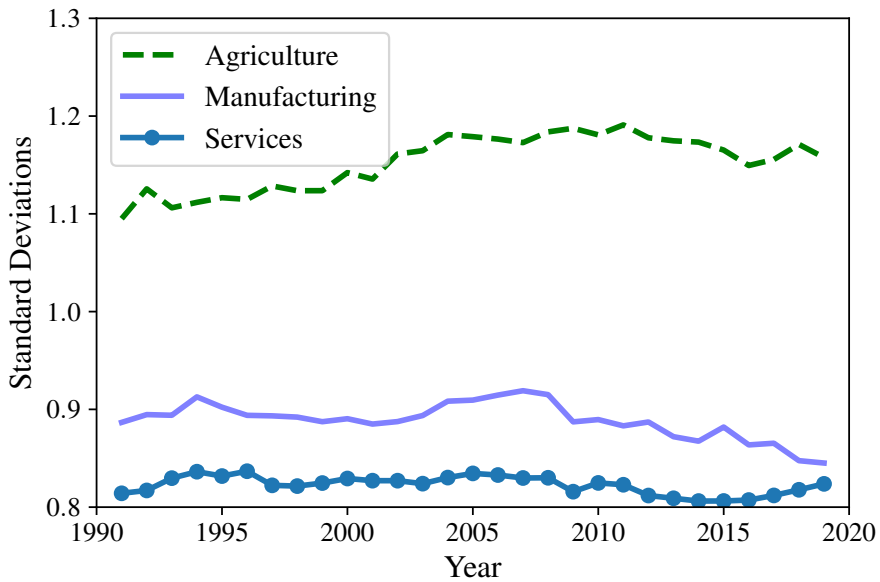
# IV. Sectoral Productivity Convergence: Evidence

# Sectoral productivity dispersion among countries

▶ Sigma convergence refers to the reduction of disparities or inequalities in productivity levels among countries over time.



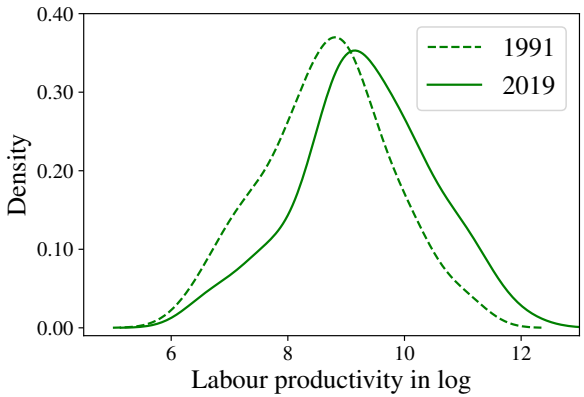

*Panel A* : 196 countries of unbalanced panel



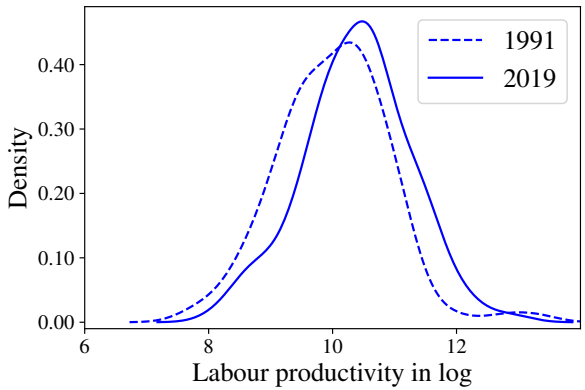

*Panel B* : 108 countries of balanced panel

**Figure 6:** Cross-Country Sectoral Productivity Dispersion

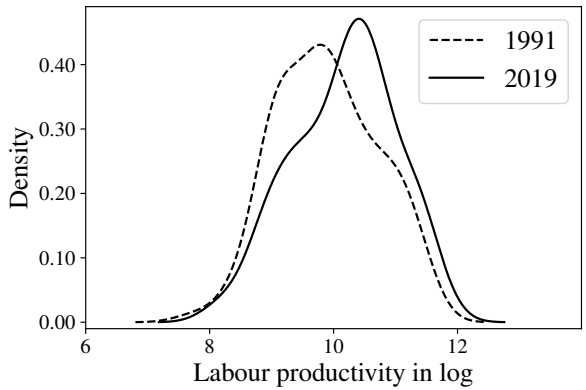
# Sectoral productivity distribution in 1991 and 2019.




