Financial Development, Technology Adoption, and Sectoral Productivity Convergence

Komla Avoumatsodo

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Job Market Paper

ESG--UQAM

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 sector level.

Motivation (2/2)

- ► The intensity of using adopted technologies varies across countries and sectors. Comin & Mestieri (2018)

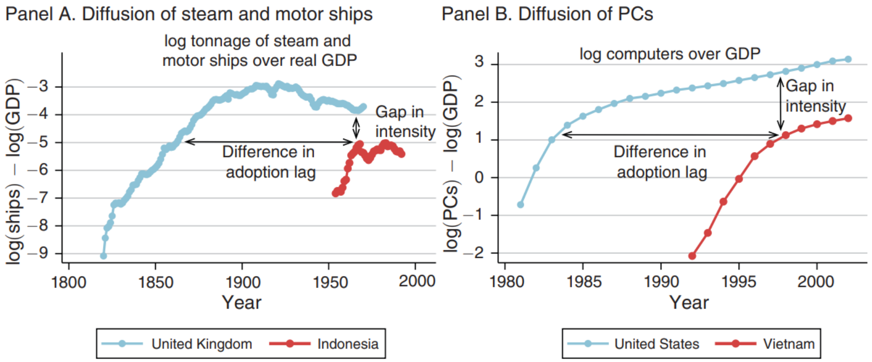


Figure 1: Technologies diffusion over time

What I do (1/2)

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

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

- *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 technology adoption vanishes beyond a 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 a schumpeterian growth model with financing frictions that builds from Aghion et al. (2005).

- I incorporate the specificity of each sector (less or more advanced) in the process of technology adoption, and *the intensity of use of new adopted technologies*.

What I do (2/2)

► I consider a schumpeterian growth model with financing frictions that builds from Aghion et al. (2005).

► I incorporate the specificity of each sector (less or more advanced) in the process of technology adoption, and *the intensity of use of new adopted technologies*.

► The model is also extended by introducing the entrepreneurial skills of innovators.

- *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 show that :
  - Financial development affects positively the intensity of use of adopted technologies only low financial developed countries and sectors/countries far from the frontier.
  - Countries with high financial development will converge faster.
  - Sectors that grow faster at the frontier will experience later convergence.

Results

- The predictions of the model show that :
  - Financial development affects positively the intensity of use of adopted technologies only low financial developed countries and sectors/countries far from the frontier.
  - Countries with high financial development will converge faster.
  - Sectors that grow faster at the frontier will experience later convergence.
- In each sector, the model classifies countries into three groups :
  - Countries that diverge: Low levels of financial development and GDP per worker;
  - 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 evidences on technology adoption, financial development and sectoral proximity to the frontier.
Comin & Nanda (2019), Aghion (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 positive impact of frontier productivity growth and financial development on the speed of convergence.

Plan

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*.

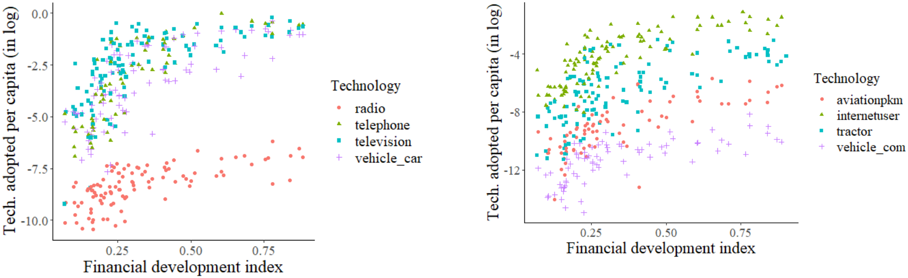
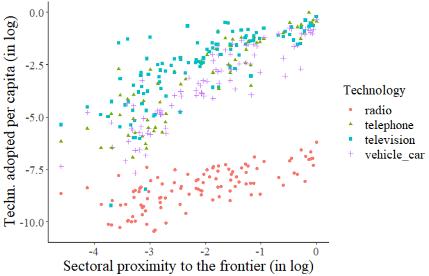


