COOPERATION, COMPETITION AND PATENTS:

Understanding Innovation in the Telecom Sector

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CEPR/JIE School on Applied IO.

MOTIVATION

- **Many activities are carried out in groups** (e.g: employees inside a firm, coauthorships, inter-firm)
- **How cooperation is rewarded** is key to its success
  - Property rights to alleviate free riding
  - Competition for property rights?
- Very salient in **technology development**
  - Interconnectivity requires compatibility
  - Patents to protect property rights

RESEARCH QUESTIONS

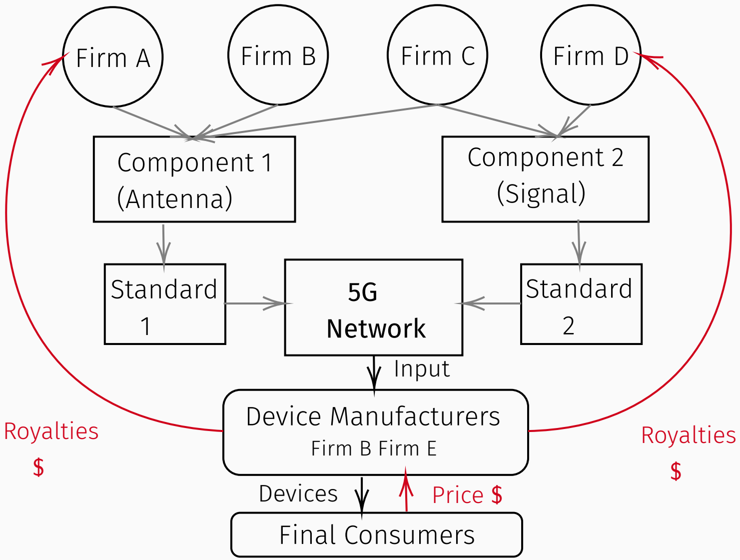
This Paper:

- **Firms incentives to cooperate in technology development**
    - Who do firms want to collaborate with?
- **Role of property right**
    - Direct incentive for cooperation
    - How competition for property rights shape cooperation?
    - Overall effect in equilibrium?

Mobile telecommunication market

- Network technology developed cooperatively
- Patents used for appropriation of part of the common value
- 5% of global GDP in 2018 and 10% by 2025 (European Commission)
- **Policy and academic debate** on the use of patents

DEVELOPMENT OF A COMMON TECHNOLOGY



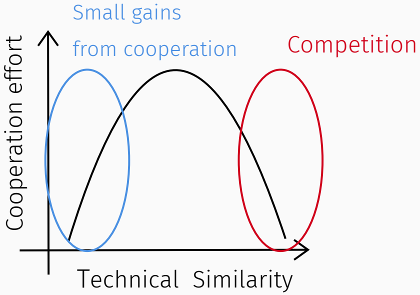
Two stage Structural Equilibrium model

- Participation and effort decisions

Novel dataset

1. Standardization process: new database developed by the Searle Center of Northwestern University:
    - Organization database: Firms , Standards, Firms' contributions.
    - Patent database: Patents holders at a firm-standard level
    - Measure → **participation, effort, development time and Patents**
2. Data on Patents from the United States Patent and Trademark Office
    - Includes technological classification of patents
    - Measure → **technological capacity and specialization**

1. Do firms have incentives to collaborate with similar firms?



Cooperation effect: Firms that are closer in the technological space develop standards faster

Competition effect: More similar firms get on average less patents

2 What is the effect of patents licensing on the development of standards?

(+) **Alleviate free riding problem in teams** (Holmstrom, 1982)

- Increase incentives to exert effort

(-) **Might distort firms' effort allocation**

- Competition for property rights might decrease firms incentives to exert effort

(?) **How these forces interact in equilibrium?:**

- Counterfactual policy: free licensing

Two-stages equilibrium model with **complete information**

1. Firms decide to participate in each standard release
    - Based on the technological match and potential profits Π
        - Technological match: standard requirements and firm's technology
        - Profits: Market revenues, licensing, Time to develop
2. Firms decide effort provision
    - $e_{f,s}$: effort exerted by firm f in standard s
    - Input for the development of the standard
    - Choose effort that maximize expected profits

→Solved using backward induction

→3 stages estimation strategy combining reduced form identification and simulated minimum distance estimator

