Technology Adoption, Financial Development and Sectoral Productivity Dynamics

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Motivation

Using HCCTAD[2] (Comin &Hobijn (2004)), I show three new observations :

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

▶ *Observation 2*: Across countries, *sectoral proximity*[3] to the frontier is positively associated with more technology adoption.

▶ *Observation 3*: The coefficient of association between financial development and technology adoption is higher for countries that are far from the technological frontier.

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

This paper builds a model that features these observations

- 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 efficiency of using new technologies*.

This paper builds a model that features these observations

▶ 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 efficiency of using new 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*".

What 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) GDP convergence analysis.	(4) Sectoral productivity convergence analysis.

Results

- Financial depth only affects positively the probability of successful adoption of advanced technologies for low financial developed countries.

- Sectoral proximity increases the probability of successful technology adoption.

- Sectoral productivity convergence in lags is possible if there is convergence in the efficiency of using new technologies.

- Countries with high financial development will converge faster.

- Sectors that grow faster at the frontier will experience later convergence.

Contribution

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

▶ Contribution to the new theory on sectoral productivity convergence :

- The role of efficiency of use new technologies adopted,
- The role of financial development and
- The role of frontier productivity growth.

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Source and data description (1/2)

Table: Variables sources

Variables	Source	Period covered
Real GDP per capita	World Bank (2021)	1960-2020
Productivity	World Bank (2021)	1991-2019
FD[4]	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[5]	1750-2004

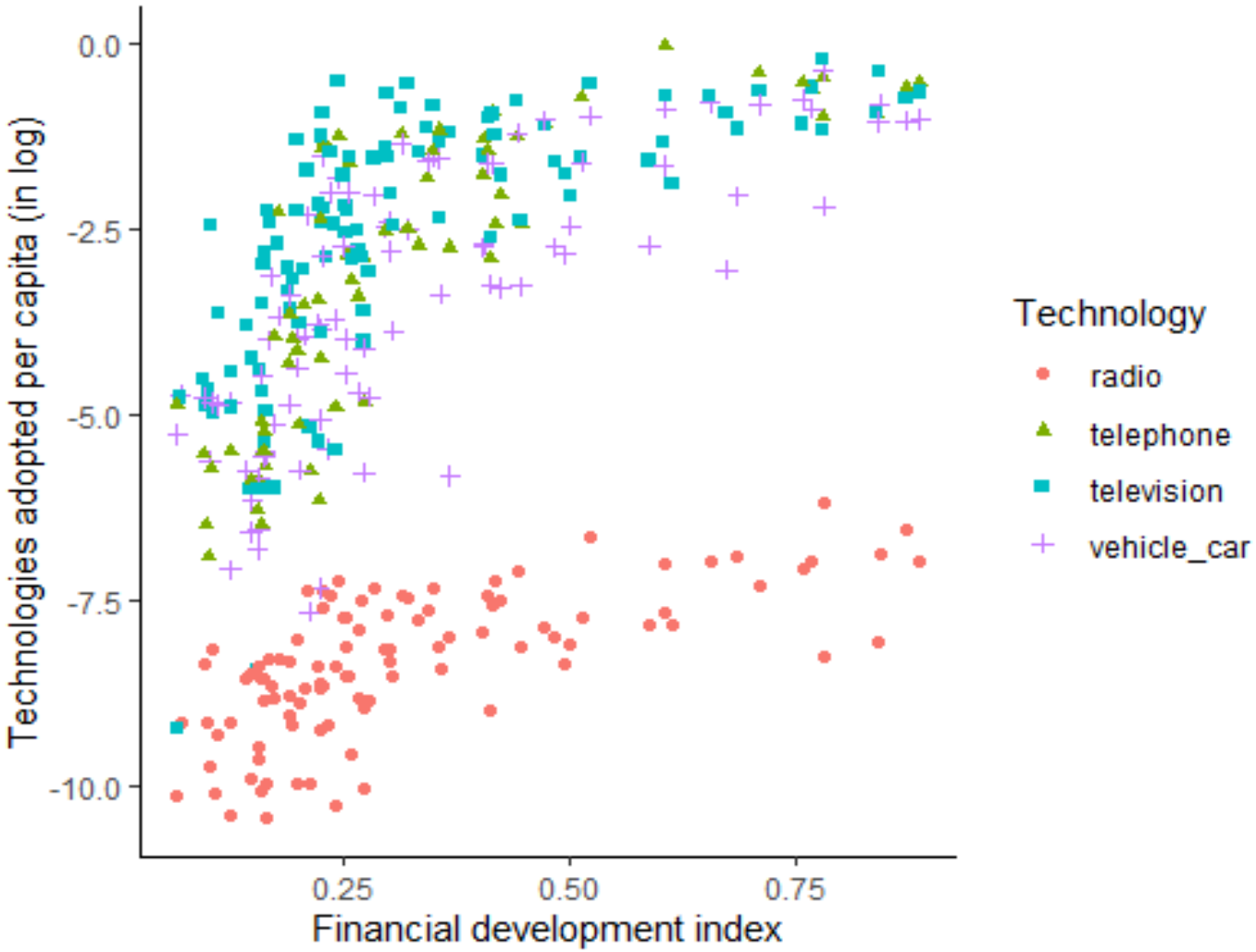
All data are aggregated to average over the period 1991-2004.

[4] Financial Development Index
[5] Historical cross countries technologies adoption data (from NBER)

Source and data description (2/2)