(a) Agriculture




(b) Manufacturing




(c) Services

**Figure 7:** Sectoral productivities distribution over time

# Financial development, aggregate productivity, and speed of convergence

▶ To examine whether less productive countries or countries with high financial development grow faster and narrow the gap with more developed economies, I estimate the equation below:

$$g_j^c = \alpha_j + \beta_j \log(A_{j0}^c) + \rho_j \kappa_0^c \log(A_0^c) + \gamma_j \log(A_{j0}) \times \kappa_0^c \log(A_0^c) + \varepsilon_j^c \;\; ; \;\; j = a, m, s$$

- $g_j^c$ is the average annual growth rate of the sector $j$ initial labor productivity $A_{j0}^c$ in constant international prices in country $c$.
- $\varepsilon_j^c$ is the error term.

$$\frac{\partial g_j^c}{\partial \log(A_{j0}^c)} = \beta_j + \gamma_j \times \kappa_0^c \log(A_0^c) \tag{5}$$

⏩ Estimation results

# Regression Results

▶ Consider a country that starts with an initial level of $\kappa_0 \log(A_0) = 2$ and a sectoral productivity level of 0.1 relative to the top ten most productive countries:

| | **Agriculture** $\bar{g}_a = 4.42\%$ | **Manufacturing** $\bar{g}_m = 1.58\%$ | **Services** $\bar{g}_s = 1.05\%$ |
|---|---|---|---|
| $\kappa_0 \log(A_0) = 2$ | 508 | 57 | 32 |
| $\kappa_0 \log(A_0) = 2.5$ | 169 | 42 | 26 |

**Table 3:** Number of years to reach 0.5 productivity level relative to the frontier by sector

# V. Conclusion

# Conclusion

▶ Using HCCTAD, I show evidence on technology adoption, finance, and Sectoral proximity to the frontier.

▶ I build a technology adoption model to explain these observations.

▶ The results show the role of finance and the frontier growth on the speed of sectoral productivity convergence.

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▶ I build a technology adoption model to explain these observations.

▶ The results show the role of finance and the frontier growth on the speed of sectoral productivity convergence.

▶ Next steps in this research program are :

- To analyze how finance and initial sectoral productivity levels, through technology adoption, can explain the differences between the paths and rates of structural change that exist between developing countries and developed countries.
- To understand how financial development and the dynamics at sector level of productivities can explain the phenomenon of "converging to convergence" of GDP per capita across countries documented by Kremer et al. (2022).