Second stage expected profits:

$$\Pi_{f,s} = (\underbrace{\text{MaxTime}}_{\text{Max. days}} - \underbrace{\text{TTD}_r(e_{f,s}, e_{-f,s})}_{\text{Time to develop r (-)}}) \times (\underbrace{A^M_{BM} BM_f}_{\text{Downstream profits of using s}} + \underbrace{A^P_{BM,r} * \text{SEP}_{f,s,r}}_{\text{Value of s that can be privately appropriated by IP rights}}) - \underbrace{c_f e^2_{f,s}}_{\text{variable cost}}$$

Marginal cost of effort

$$c_f \sim \text{lognormal}(\mu^C_f, \sigma^2)$$

Participation condition (revealed preferences)

$$P_{f,s} = 1 \iff \mathbb{E}(\Pi_{f,s}(P_{f,s} = 1) - F_{f,s} + \epsilon^P_{f,s} \mid \mathcal{J}_f) \geq \mathbb{E}(\Pi_{f,s}(P_{f,s} = 0) + \epsilon^{NP}_{f,s} \mid \mathcal{J}_f)$$

Time To Develop

$$\mathrm{ttd}_s = \beta_0 + \beta_1 \sum_{i \in S} e_{i,s} + \frac{\beta_2}{2} \sum_{i \in S} e_{i,s}^2 + \frac{\phi}{2} \sum_{i \in S} \sum_{j \in S} e_{i,s} e_{j,s} \mathrm{simil}_{i,j} + \mu_r^t + \epsilon_s^t$$

where:

- $\mathrm{ttd}_s = \frac{\mathrm{TTD}_s}{\mathrm{Broad}_s}$
- $\phi \rightarrow$ cooperation effect parameter

function

$$\mathrm{SEP}_{f,s} = S(\mathrm{simil}_{f,s;-f,s}, X_f^S; \theta^S) = \alpha^S + \psi \mathrm{simil}_{f,s;-f,s} + \mu_f^S + \mu_r^S + \epsilon_{f,s}^S$$

where:

- $\psi \rightarrow$ competition parameter

MAIN COUNTERFACTUAL SCENARIO: FREE LICENSING

Result →**Increase in standardization time**

The delay is explained by:

- **Decrease in participation** around 7%
- **Decrease in effort** around 18%

Despite:

→**Increase in firms' similarity within standardization group** of 4.7%

In terms of dollars:

- Initial releases of 4G →1 year delay out of 4 years
- One year royalties: $ 13,500 millions
- One year Smartphones sales: $ 280,600 millions

APPENDIX

- It is a consortium of 7 SSO from all over the world (Europe, US, Japan, China, Korean and India)
- Membership to one of these 7 organizations is required. Membership is open up to a fee.

It was founded in 1998 with the original mission of developing global standards for the 3rd generations of mobile technology, using GSM technology.

The 3G was a great success and the organization continued working on developing LTE (4G)

Currently working on the development of the 5th generation.

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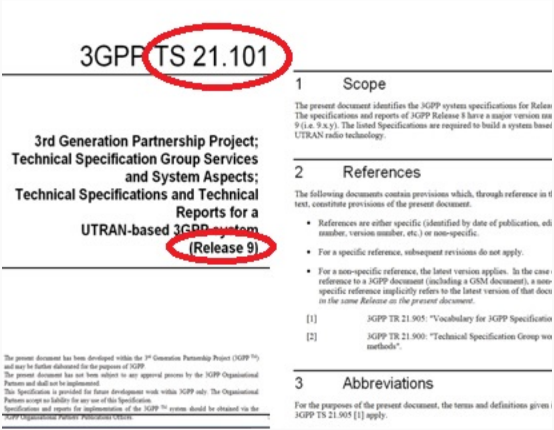
3GPP TECHNICAL SPECIFICATION (TS)- STANDARD



3GPP TS 21.101

3rd Generation Partnership Project;
Technical Specification Group Services
and System Aspects;
Technical Specifications and Technical
Reports for a
UTRAN-based 3GPP system
(Release 9)

The present document has been developed within the 3rd Generation Partnership Project (3GPP TM) and may be further elaborated for the purposes of 3GPP.
The present document has not been subject to any approval process by the 3GPP Organizational Partners and shall not be implemented.
This Specification is provided for future development work within 3GPP only. The Organizational Partners accept no liability for any use of this Specification.
Specifications and reports for implementation of the 3GPP TM system should be obtained via the 3GPP Organizational Partners' Publications Offices.

1 Scope

The present document identifies the 3GPP system specifications for Relea
The specifications and reports of 3GPP Release 8 have a major version nu
9 (i.e. 9.x.y). The listed Specifications are required to build a system based
UTRAN radio technology.

2 References

The following documents contain provisions which, through reference in t
text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edi number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that docu *in the same Release as the present document.*

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specificatio

[2] 3GPP TR 21.900: "Technical Specification Group wo methods".