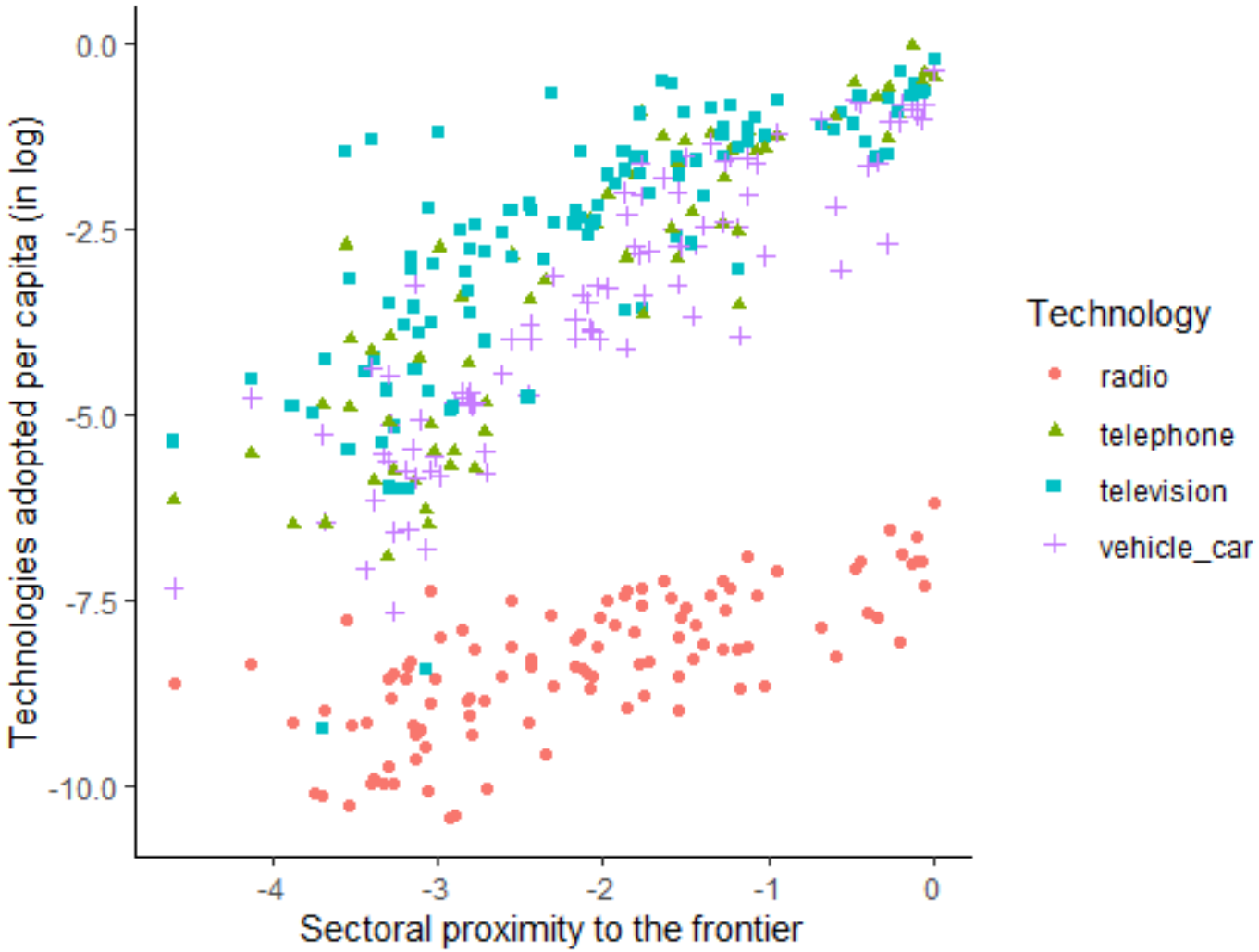
	Technology	Measure	Sector	Countries
1	Harvesters	Number in operation	Agriculture	100
2	Tractors	Number in operation	Agriculture	128
3	Electric production	KwHr produced	Industry	117
4	Railroad	Km of track installed	Industry	78
5	Electric arc steel	Tons produced	Industry	71
6	Blast furnace steel	Tons produced	Industry	43
7	Aviation pkm	Million pass. km	Services	65
8	Cable TV	Number of users	Services	85
9	Commercial vehicles	Number in operation	Services	69
10	Computers	Number in operation	Services	112
11	Internet users	Num. of ind. using internet	Services	125
12	Mail	Million units handled	Services	24
13	Radio	Number in operation	Services	103
14	Telegram	Telegrams sent	Services	18
15	Telephone	Number connected	Services	75
16	Private vehicles	Thous. of priv. owned veh.	Services	92
17	Television	Number in operation	Services	114
	Total			**130**

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



More graphs

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



More graphs

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Econometric specification

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

- y_{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.

	log technology diffusion per capita					
	(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

(1)Robust pvalues. (2)*** p<0.01, ** p<0.05, * p<0.1

	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

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Model : the 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 intermediairies

- 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 :

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

i.e. $z_{j,t} \leq \kappa\, w_t$ where $\kappa = \dfrac{(1-q)(1+r)}{(1-q)(1+r) - h} s.$

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

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

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

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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

At equilibrium

- $\pi_{jt} = \pi A_{jt} L_t$ 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. Monopolists can access an existing technology frontier. For each intermediate sector j there is one born person at each period t who can innovate for the next period by adopting new technology for period $t+1$.
2. $$A_{jt+1} = \begin{cases} \theta \overline{A}_{jt} + (1-\theta) A_{jt} & \text{with probability } \mu_{jt} \\ A_{jt} & \text{with probability } 1-\mu_{jt} \end{cases}$$
   $$\overline{A}_{jt+1} = (1+\overline{g}_j)\overline{A}_{jt}$$
3. Cost of innovation z_{jt} is convex in μ_{jt} and increasing in $\overline{A}_{jt}$:
   $$\lambda_{jt} \frac{z_{jt}}{\overline{A}_{jt}} = \eta \mu_{jt} + \frac{\psi}{2} \mu_{jt}^2 \quad \text{with } \eta,\ \psi > 0 \tag{3}$$
4. $\lambda_{jt} = \lambda A_{jt}$

Equilibrium probability of technology adoption (1/2)