# Thank You !

# Observation 1

Back to data

Back to model predictions

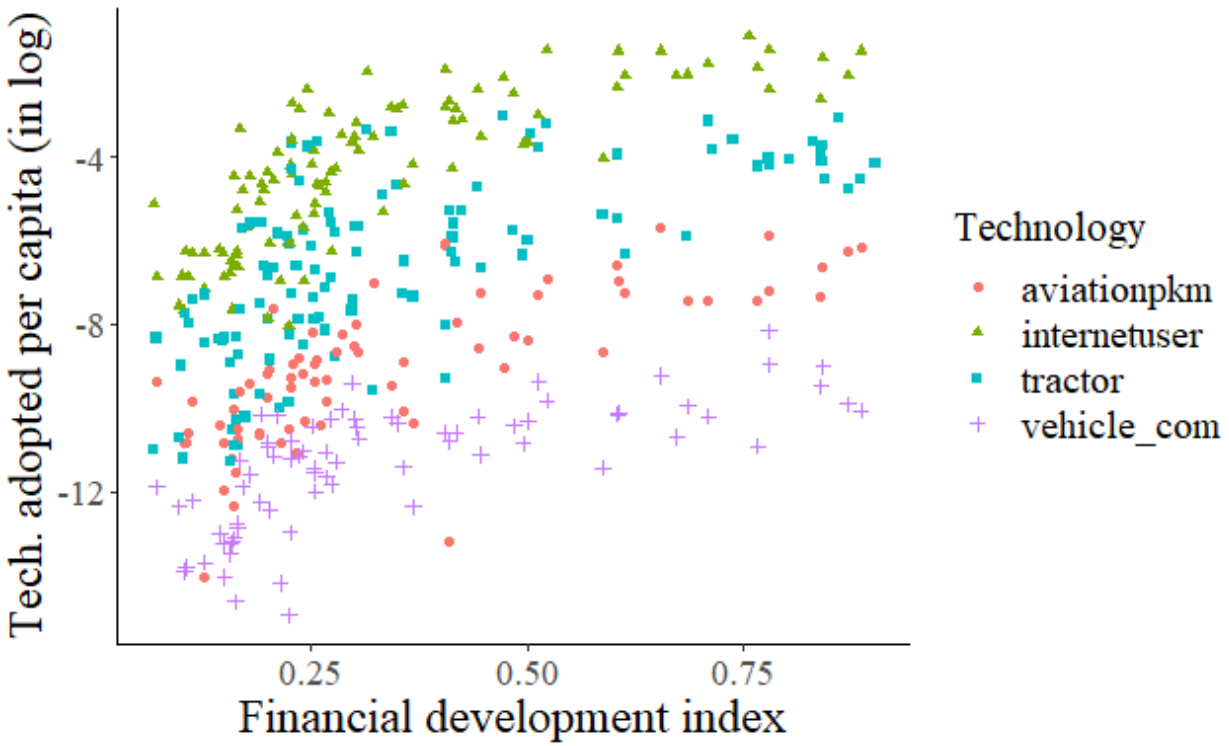


**Figure 8:** Average of financial development and technology adoption in log , 1980-2003

# Observation 1

Back

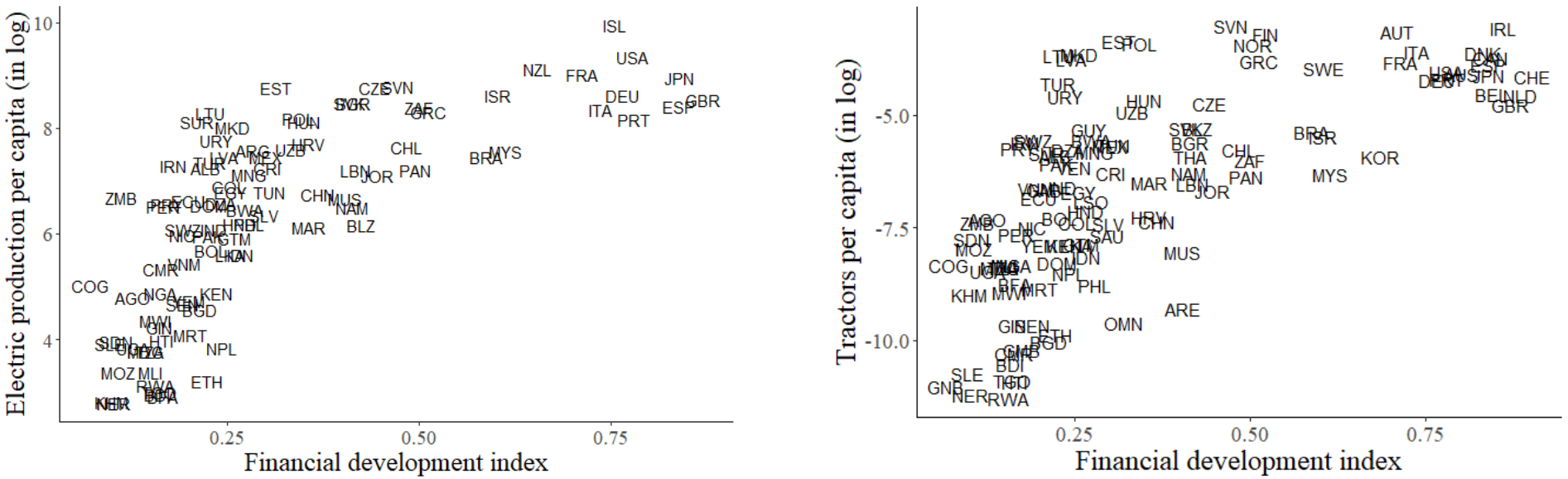


**Figure 9:** Average of financial development and technology adoption in log , 1980-2003

# Observation 2

Back

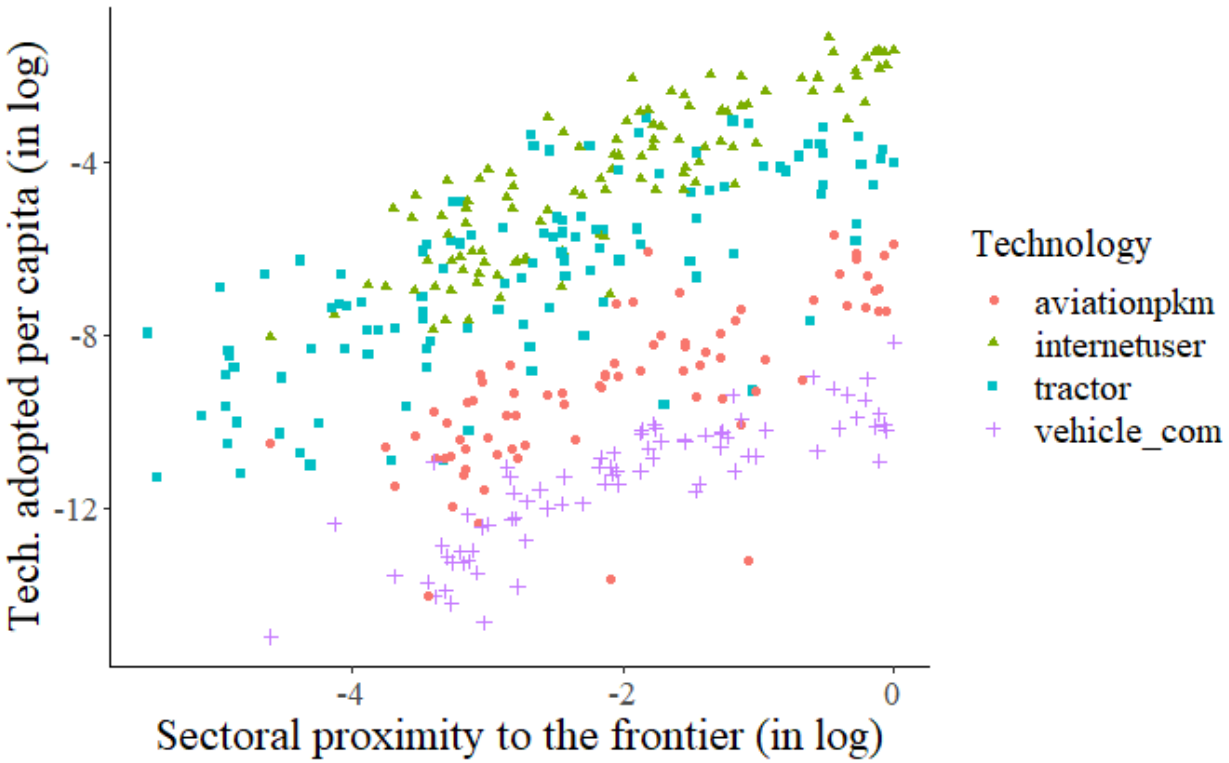


**Figure 10:** Average of distance to frontier and technology adoption in log , 1991-2003

# Observation 2

Back

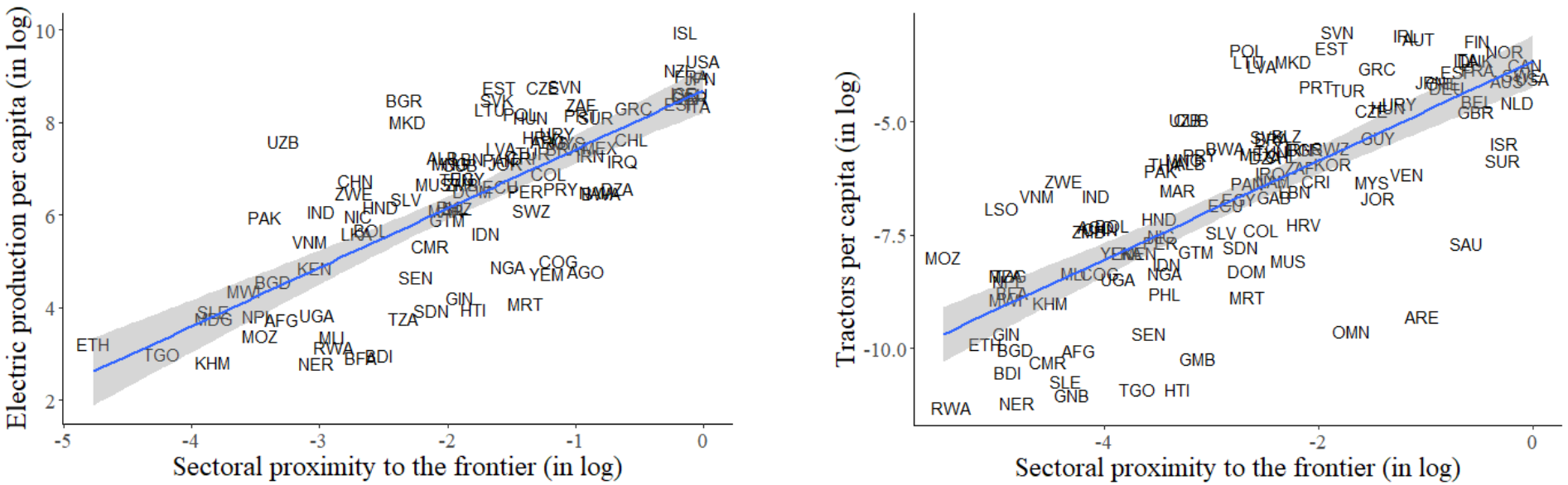


**Figure 11:** Average of distance to frontier and technology adoption in log , 1991-2003

## Differences from Aghion et al. (2005)

| Aghion et al. (2005) | This paper |
|---|---|