3 Abbreviations

For the purposes of the present document, the terms and definitions given i
3GPP TS 21.905 [1] apply.

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First step in standardization is a technological goal

- 5G : Very low latency; Energy efficiency

After that they decide which components develop/modify to achieve these goals

- New kind of antenna; new signalling

Initial ideas might be proposed from inside and outside organization

→ **If a standard is affected by many initial ideas it is a broad standard**

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STANDARD HETEROGENEITY

Standards (St) are heterogeneous in their goals:

- Broad St: include more goals and cover more technologies
- Narrow St: fewer goals, fewer technologies

Use goals' proposal to account for this

- Goals' proposal includes potential St that might be affected
- Construct measure of broadness by counting how many proposals mentioned the St
- Account for almost 3000 proposed goals

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Table: Releases

Release	Start	Generation Year	Technology	Total number contributions
Rel-3	2000	3G	WCDMA	1851
Rel-4	2001	3G	UMTS	4328
Rel-5	2002	3G	IMS HSDPA	6786
Rel-6	2004	3G	HSUPA WLAN	6786
Rel-7	2007	3G	EDGE EVOLUTION	9901
Rel-8	2008	4G	LTE	32394
Rel-9	2009	4G	WIMAX LTE Dual Cell	24023
Rel-10	2011	4G	LTE Advanced	18330
Rel-11	2012	4G	LTE HetNet	10852

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FIRMS AND ALLIANCES BY YEAR

Table: Releases, groups and number of firms

Release	Groups	Active Firms	Average Firms in group	Average number groups by Firm
Rel-99	36	22	4.1	4.2
Rel-4	47	28	4.4	5.9
Rel-5	70	30	4.6	9.2
Rel-6	148	31	5.0	21.3
Rel-7	237	28	5.3	35.9
Rel-8	387	29	6.7	73.7
Rel-9	362	28	6.9	71.0
Rel-10	344	28	6.5	63.8
Rel-11	268	28	6	46.0

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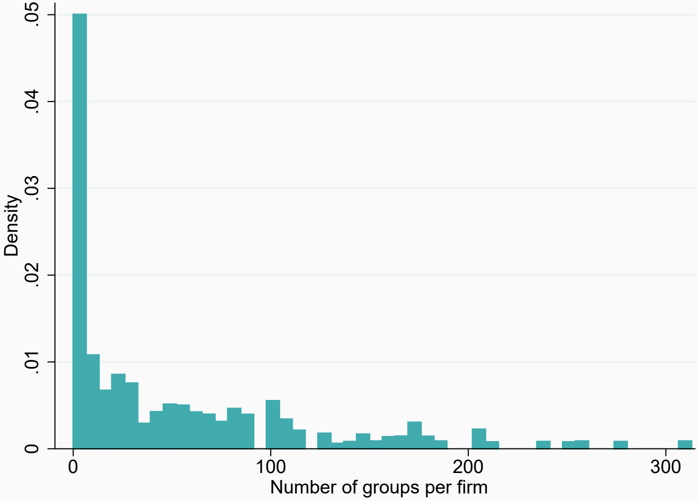
NUMBER OF GROUPS BY FIRM



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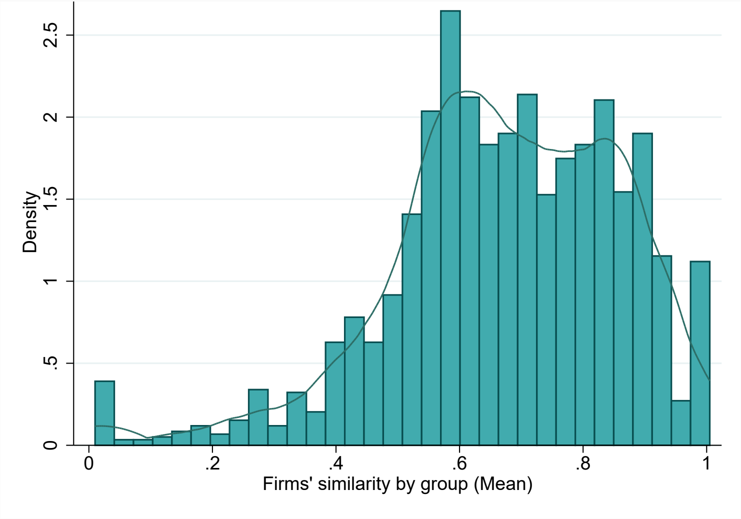
PARTICIPATION AND SIMILARITY