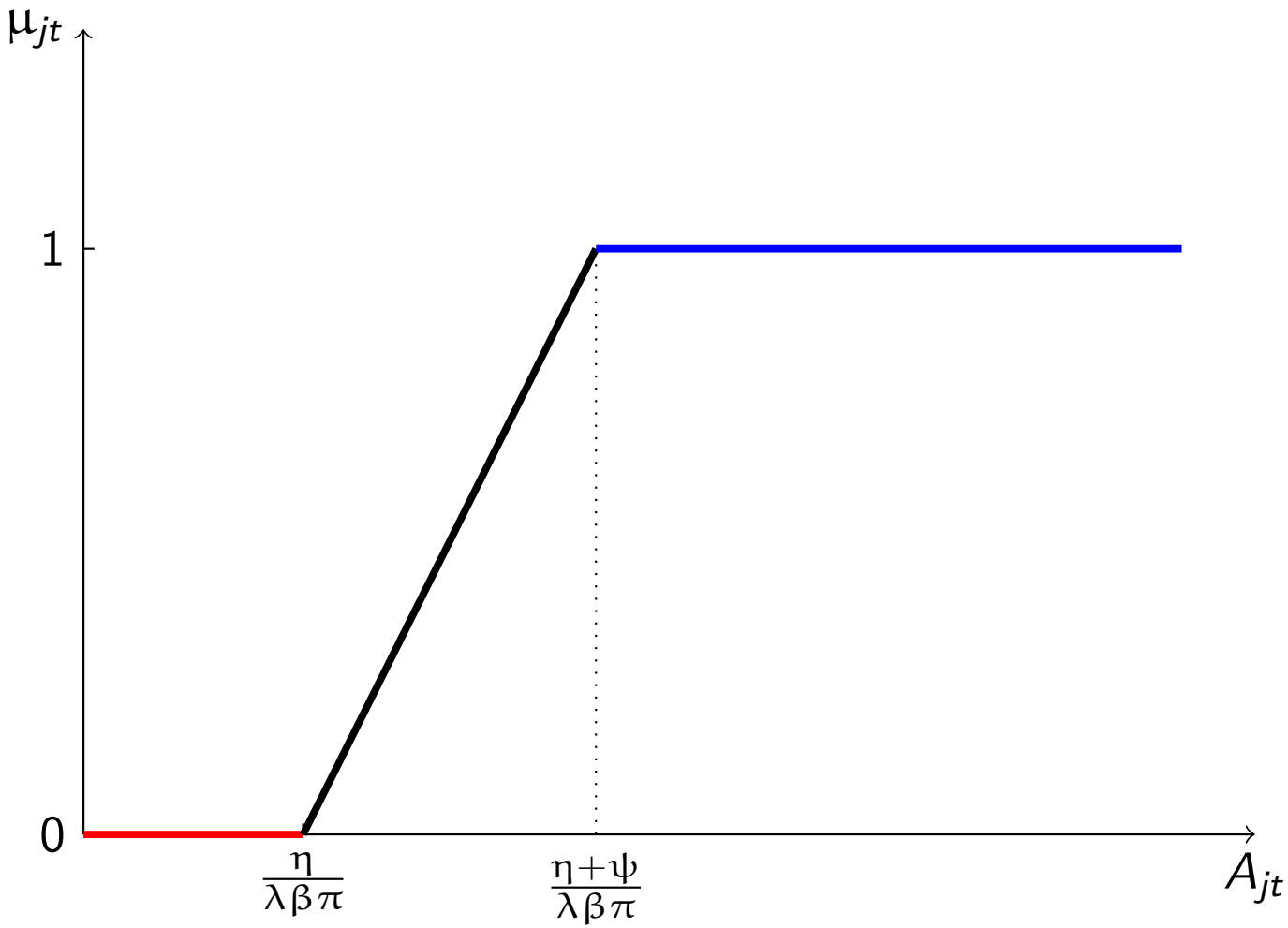

Figure: Equilibrium Innovation under Perfect Credit Markets

Equilibrium probability of technology adoption (2/2)

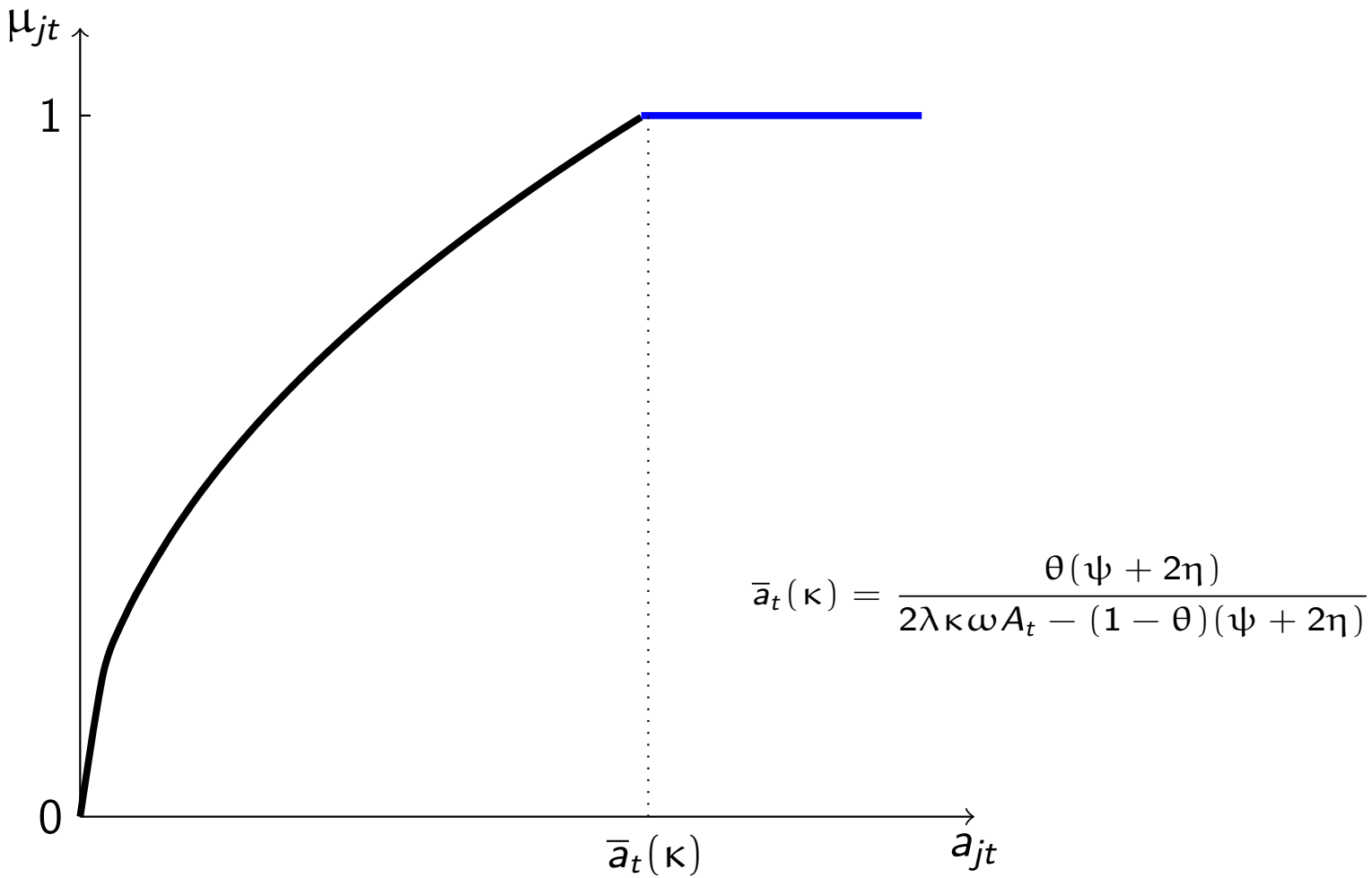

Figure: Equilibrium probability in presence of credit contraints.