Figure 2: Average levels of financial development and log technology adoption per capita, 1980-2003

⏩ More graphs

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



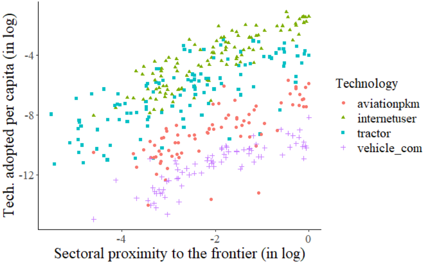


Figure 3: Average levels of log technology adoption per capita and log sectoral productivity relative to US, 1991-2003

More graphs

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Econometric specification

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

- θ_{cjt} is the measure of technology j in country c at time t;
- η_{jt} is technology-year-fixed effect;
- δ_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 Ethiopia1 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 (1/2)

- The amount invested in sector j at date t for technology adoption is z_{jt} and the amount borrowed is $z_{jt} - sw_t$.
- 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 :

$$\underbrace{hz_{jt}}_{\text{cost of hiding}} + q\underbrace{(1+r)(z_{jt} - sw_t)}_{\text{Repayment of the loan}} \geq (1+r)(z_{jt} - sw_t)$$

i.e $z_{j,t} \leq \dfrac{(1-q)(1+r)}{(1-q)(1+r)-h} sw_t$

Financial intermediaries (2/2)

- The lender can influence the probability q by spending a unit cost per loan amount, given by: $C(q) := c \ln\left(\frac{1}{1-q}\right)$ with $c > h$ and $c > 1 + r$.

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- Lender's problem :

$$\max_{\{q\}} [\, q(1+r) + c \ln(1-q)] \, (z_{jt} - s\, w_t)$$

$$q^* = 1 - \frac{(1+r)}{c}$$

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$$q^* = 1 - \frac{(1+r)}{c}$$

- Then $z_{jt} \leq \kappa w_t$ where $\kappa := \frac{s}{1-\hbar}$ is the credit multiplier which is increasing with $\hbar = h/c$ and the saving rate s.

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

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

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

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

- **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 π_{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 :

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

- A_{jt+1} : The country's sector j productivity at period $t+1$.
- θ_{jt+1} : The intensity of use of 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 θ_{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):

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

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

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Effect of Financial Development on Technology Adoption

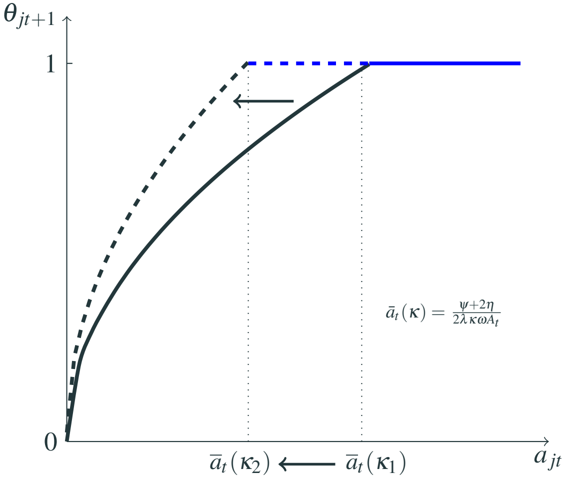


Figure 4: Effect of financial development on the intensity of use of adopted technology : $\kappa_1 < \kappa_2 < \underline{\kappa}_{jt} = \frac{2\eta+\psi}{2\lambda w_t a_{jt}}$