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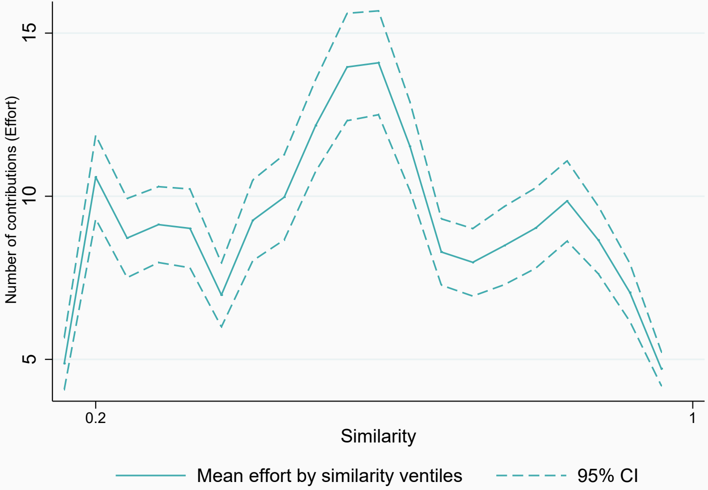

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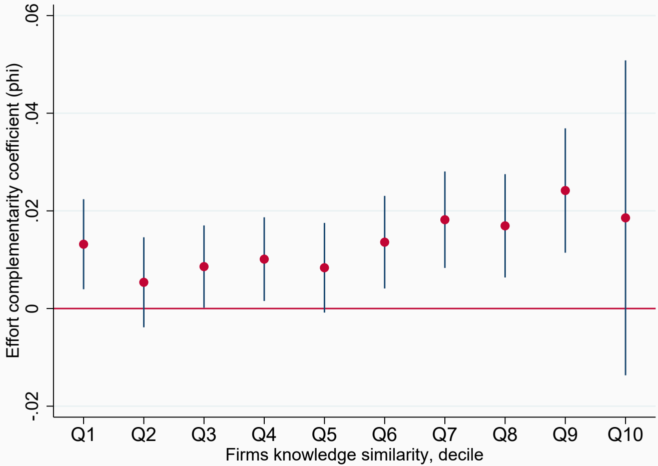
NON-LINEAR COOPERATION EFFECT



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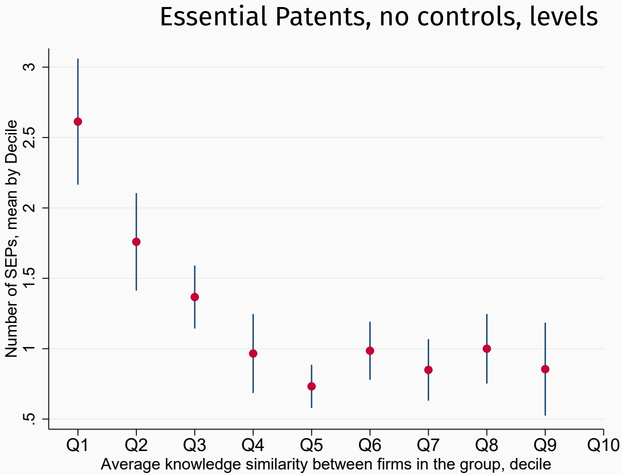
PATENT COMPETITION AND KNOWLEDGE SIMILARITY



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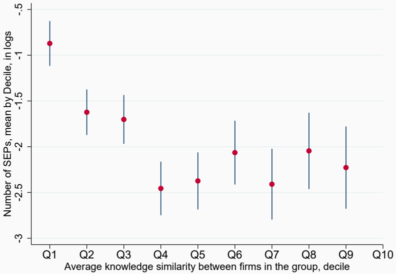
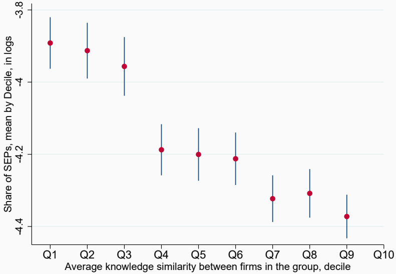
Patents (left) and Share of Patents (right), no controls





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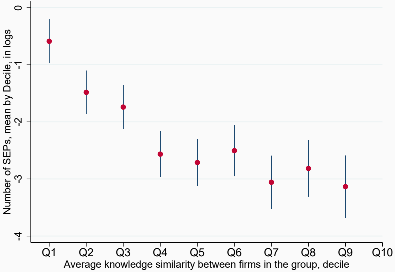
Patents (left) and Share of Patents (right), controlling by number of firms participating