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Effect of financial development on technology adoption

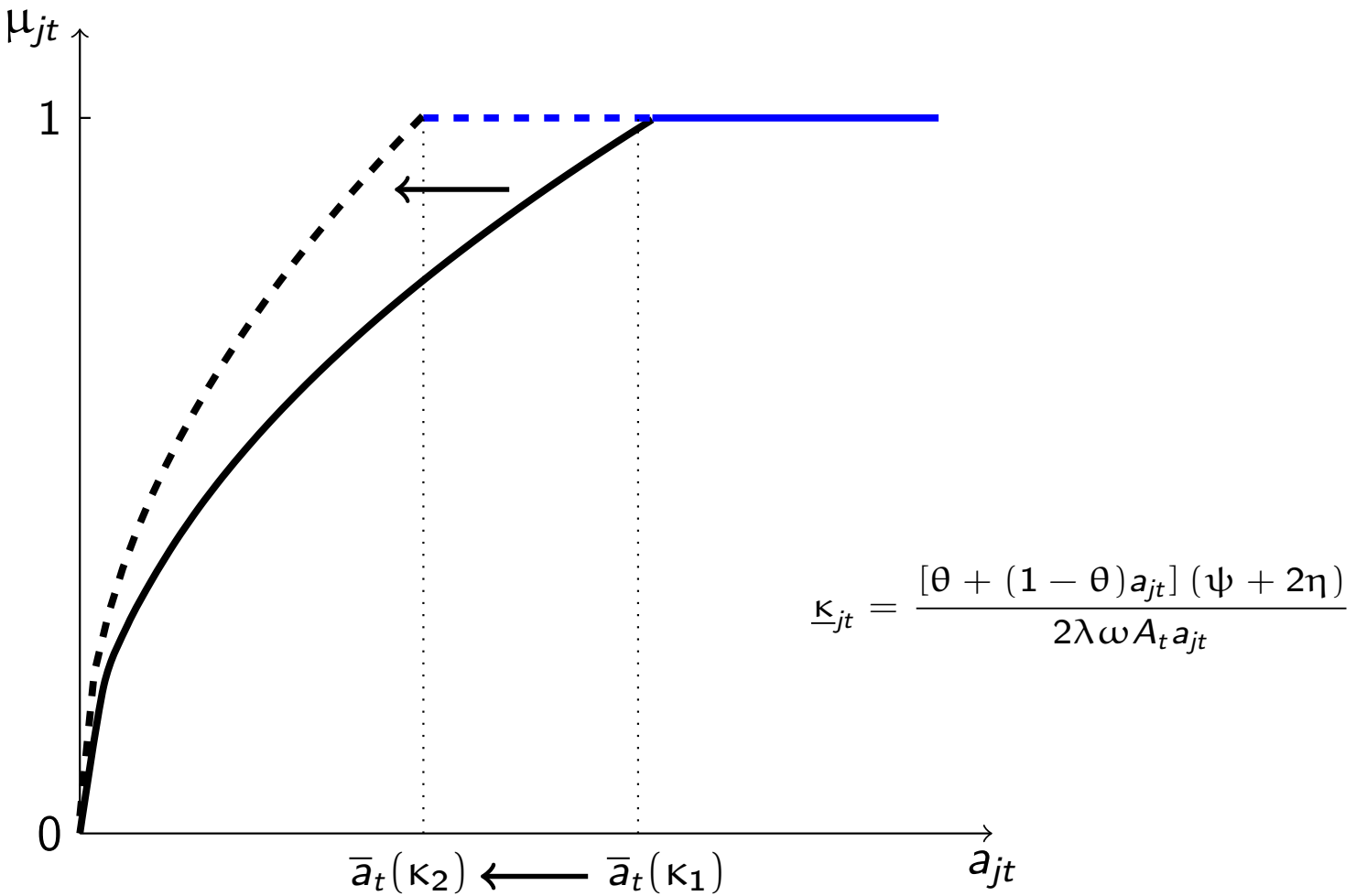

Figure: Effect of financial development on the probability of technology adoption ($\kappa_1 < \kappa_2 < \underline{\kappa}_{it}$)