| (1) Only Finance explains technology adoption. | (1) Finance and country's sectoral proximity to the frontier determine technology adoption. |
| (2) Only the productivity of the technology to be adopted matters in the adoption project. | (2) I show in the data that the country sectoral productivity also matters. |
| (3) Cross-country technology adoption analysis. | (3) Within and cross-country analysis. |
| (4) Aggregate productivity convergence analysis. | (4) Sectoral productivity convergence analysis. |
| (5) Countries are confined in singular categroy. Back | (5) As the GDP per capita grows, countries can transition from one category to another. |

## Controlling for Governance in Estimations of Technology Adoption

| | Governance variables used | | | | | |
|---|---|---|---|---|---|---|
| | **GE** | **CC** | **VA** | **PV** | **RQ** | **RL** |
| FD | 4.896 | 3.300 | 3.988 | 4.257 | 4.262 | 3.757 |
| dist | 0.221** | 0.220** | 0.220** | 0.221** | 0.222** | 0.221** |
| FD×dist | -0.755** | -0.758** | -0.756** | -0.757** | -0.762** | -0.758** |
| GDP | 0.055 | 0.068 | 0.060 | 0.141 | -0.036 | 0.103 |
| GDP×FD | -0.824 | -0.469 | -0.437 | -1.010 | -0.370 | -0.534 |
| hc | 0.810 | 0.816 | 0.483 | 0.669 | 0.595 | 0.763 |
| hc × FD | -0.373 | -0.112 | 0.269 | 0.472 | 0.382 | -0.165 |
| **Gov.** | -0.080 | -0.145 | -0.069 | -0.333 | 0.283 | -0.085 |
| FD×**Gov.** | 0.795 | 0.072 | -0.428 | 1.010 | -0.912 | 0.222 |
| Tech. FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1,416 | 1,416 | 1,416 | 1,416 | 1,416 | 1,416 |
| $R^2$ | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |