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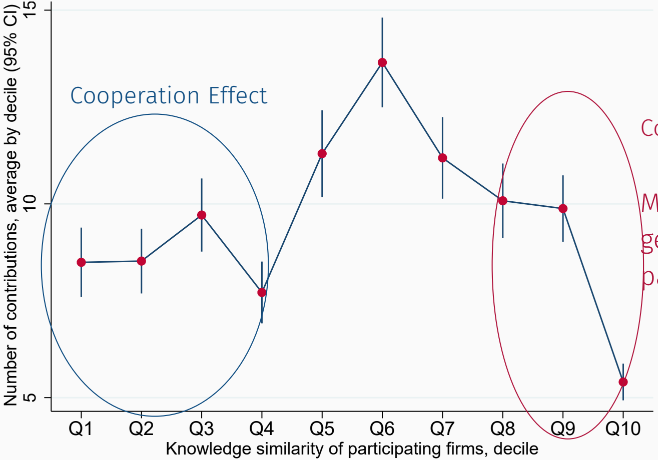
INVERTED U-SHAPED RELATIONSHIP: THE FIRM'S TRADE-OFF



Competition Effect

↓

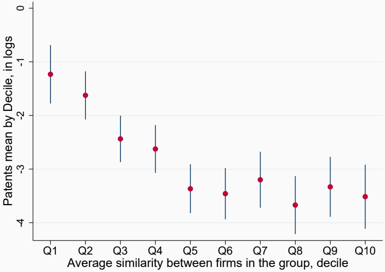
More similar firm get on average le patents

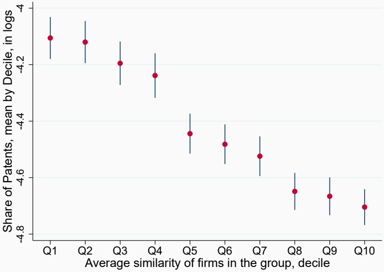
Gains from cooperation are greater the more similar the firms

Participation | Effort ventiles | Sim dist.using 15 classes

COMPETITION EFFECT: PATENTS KNOWLEDGE SIMILARITY

Do firms get smaller shares when teaming up with similar firms?





Without FE | levels | Number of participating firms | Estimation Results

Idea behind:

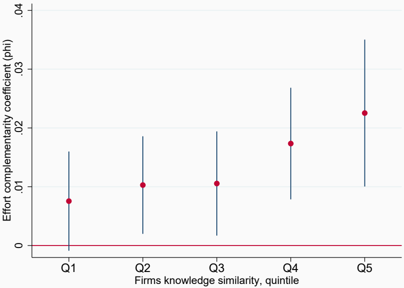
- Only one solution for each standard feature
- If several firms specialized in same area: compete for their technologies be chosen as the solutions for the standard

COOPERATION EFFECT: COMPLEMENTARITIES AND SIMILARITY

$$-TTD_{s,r} = \beta_1 \sum_{i \in S} C_{i,s,r} + \frac{1}{2}\beta_2 \sum_{i \in S} C^2_{i,s,r} + \sum_{q=1}^{q=Q} \frac{\phi_q}{2} \sum_{i \in S} \sum_{j \in S} C_{i,s,r} C_{j,s,r} D_q + \mu^t_s + \mu^t_r + \epsilon^t_{s,r}$$

Where:

- s and r: standard and release
- i denotes the firm
- C: Number of contributions
- μ^t_s and μ^t_r: standard and release FE
- ϕ_q : efforts' complementarities by decile q of similarity



Deciles | Estimation Results | Effects | Linear

PATENT COMPETITION AND KNOWLEDGE SIMILARITY

Table: Dependent variable: $\text{NumberSEP}_{f,s,r}$ Back to presentation

	(1) Baseline	(2) Controls	(3) Other firms controls	(4) Tobit
Firms' knowledge similarity	**-1.723*** (0.000)**	**-0.875* (0.093)**	**-1.286** (0.015)**	**-2.470*** (0.000)**
Firm characteristics (Portfolio, R&D)	No	Yes	Yes	Yes
Charact. other firms in the group	No	No	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Release FE	Yes	Yes	Yes	Yes
Standard FE	Yes	Yes	Yes	No
Standard- release charact. (Nfirms,Broadness, First time)	No	Yes	Yes	Yes
Average Patents per firm-st-rel	1.5	1.5	1.5	1.5
Firms' average knowledge sim	0.64	0.64	0.64	0.64
N	2059	2059	2059	2059
adj. R^2	0.137	0.286	0.300	

p-values in parentheses. Errors are robust to heteroskedasticity. All values are in logs