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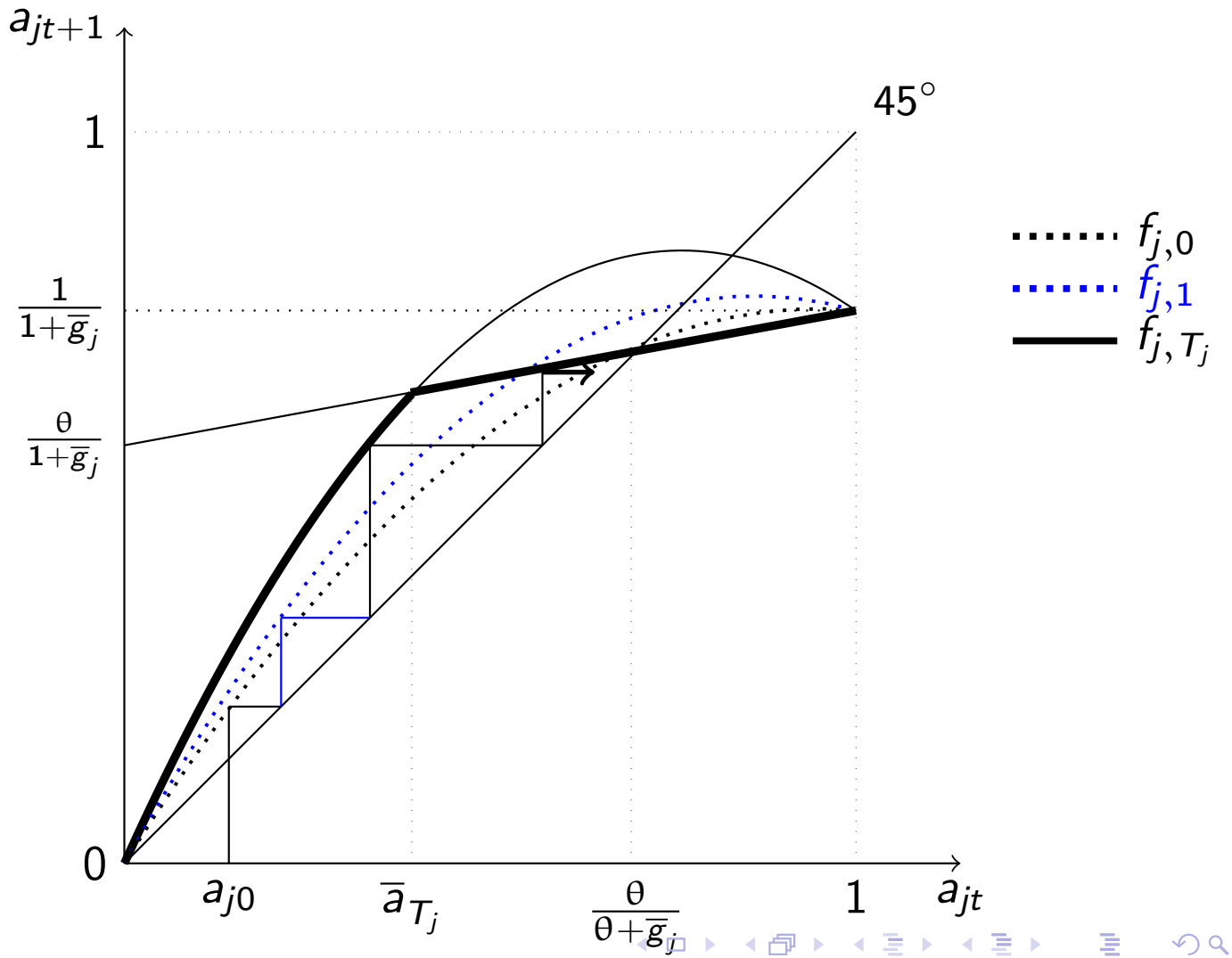
Sectoral productivity gap dynamics

Demonstration



Long-run predictions

1. Sectoral productivities across countries will converge the same steady-state if the efficiency θ of using new technologies converge across countries.

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

Proof.

Let j_1 and j_2 be two sectors such that: $\overline{g}_{j_1} < \overline{g}_{j_2}$. The $T_j = min(D_j)$ where :

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

Then $T_{j_1} \leq T_{j_2}$, for $D_{j_2} \subset D_{j_1}$. □

Financial development and sectoral productivity convergence

- **Financial development increases the speed of convergence.**

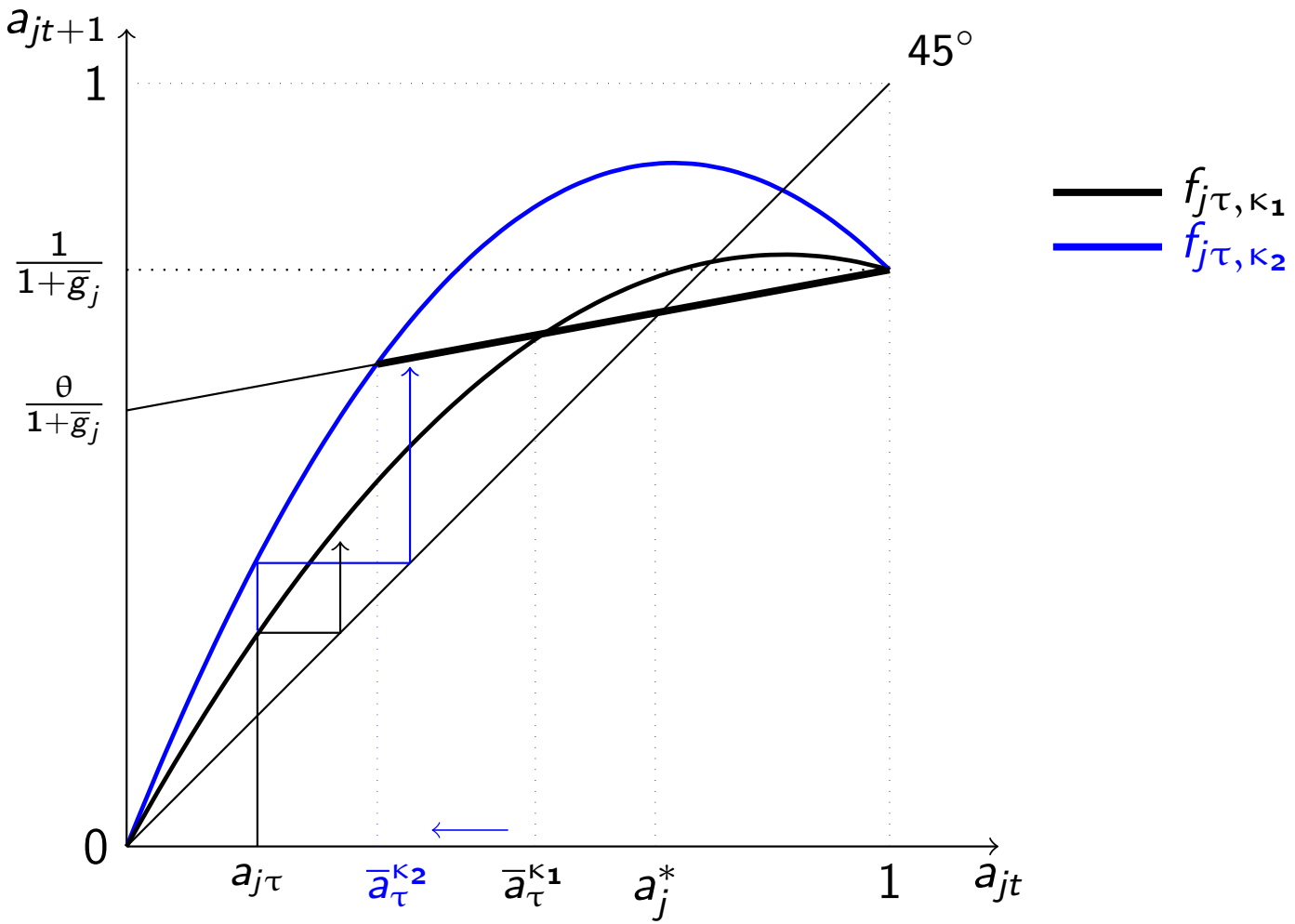


Figure: Financial development and convergence speed : $\kappa_1 < \kappa_2$

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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, and the role of efficiency of using new technologies on the convergence.
- Next steps in this research program could be :
  ▶ to analyze how finance and initial sectoral productivity levels, through technological adoption, can explain the differences between the paths and rates of structural change that exist between developing countries and with developed countries.

