The Impact of Regulation and Competition on the Migration from Old to New Communications Infrastructure: Recent Evidence from European Incumbents and Entrants

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Motivation

- **Why is traditional copper-based broadband not "enough"?**
  - new services: HD-TV, streamed video on demand, 3D applications/3D-TV, social networks, cloud computing, live video-conferences, etc
  - constantly increasing bandwidth demand (mobile apps, …)
- **Positive impact of broadband deployment on economic growth / employment**
  - e.g. Röller/Waverman (2001), OECD (2009), Czernich et al. (2011)
- **Digital Agenda Europe (DAE): all Europeans should have access to internet speeds > 30 Mbps by 2020**

  => 100% coverage with fast broadband infrastructure
- **But,**
  - high investment of fibre technology („Next generation networks" - NGN) and high risks for infrastructure operators
  - controversial discussion on the role of regulatory policies / competition

Research questions

- **What is the impact / role of**
  - ex ante broadband access regulations / service-based (s-b) competition on NGN investment?
  - infrastructure-based competition / existing broadband infrastructures on NGN investment?

- **[Investment ≠ welfare, but**
  - positive externalities not captured in the markets
  - real NGN investment data but we re-estimate models with NGN penetration data (output-related /closer to welfare)]

Empirical evidence: Related & recent literature

- **Impact of regulation & s-b competition on NGN investment/penetration**
  - Wallsten/Hausladen (2009, RNE): negative impact of unbundling on NGN lines
    - EU penetration data from an early stage (2002 to 2007)
  - Briglauer et al. (2013, IEP): s-b competition has negative impact on NGN deployment
    - NGN investment data for EU27 (2005 to 2011)
  - Briglauer (2014, JRE): broadband access regulation has negative impact on NGA penetration
    - NGN penetration data for EU27 (2004 to 2012)
  - Bacache et al. (2014, RIO): no support migration from unbundling to NGN deployment
    - NGN penetration data for European countries (2002 to 2010)

Empirical evidence:
Related & previous literature

- **Impact of regulation & s-b competition on broadband investment**
  - Cambini/Jiang (2009, TELPOL)
    - survey older literature and find *„most of the evidence shows that local loop unbundling … discourages both ILECs and CLECs from investing in networks*"
  - Grajek/Röller (2011, JLE): negative relationship between regulation and total telecommunications investment
    - very broad measure of investment

- **Summarizing,**
  - s-b competition / access regulations are negatively related to NGN investment / penetration
  - finding in line with majority of previous broadband literature
  - finding in line with the economics of NGN

Regulation: Preliminary remarks

- **Controversial questions**
  - should emerging NGN be subjected to sector-specific regulations? (regulatory holidays or potential threat of a new and more intense "bottleneck" monopoly)
  - what is the impact of current broadband access regulations on NGN investment?

- **How to measure regulation?**
  - Access charges: unbundling prices
  - Regulatory intensity: formal regulation indices such as OECD or Polynomics (Grajek/Röller, 2011)
  - Regulatory effectiveness: s-b competiton which combines regulation and market outcome (Bacache et al., 2014; Briglauer et al., 2013)
    - hinges directly on ex ante access regulations

- **Theory predicts opposing effects of regulation on investment**

Intramodal Competition

- **Replacement effect** (Arrows, 1962) wrt **1stGen infrastructure**
  - 2ndGen NGN investments cannibalize rents on conventional 1stGen broadband services
    - copper-based infrastructure („legacy")
    - coax cable-based infrastructure (CATV)

- **Switching costs wrt 1stGen services**
  - Conventional broadband services enjoy broad consumer acceptance in most EU states =>switching costs hinder migration to NGN services
  - if consumers are largely content with services offered via 1stGen broadband infrastructure or incremental benefits of new services are not transparent enough

Intermodal competition

- ***fixed-mobile substitution:*** most important source of intermodal competition
  - narrowband
  - broadband
  - [high-speed broadband (LTE)]

- **Schmutzler (2010/2011):** there is no clear prediction at the micro-level
  - investments can be increasing or decreasing functions of competition
  - inverse U-shaped relation is not necessarily more likely than U-shaped relation

Dynamics: adjustment process

- **Gradual NGN investment => partial adjustment**
  - nature of cost factors implies a gradual (partial) adjustment process towards a long-run optimal infrastructure stock
  - operators do not/cannot immediately adjust infrastructure to changing market conditions
    - partial adjustment due to technical and legal reasons (rights of way, planning, capital requirements, institutional rigidities, contractual obligations (house owners, …)
    - increasing marginal costs in NGA deployment (low cost areas ("low hanging fruits") first)
    - allows to distinguish long run and short run effects (DAE)

- **Overall, we expect gradual adjustment / only limited persistence**

DATA
EMPIRICAL SPECIFICATION
RESULTS

Data

We employ yearly data on EU27 member states from 2004/5-2012/13

Dependent variable

Real NGN investment
Log of number of NGN lines (FTTC/B/H/+ DOCSIS3.0) deployed („homes passed"): *Ln(NGN_total)*

Regulatory variables

s-b compet.: Share of regulated broadband lines (= unbundling bitstream, resale) to total retail broadband lines

Access charge: Unbundling price

Robustness var: Polynomics Broaband index

Infrastructure Competition

Intermodal competition: Share of total number of mobile lines to the total number of fixed lines

Intramodal competition: Fixed legacy / coax infrastructure of / incumbent/entrant (replacement eff.)