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

⇒ **Firms that cooperate with similar firms have less patents**

Compute complementarities: linear model of translog production function:

$$TTD_{s,r} = \beta_1 \sum_{i \in S} C_{i,s,r} + \frac{1}{2}\beta_2 \sum_{i \in S} C^2_{i,s,r} + \frac{\phi}{2} \sum_{i \in S} \sum_{j \in S} C_{i,s,r} C_{j,s,r} + \mu^t_s + \mu^t_r + \epsilon^t_{s,r}$$

Where:

- s and r: standard and release (together define the group)
- i denotes the firm
- ϕ accounts for the complementarities:

Non-linear complementarities: COOPERATION EFFECT

- Discretize similarity by quintiles (q)
- Construct dummy D_q takes value 1 if similarity belongs to quintile q
- Estimate a different ϕ for each quintile of similarity

$$TTD_{s,r} = \beta_1 \sum C_{i,s,r} + \frac{1}{2}\beta_2 \sum C^2_{i,s,r} + \sum^{q=Q} \frac{\phi_q}{2} \sum \sum C_{i,s,r} C_{j,s,r} D_q + \mu^t_s + \mu^t_r + \epsilon^t_{s,r}$$

Table: Dependent variable: $\frac{-TTD_{s,r}}{Broadness_{s,r}}$ Back to presentation

	(1) Restricted model	(2) Non-linear Effects
Contributions	0.195***	0.181***
	(0.000)	(0.000)
Squared number of contributions	-0.0107**	-0.00860**
	(0.015)	(0.032)
Joint effort	0.0114**	PLOT
	(0.011)	
Firm patent portfolio	Yes	Yes
Standard first time (dummy)	Yes	Yes
Standard FE	Yes	Yes
Release FE	Yes	Yes
N	1,899	1,899
adj. R^2	0.543	0.544

p-values in parentheses. Errors are robust to heteroskedasticity All values are in logs

* p < 0.10, ** p < 0.05, *** p < 0.01

In the sample:

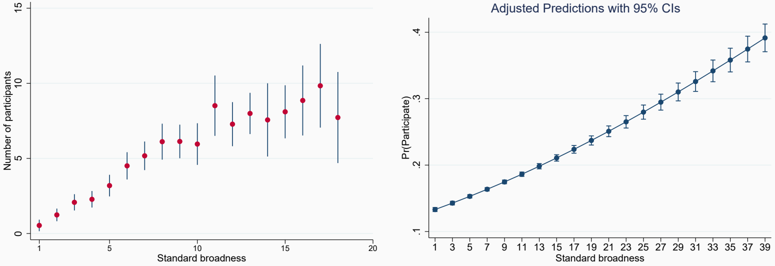
- Average TTD for a standard: 720 days
- Average number contributions per standard: 11

$\uparrow$ contributions of 10% by firm f:

- **Individual effect:** $\downarrow$ 1.8% TTD per unit of broadness (15 days)
- **Joint effect:** Cooperation effect
    - $\downarrow$ 0.23% if similarity with other firms group is on the top 20% (1.8 days)
    - $\downarrow$ 0.075% if similarity with other firms group is on the bottom 20% (0.54 days)

$\Rightarrow$ Efforts are stronger complements the more similar firms' knowledge Back to presentation

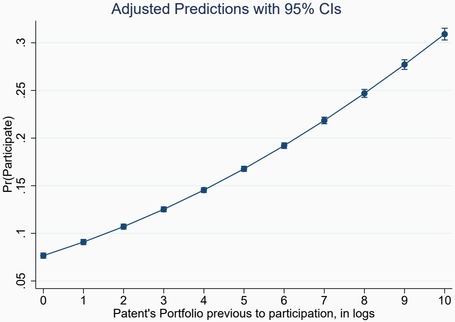
BROADER STANDARDS ATTRACT MORE FIRMS?



⇒ Probability of participation increases with standard's broadness up to 40%

→Broader standards are associated with higher number of participants

DO FIRMS WITH MORE TECHNOLOGICAL CAPACITY PARTICIPATE MORE?