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

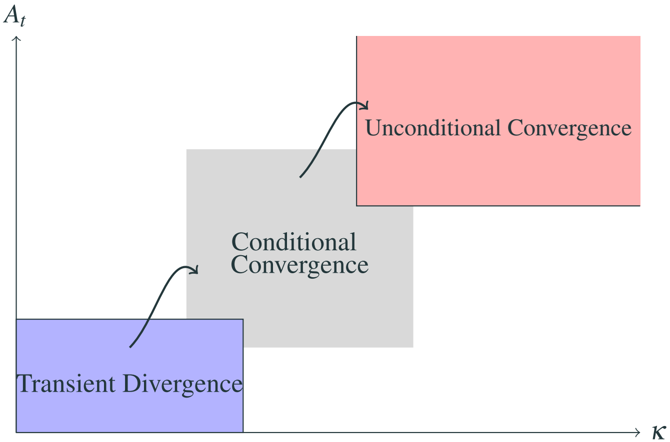
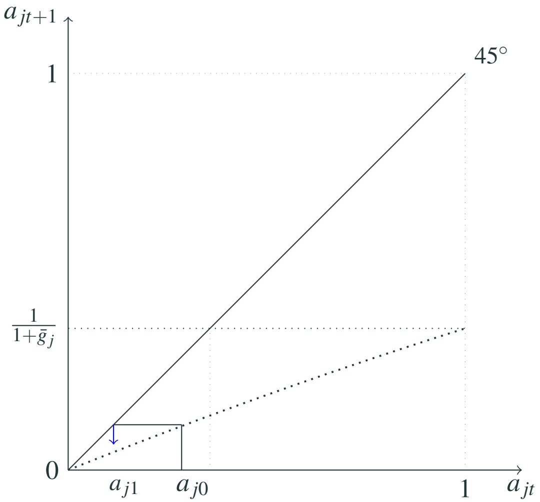


Figure 5: Dynamic Transitions of Countries Across Financial Development and Aggregate Productivity Groups

Sectoral Productivity Gap Dynamics

- **Category 1**: Transient divergence in sectoral productivity for low levels of financial development and aggregate productivity countries and/or faster productivity growth at the frontier: $\kappa A_0 < \frac{\eta \bar{g}_j}{\lambda \omega}$



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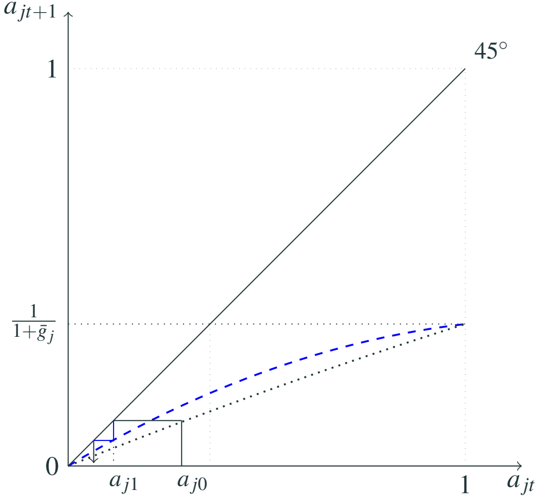
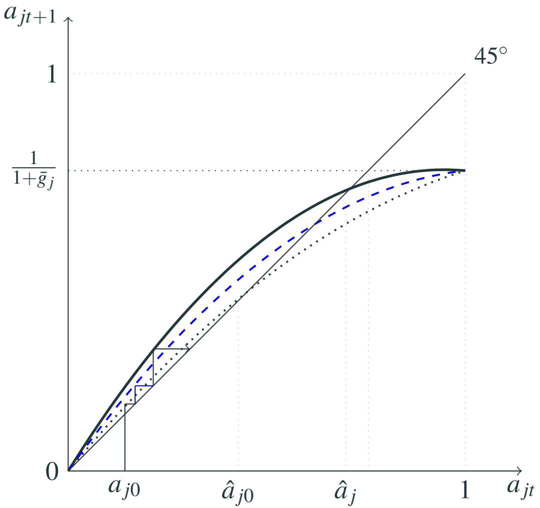