  ▶ to dig deeper into the determinants of variation in the efficiency of technology use across countries to better understand the divergence in sectoral productivity.

Thank You !

Sectoral productivity gap dynamic

Back The dynamics of the secotral technology gap can be written as follows:

$$a_{jt+1} = \frac{\theta \mu_{jt} (1 - a_{jt}) + a_{jt}}{1 + \overline{g}_j} \tag{4}$$

Thus $a_{jt+1} = \min \left\{ h_j(a_{jt}),\ f_{jt}(a_{jt}) \right\} \ \forall a_{jt} \in [0,1]$ where :

$$f_{jt}(a) = \frac{a + \theta(1-a)\overline{\mu}_t(a)}{1 + \overline{g}_j} \tag{5}$$

$$h_j(a) = \frac{\theta}{1 + \overline{g}_j} + \frac{1-\theta}{1 + \overline{g}_j} a \tag{6}$$

with $\overline{\mu}_t(a) = -\frac{\eta}{\psi} + \left[\left(\frac{\eta}{\psi} \right)^2 + \frac{2\lambda\kappa w_t a}{\psi \left[\theta + (1-\theta)a \right]} \right]^{\frac{1}{2}}$

$$\begin{cases} f_{jt}^{'}(0) \leq 1 & if \quad \kappa A_t \leq \dfrac{\eta \overline{g}_j}{\lambda \omega} \\ f_{jt}^{'}(0) > 1 & if \quad \kappa A_t > \dfrac{\eta \overline{g}_j}{\lambda \omega} \end{cases}$$

Sectoral productivity gap dynamic

Back

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and

$$\begin{cases} f_{jt}^{'}(1) < \dfrac{1-\theta}{1+\overline{g}_j} & if \quad \kappa A_t > \dfrac{\psi + 2\eta}{2\lambda\omega} \\ f_{jt}^{'}(1) \geq \dfrac{1-\theta}{1+\overline{g}_j} & if \quad \kappa A_t \leq \dfrac{\psi + 2\eta}{2\lambda\omega} \end{cases}$$

$f_{jt}^{'}(1) < \frac{1-\theta}{1+\overline{g}_j}$ since $\kappa A_t > \frac{\psi+2\eta}{2\lambda\omega}$ [6] and $f_{jt}^{'}(0) > 1$ for $\frac{\psi+2\eta}{2\lambda\omega} > \frac{\eta\overline{g}_j}{\lambda\omega}$.

[6] $\kappa A_t > \frac{\psi+2\eta}{2\lambda\omega}$ follows from the inequality $A_{jt} > \frac{\eta+\psi}{\lambda\beta\pi}$ as $\alpha\omega = \pi$.

Observation 1

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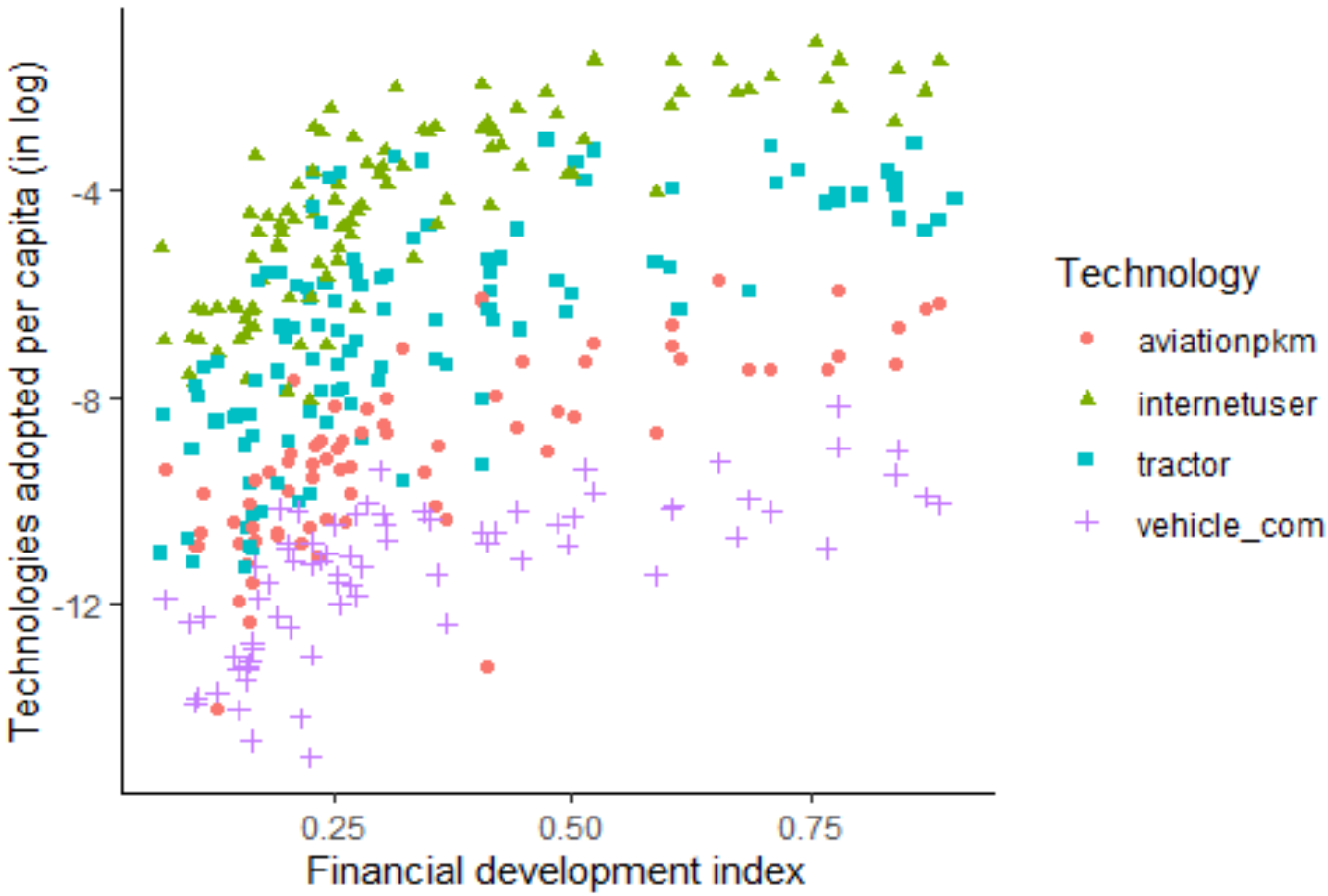