⇒ Probability of participation increases with firm's portfolio up to 30%

→Firms with more technological capacity participate more

Table: Time production function and Patent equation estimates

	Individual effect of effort ($-\beta_1$)	Effort's squared term ($-\beta_2$)	Cooperation effect ($-\phi$)	Competition effect(ψ)
Estimate	0.4068 ***	-.0027**	.0068***	-5.1673***
SE	0.0510	0.0007	0.0027	0.6493
Standard charact.	Yes	Yes	Yes	Yes
Release FE	Yes	Yes	Yes	Yes
Standard FE	No	No	No	No
Firms FE	No	No	No	Yes
N	1,880	1,880	1,880	2,824
R^2	0.5650	0.5650	0.5650	0.08

Boostrapped errors with 1000 samples. Errors are robust to heteroskedasticity.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

ESTIMATION STRATEGY

3 stages estimation strategy:

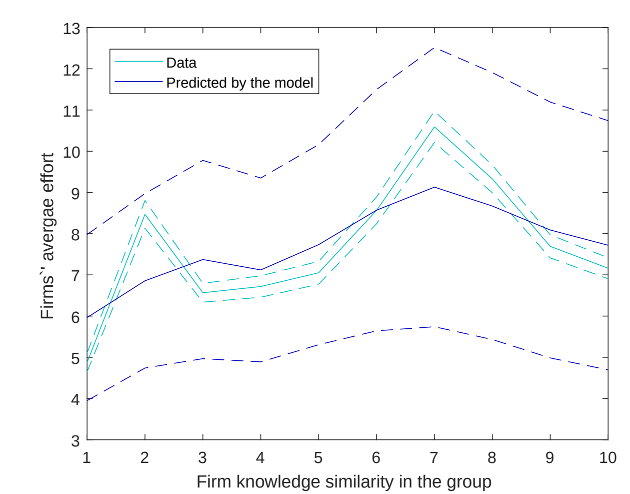
1. Estimate θ^{T} and θ^{S}
   - within group estimator
2. Estimate θ^{V} and θ^{C}
   - Use $\hat{\theta}^{\mathrm{T}}$ and $\hat{\theta}^{\mathrm{S}}$ and the equilibrium conditions of the model to simulate moments
   - I match them with the data using **Simulated Minimum Distance estimator** (Duffie and Singleton, 1993; Gouriéroux and Monfort, 1996)
3. Estimate γ
   - Use all $\hat{\theta}$ to compute $\boldsymbol{\Delta\Pi}$
   - Assume parametric distribution for the error terms
   - Use equilibrium conditions and estimate γ by maximum likelihood (logit model)

IDENTIFICATION ASSUMPTIONS (IA)

- **Time production and Patent function:** $\theta^{T}; \theta^{S}$
  - **IA:** Standard fixed effects strategy
- **Market revenues parameter:** A^{M}_{BM}
  - Exploits the variation in effort across firm's BM
  - **IA:** revenues of producing goods only vary with a firm's business model
- **Value of IP rights parameters:** $A^{P}_{r,BM}$
  - Exploits the variation of effort across releases and firm's bm
  - **IA:** variation in effort across releases and bm is due to changes in the value of SEPs.
- **Marginal cost parameters:** c_f
  - Exploits the variation of effort across firms
  - **IA:** Everything else equal, two firms exert different levels of effort because of the difference in their marginal costs.
- **Participation parameters:** c_f
  - **IA:** Parametric (EV) distribution of the error term

FIT OF THE MODEL - UNTARGETED MOMENTS

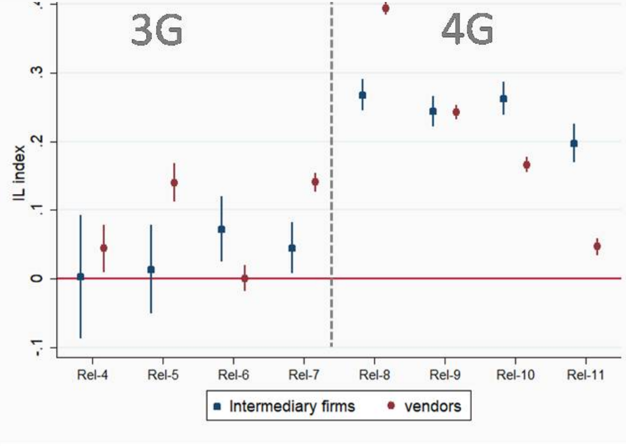
Figure: Untargeted moments - Effort per firms' similarity decile



REVENUE PARAMETERS ESTIMATES: LICENSING IMPORTANCE (LI) INDEX

For an easier interpretation of the results, I construct:

$$\text{LicensingImportance}_{bm,r} = \frac{\text{LicensingRevenues}}{\text{TotalRevenues}} = \frac{A^{P}_{r,BM} \times \text{AvgSEP}_{r,BM}}{A^{P}_{r,BM} \times \text{AvgSEP}_{r,BM} + A^{M}_{BM}}$$



Patents licensing represent a significant portion of standardization profits:

- Intermediate: average 21% →4.2% in 3G and 25% in 4G
- Vertically Integrated: average 19.5% →8.7% in 3G and 23% in 4G