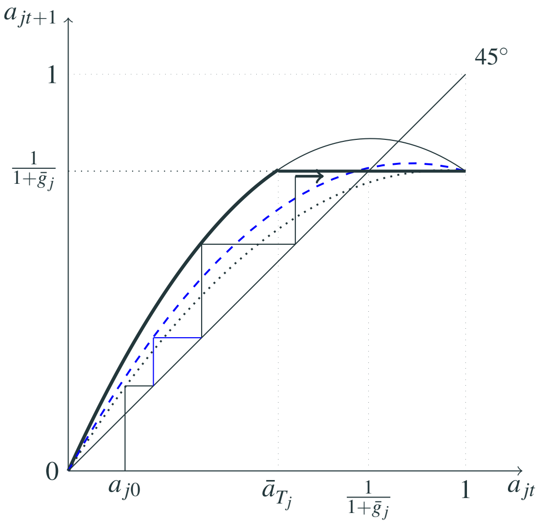
Sectoral Productivity Gap Dynamics

► **Category 2**: Conditional convergence toward a lower level of productivity for countries with moderate levels of financial development and aggregate productivity that are neither too high nor too low : $\frac{\eta \bar{g}_j}{\lambda \omega} < \kappa A_0 < \frac{\psi + 2\eta}{2\lambda\omega}$



Sectoral Productivity Gap Dynamics

- **Category 3**: Sectoral productivity convergence for high financial developed and high aggregate productivity countries : $\kappa A_0 > \frac{\psi+2\eta}{2\lambda\omega}$



Financial Development and Speed of Convergence

- Financial development accelerates the speed of convergence.

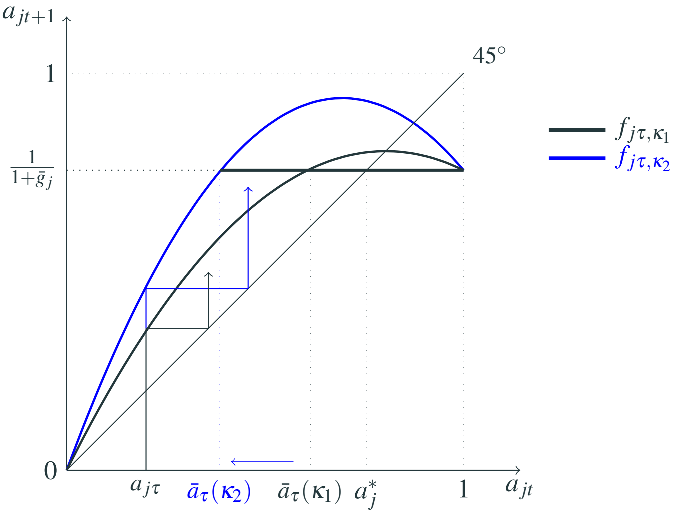


Figure 6: Financial development and convergence speed : $\kappa_1 < \kappa_2$

Frontier Growth and Speed of Convergence

► Sectors that grow slower at the frontier will experience faster convergence to their steady-state $\frac{1}{1+\bar{g}_j}$.

Proof.
Let j_1 and j_2 be two sectors such that $\bar{g}_{j_1} < \bar{g}_{j_2}$. Define the time of convergence $T_j = \min(D_j)$ as the time from which sector j becomes unconstrained, where:

$$D_j = \left\{ t \geq 0 \quad \text{such that } \; a_{jt} \geq \bar{a}_t(\kappa) \right\}$$

Due to the widening of the sectoral productivity gap with frontier growth, if τ is a point in the set D_{j_2}, it implies that τ is also in the set D_{j_1} : $D_{j_2} \subset D_{j_1}$
Consequently, the time T_{j_1} at which sector j_1 becomes unconstrained is less than or equal to the time T_{j_2} for sector j_2 : $\min(D_{j_1}) \leq \min(D_{j_2})$. □

IV. Sectoral Productivity Convergence: Evidence

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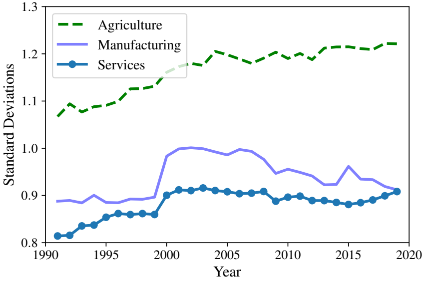
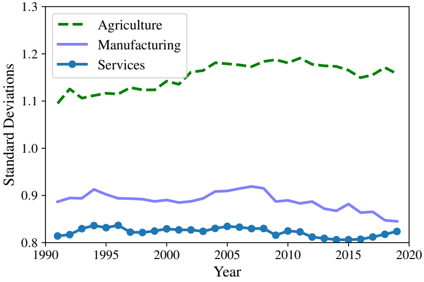