Governance variables are **GE** :Gov. Effectiveness, **CC**: Control of Corruption, **VA** : Voice and Account., **PV**: Pol. Stability and Absence of Viol./Terrorism, **RQ** : Regulatory Quality, **RL** : Rule of Law

Back

# $\beta-$ Convergence : Regression Results

| | 1991–2005 | | 2005–2019 | | 1991–2019 | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| ***Agriculture equation*** | | | | | | |
| $A_{a0}$ | 0.003 | 0.003 | -0.003 | -0.002 | -0.001 | -0.002 |
| $\kappa A_0$ | | 0.071** | | 0.056*** | | 0.028 |
| $A_{a0} \times \kappa A_0$ | | -0.007** | | -0.005*** | | -0.002 |
| Countries | 121 | 107 | 166 | 148 | 120 | 107 |
| ***Manufacturing equation*** | | | | | | |
| $A_{m0}$ | -0.005* | -0.009** | -0.010*** | -0.017*** | -0.008*** | -0.010*** |
| $\kappa A_0$ | | 0.059 | | 0.024 | | 0.054 |
| $A_{m0}A_0$ | | -0.004 | | -0.002 | | -0.004 |
| Countries | 114 | 101 | 160 | 142 | 113 | 101 |
| ***Services equation*** | | | | | | |
| $A_{s0}$ | -0.005 | -0.015*** | -0.004** | -0.004 | -0.006*** | -0.012*** |
| $\kappa A_0$ | | 0.107** | | 0.068*** | | 0.086** |
| $A_{s0} \times \kappa A_0$ | | -0.008* | | -0.006*** | | -0.007** |
| Countries | 108 | 96 | 157 | 139 | 107 | 96 |

Back

# Altrenative estimations for $\beta$-Convergence (1/2)

**Table 4:** 10 years period Panel Regression Results, dependent variable: Avergage Growth in log Producitivity Back

| | Agriculture | | Manufacturing | | Services | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $\beta_j$ | 0.001 | -0.042*** | -0.007*** | -0.063*** | -0.003*** | -0.042*** |
| $\rho_j$ | | 0.097*** | | 0.020 | | 0.087*** |
| $\gamma_j$ | | -0.009*** | | -0.002 | | -0.008*** |
| Country FE | No | Yes | No | Yes | No | Yes |
| Period FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Countries | 175 | 156 | 170 | 151 | 171 | 152 |
| Obs. | 336 | 299 | 323 | 287 | 322 | 285 |
| R-squared | 0.01 | 0.83 | 0.08 | 0.79 | 0.03 | 0.88 |

All data are aggregated to 10-year time periods spanning 1991-2019.

# Altrenative estimations for $\beta$-Convergence (2/2)

**Table 5:** Panel regression results with Financial Development Index, dependent variable: Growth in log producitivity Back

| | Agriculture | | Manufacturing | | Services | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $\beta_j$ | 0.001 | -0.044*** | -0.007*** | -0.062*** | -0.003*** | -0.058*** |
| $\rho_j$ | | 0.127*** | | 0.023 | | 0.173*** |
| $\gamma_j$ | | -0.012*** | | -0.003 | | -0.016*** |
| Country FE | No | Yes | No | Yes | No | Yes |
| Period FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Countries | 176 | 157 | 171 | 152 | 174 | 155 |
| Obs. | 828 | 736 | 797 | 708 | 793 | 703 |
| R-squared | 0.01 | 0.48 | 0.05 | 0.53 | 0.05 | 0.62 |

All data are aggregated to 5-year time periods spanning 1991-2019.