Figure: Average of financial development and technology adoption in log , 1980-2003

Observation 1

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Figure: Average of financial development and technology adoption in log , 1960-2003

Observation 2

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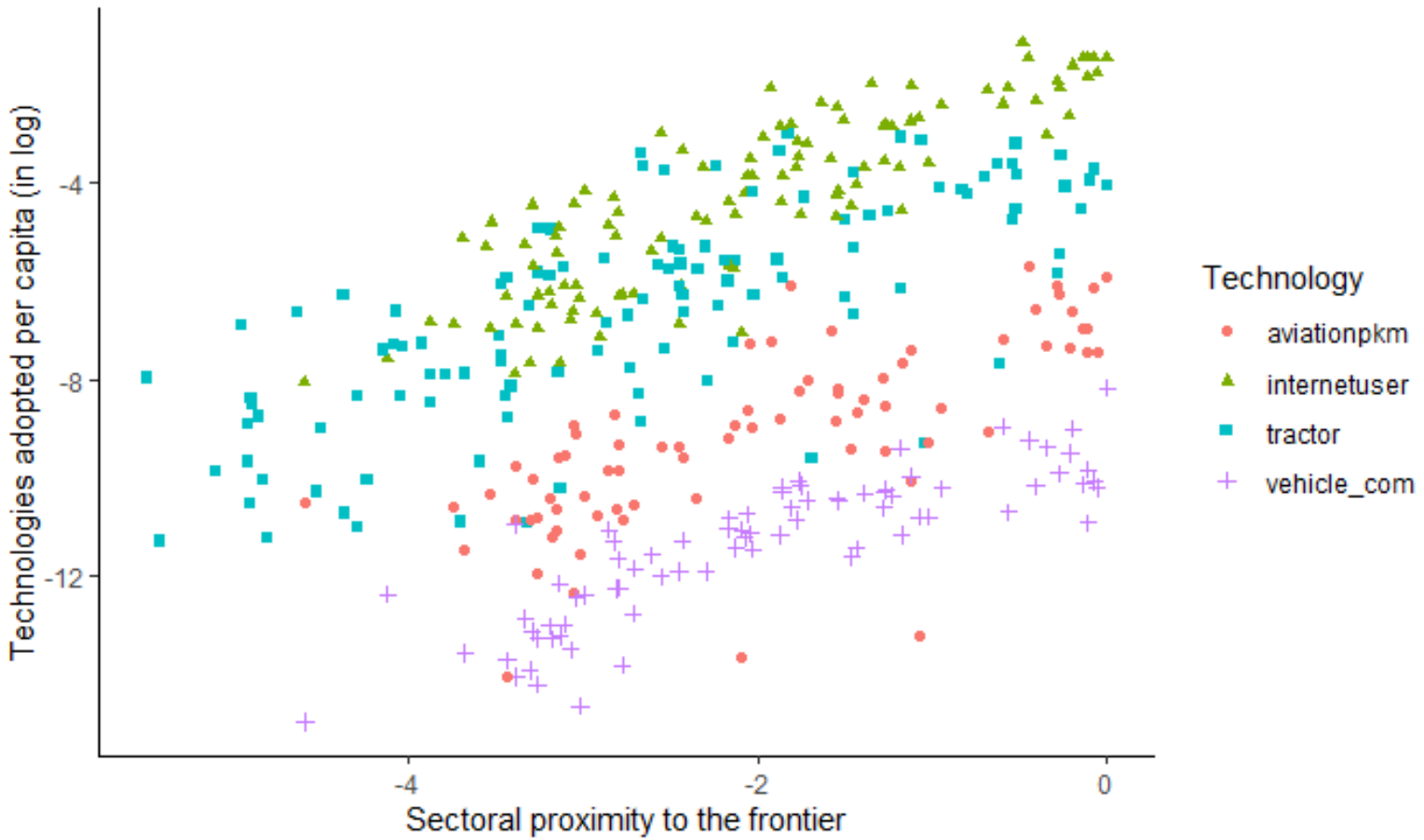