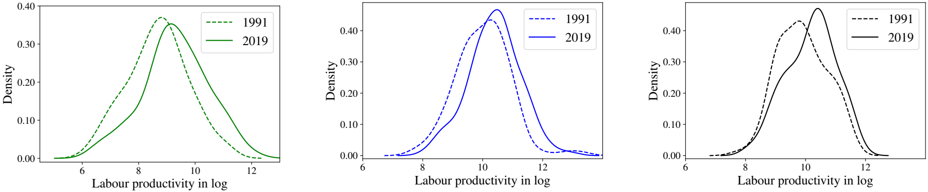
Panel A : 196 countries of unbalanced panel



Panel B : 108 countries of balanced panel

Figure 7: Cross-Country Sectoral Productivity Dispersion

σ-Convergence



(a) Agriculture

(b) Manufacturing

(c) Services

Figure 8: Sectoral productivities distribution over time

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β-Convergence: Econometric Specification

► β-convergence refers to the process by which less productive economies grow faster and close the gap with more developed economies.

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

- 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.
- ε_j^c is the error term.

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

$\beta-$ Convergence : Regression Results (1/2)

	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
κA_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***
κA_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***
κA_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

Alternative estimations

$\beta-$ Convergence : Regression Results (2/2)

► 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

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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.

- ► 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

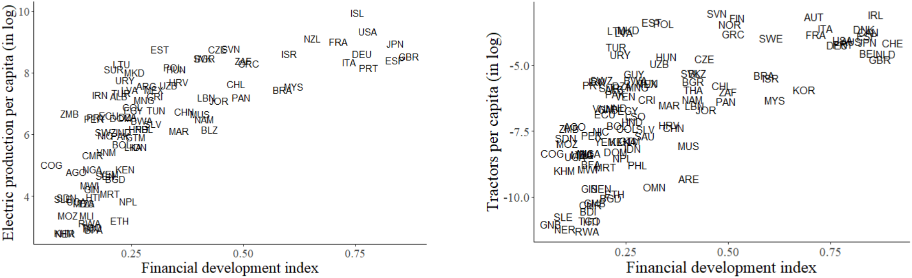

Figure 9: Average of financial development and technology adoption in log , 1980-2003

Observation 2

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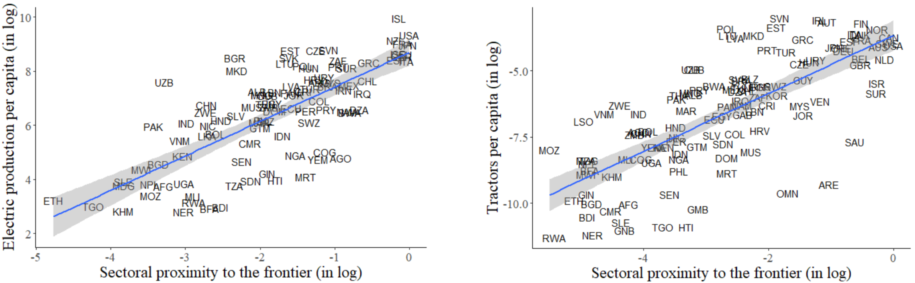

Figure 10: Average of distance to frontier and technology adoption in log , 1991-2003

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

Altrenative estimations for β-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)
β_j	0.001	-0.042***	-0.007***	-0.063***	-0.003***	-0.042***
ρ_j		0.097***		0.020		0.087***
γ_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 β-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)
β_j	0.001	-0.044***	-0.007***	-0.062***	-0.003***	-0.058***
ρ_j		0.127***		0.023		0.173***
γ_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.