Control variables

Demand side: Broadband lines/penetration business applications Internet usage; GDP_pc; education; ICT affinity of pop.

Cost side: Share of urban population; household structure; labour and construction costs / wage; interest rate

Fixed effects: Control for many time-invar. cost, demand and institutional factors

Data sources: FTTH Council/IDATE, EIU, EUROSTAT/COCOM, EUROMONITOR, EU Progress Report, ITU, IMF, ECB, WB

Econometric specification:
Total NGA investment

$$\ln(NGN\_total_{jit}) =$$

$$\alpha_0^{total} + \beta_1 sbc\_bb_{i(t-1)} + \beta_2 price\_ull_{i(t-1)} + \beta_3 fms_{i(t-1)} + \beta_4 fms^2{}_{i(t-1)} +$$

$$\beta_5 cable_{i(t-1)} + \beta_6 cable^2{}_{i(t-1)} + \beta_7 legacy_{i(t-1)} + \beta_8 bb\_lines\_w_{i(t-1)} +$$

$$\beta_9 \ln(bb\_lines)_{i(t-1)} + \gamma' \mathbf{Z}_{i(t-1)} + \theta_i + \lambda_t + \alpha_1 \ln(NGN\_total_{ji(t-1)}) + \varepsilon_{jit}$$

I, *E*	*j* = *I* (incumbent), *E* (Group of entrants)
λ_t:	Time-specific fixed effects
θ_i :	Individual fixed effects
$Z_{i(t-1)}$:	Vector of demand and cost controls

Dynamic model:

$ln(NGN\_total_{(t-1)})$:	Lagged dep. var. to capture partial adjustment
α_1:	$0 < \alpha_1 < 1$
$(1 - \alpha_1)$:	"speed of adjustment" = percentage of the gap between the long-run stock of NGA infrastructure and the stock in the previous period that is closed each period

Identification/Endogeneity – GMM+LSDVC

Dynamic panel GMM estimators

- GMM-DIFF (Arellano and Bond (1991)) estimator
  - controls for the dynamic bias and provides sufficient internal instruments (T = 9) for all potentially endogenous variables

Bias-corrected fixed-effects estimator

- LSDVC estimator (Bruno (2005)) for robustness checks
  - designed for unbalanced panels and equations with lagged dependent variable when n is small (N = 27)
  - estimator, however, requires strict exogeneity of regressors, but
    - period and fixed effects (no omitted time-invariant vars)
    - large number of controls (to reduce bias due to time-variant heterogeneity)
    - explanatory variables are lagged once (predetermined vars)
    - lagged dependent controls for serial correlation (dynamically complete)

Estimation results for GMM models without controls, constant and year dummies
Dep.var.: *ln(NGN_total)* in regr. (1-5), *ln(NGN_total_w)* in regr. (6)

Regression nr.	(1)	(2)	(3)	(4)	(5)	(6)
	Full_total	Full_total _r	Final_ total	Full_ i _ull_price	Final_i_ ull_price	Final_ total_w
Dep. var.$_{ji(t-1)}$	0.3751***	0.4025***	0.4142***	0.3801***	0.2234***	0.3299***
	(8.27)	(9.52)	(9.80)	(8.20)	(4.37)	(8.14)
sbc_bb$_{i(t-1)}$	-1.5719**		-1.5665*	-3.5791***	-5.3002***	-3.0296**
	(-2.03)		(-1.94)	(-3.84)	(-3.92)	(-2.56)
price_ull$_{i(t-1)}$	0.0054	0.0014	-0.0489	-0.0235	-0.0910	-0.0056
	(0.09)	(0.02)	(-0.87)	(-0.35)	(-1.16)	(-0.08)
i_ull_price_sh$_{i(t-1)}$				0.2962**	0.6463**	
				(1.96)	(2.40)	
rdi_bb$_{i(t-3)}$		-1.9096***				
		(-2.86)				
fms$_{i(t-1)}$	-1.3152*	-1.1435	-1.4573*	-0.8434	-1.2543	-1.3004
	(-1.71)	(-1.57)	(-1.93)	(-1.09)	(-1.22)	(-1.18)
fms$^2_{i(t-1)}$	0.0666	0.0632	0.0794	0.0380	0.0844	0.0871
	(1.36)	(1.35)	(1.57)	(0.75)	(1.29)	(1.28)
cable$_{i(t-1)}$	-6.4695	-7.2950*	2.7985*	-5.9891		1.3004
	(-1.40)	(-1.67)	(1.72)	(-1.47)		(0.60)
cable$^2_{i(t-1)}$	8.5428***	8.3089***		7.5080***		
	(3.15)	(3.16)		(3.11)		
legacy$_{i(t-1)}$	-0.1399**	-0.1013*	-0.1491***	-0.1291**		-0.1590**
	(-2.26)	(-1.89)	(-3.08)	(-2.21)		(-2.12)
bb_lines_w$_{i(t-1)}$	-21.09***	-18.116***	-19.553***	-23.4043***	-29.380***	-17.5572***
	(-3.89)	(-4.27)	(-3.46)	(-3.81)	(-3.91)	(-3.34)
ln(bb_lines)$_{i(t-1)}$	1.2984***	1.2870***	0.8152**	1.1001***	0.8943*	0.7881*
	(5.60)	(5.78)	(2.40)	(5.05)	(1.77)	(1.95)
chi²	2.637e+10	7.09e+09	8495.8089	3.884e+09	1896.1466	813389.1
AR(1) test	-3.8475	-3.8177	-3.8319	-3.6708	-3.6144	-3.3066
AR(2) test	-0.9840	0.0485	-1.1719	-0.7824	-1.2130	-1.2540
Hansen test (p-value)	(1.000)	(1.000)	(1.000)	(1.000)	(1.000)	(1.000)
#Observations	428	428	428	428	428	428