Figure: Average distance to frontier and technology adoption in log , 1991-2003

Observation 2

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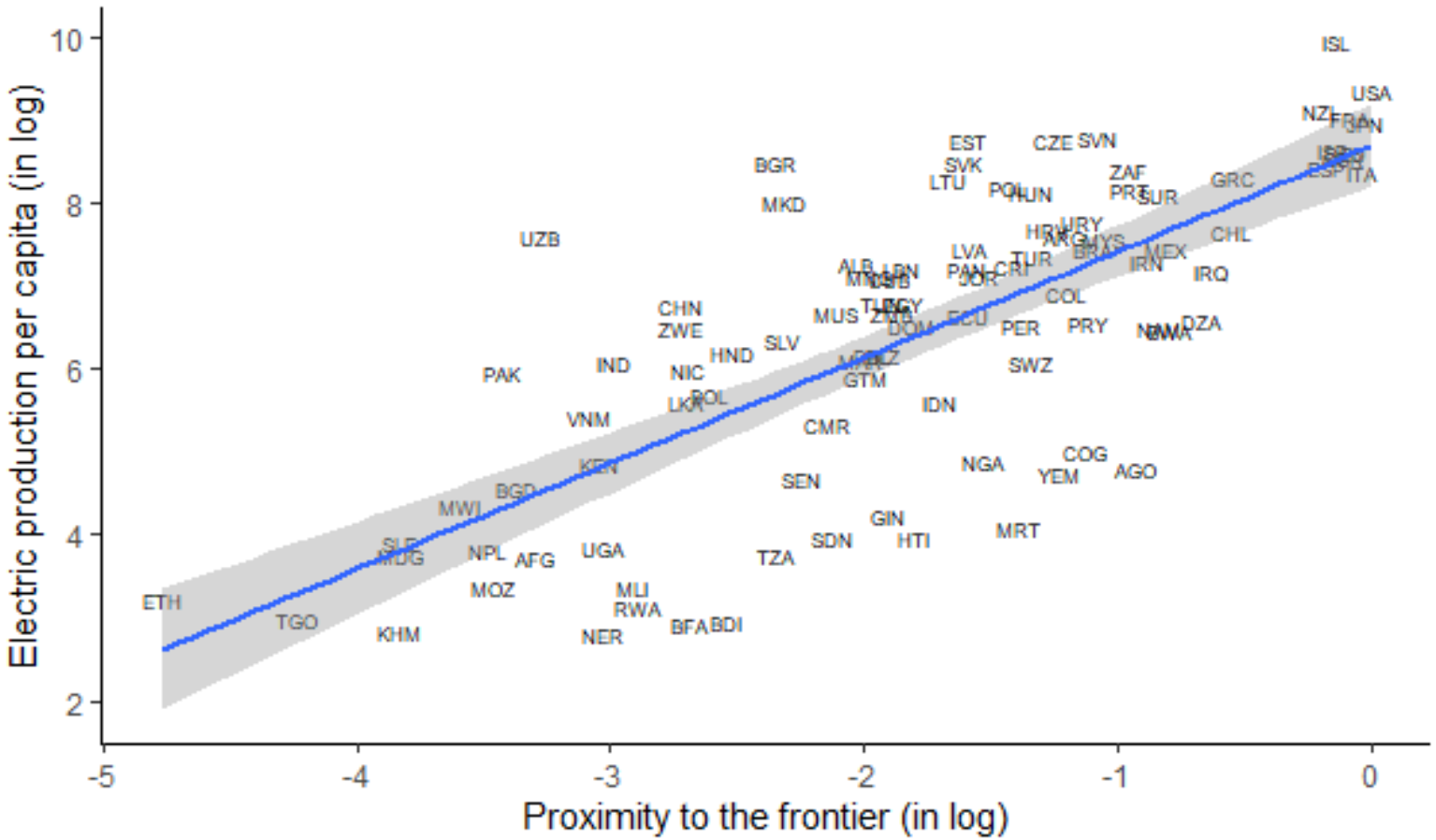

Figure: Average of distance to frontier and technology adoption in log , 1991-2003

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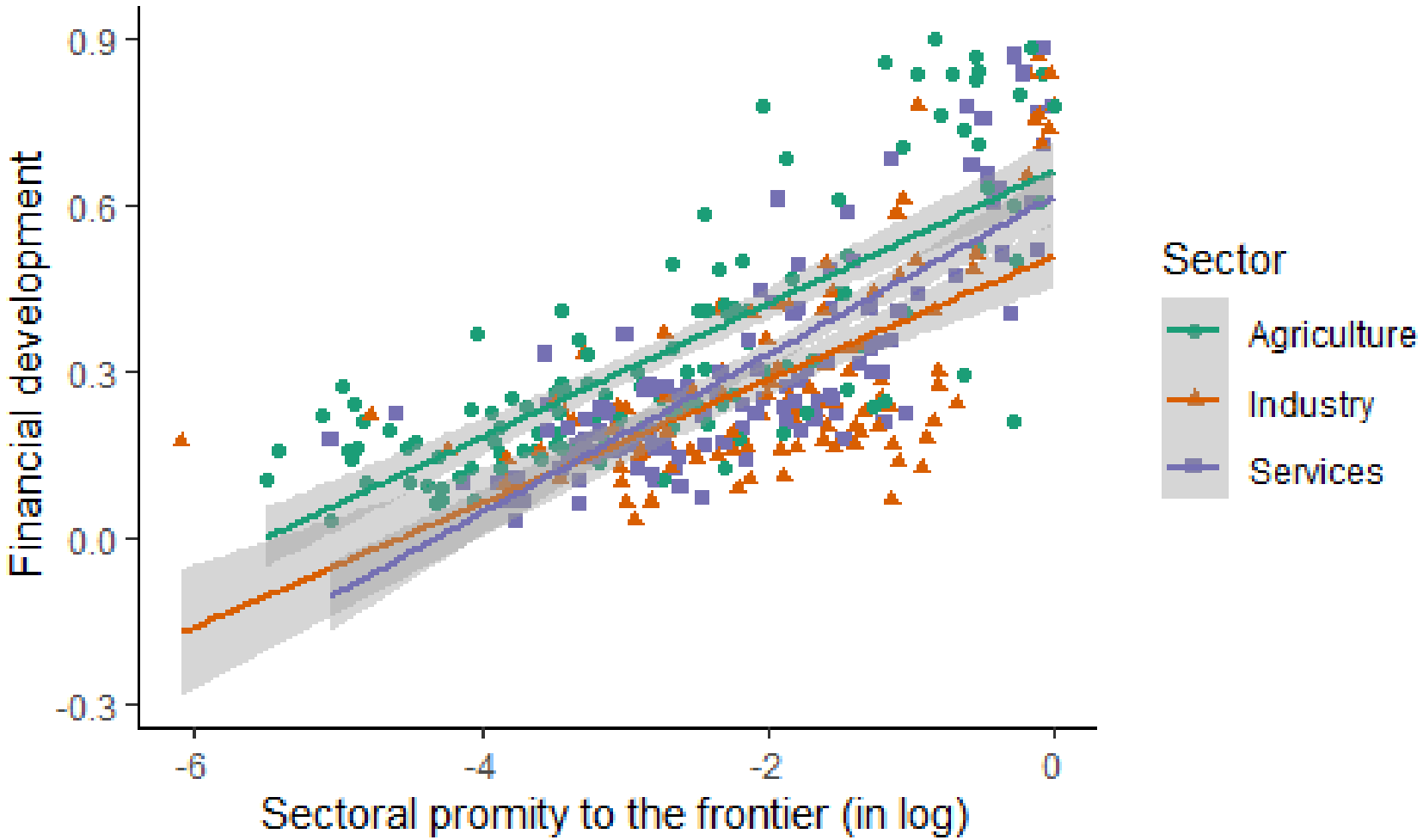

Figure: Average of distance to frontier and average financial development in log , 1991-2003