⇒ Big change with 4G

Comparing with data from Financial Reports

Qualcomm: report both profits

- Model results (4G): **LI = 60% - 66%**
- Financial data: $\frac{\text{LicensingEarnings}}{\text{TotalEarnings}}$ = **63% -73%**

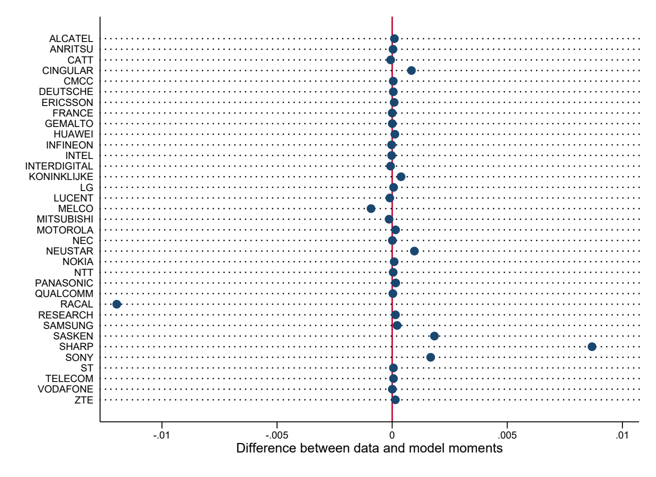
Total Royalties

- Data from Galetovic et al (2018)
- Assuming royalties 3G where same with and without 4G
- Royalties increased 20% between 3G and 4G

More in royalties calculations

FIT OF THE MODEL- TARGETED MOMENTS

Figure: Targeted moments - Firms effort



Presentation

FIT OF THE MODEL- TARGETED MOMENTS

Table: Model fit - targeted moments

	Data	Model
Upstream firms average effort	0.04512	0.04512
Vendors average effort	0.90027	0.90026
Operators average effort	0.16442	0.16442
Intermediary firms average effort	0.21695	0.21695

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Table: Average SEP value

	Rel-3	Rel-4	Rel-5	Rel-6	Rel-7	Rel-8	Rel-9	Rel-10	Rel-11
Upst.	0.55	0.61	0.71	0.78	0.80	1.17	0.91	1.07	0.75
	(0.000)	(0.001)	(0.001)	(0.003)	(0.012)	(0.014)	(0.019)	(0.018)	(0.017)
Vend.	0.51	0.55	0.49	0.00	0.33	0.77	0.36	0.20	0.08
	(0.002)	(0.001)	(0.003)	(0.005)	(0.021)	(0.028)	(0.019)	(0.034)	(0.015)
Inter.	0.55	0.55	0.43	0.60	0.56	0.48	0.55	0.55	0.55
	(0.000)	(0.003)	(0.023)	(0.019)	(0.022)	(0.007)	(0.001)	(0.000)	(0.000)

Note: Bootstrapped SE in parenthesis. Bootstrap at a Standard level, 1000 samples.

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COMPARISON WITH ROYALTY DATA

Royalty revenues (Galetovic et al 2018:)

- 3G Royalties collected 2008-2011: $ 67,760 millions
- Royalties collected 2012-2016: $ 30,617 millions
  - Problem: Includes 3G and 4G royalties

Assuming royalties payed for 3G were constant over time

- $$\underbrace{\$67,760}_{\text{Royalties collected2012-2016}} - \$\underbrace{30,617}_{\text{3G royalties}} = \$\underbrace{37,143}_{\text{4G royalties}}$$

Royalties in 4G Represent around 20% more than in 3G

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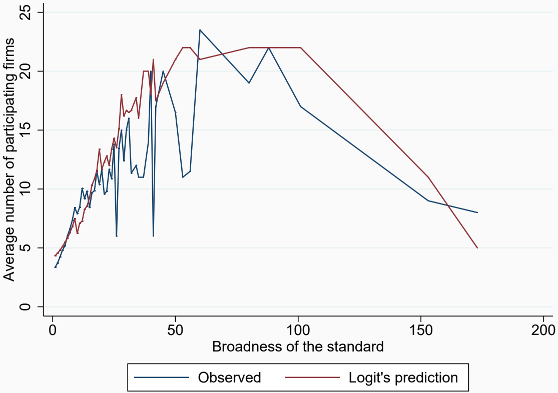
FIT OF THE PARTICIPATION MODEL



Good average fit:

- Avg. sample participation: 16.64 %
- Avg. predicted participation: 16.84%

Not so good at predicting entry identity

- Correctly predicted entries: 56.31 %
- Correctly predicted entries: 91.04%

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