***Robust t* statistics in parentheses; * *p* < 0.10, ** *p* < 0.05, *** *p* < 0.01**

Estimation results for LSDVC and GMM models without controls, constant and year dummies
Dep.var.: *ln(NGN_total)* in regr. (1-3), *ln(NGN_adop)* in regr. (4-5)

Regression nr.	(1)	(2)	(3)	(4)	(5)
	Full_LSDVC	Full_i_LSDVC	Final_LSDVC	Full_adop_GMM	Full_adop_r_GMM
Dep. var.$_{ji(t-1)}$	0.5593***	0.5513***	0.5752***	0.3378***	0.3632***
	(13.03)	(12.86)	(14.12)	(4.33)	(3.94)
Dep. var.$_{ji(t-2)}$				-0.0239	-0.0543
				(-0.64)	(-1.44)
sbc_bb$_{i(t-1)}$	-2.3861*	-3.8625**	-2.3495*	-2.3110**	-2.4204**
	(-1.93)	(-2.51)	(-1.88)	(-2.27)	(-2.06)
price_ull$_{i(t-1)}$	-0.0182	-0.0502	-0.0207		0.0153
	(-0.40)	(-1.06)	(-0.48)		(0.34)
i_ull_price_sh$_{i(t-1)}$		0.3112*			
		(1.77)			
rdi_bb$_{i(t-3)}$					-0.0007
					(-0.00)
fms$_{i(t-1)}$	-0.4770	-0.3395	-0.5590	-1.4494***	-0.8625
	(-0.64)	(-0.44)	(-0.78)	(-2.66)	(-1.38)
fms²$_{i(t-1)}$	0.0048	0.0006	0.0136	0.0629**	0.0258
	(0.09)	(0.01)	(0.26)	(2.10)	(0.71)
cable$_{i(t-1)}$	-6.3010**	-4.9659	-6.5407**	1.9997	-2.4592
	(-2.06)	(-1.59)	(-2.46)	(1.06)	(-0.60)
cable²$_{i(t-1)}$	8.6867***	7.5363***	9.3140***		4.9203*
	(3.44)	(2.95)	(3.92)		(1.65)
legacy$_{i(t-1)}$	-0.1629***	-0.1523***	-0.1590***	-0.0694	-0.0444
	(-2.83)	(-2.60)	(-2.93)	(-1.42)	(-0.83)
bb_lines_w$_{i(t-1)}$	-14.1515**	-15.0065**	-11.5538**	-10.3747*	-14.6078***
	(-2.45)	(-2.56)	(-2.46)	(-1.94)	(-2.65)
ln(bb_lines)$_{i(t-1)}$	1.6169***	1.1272*	1.5364***	0.4257	0.7765*
	(2.96)	(1.92)	(4.55)	(1.14)	(1.67)
chi²				799.5048	729.7756
AR(1) test				-1.6815	-1.8673
AR(2) test				-1.4311	-1.2170
Hansen test (p-value)				(1.000)	(1.000)
#Observations	480	480	480	422	422

***Robust t* statistics in parentheses; * *p* < 0.10, ** *p* < 0.05, *** *p* < 0.01**

Summary and conclusions

- **s-b competition** variable is significantly **negative throughout**
  - => more intense s-b competition has substantially negative impact on NGA investment
  - confirmed by unbundling access charge and robustness variable
  - => deregulatory approaches towards 1st and 2nd Gen infrastructure appear to stimulate NGA investment
- wrt the **replacement effect** we find strong evidence that existing **legacy infrastructure** of incumbents exerts a **negative effect on NGA investment**
- **Fixed-mobile substitution** and **switching costs** further **hinder migration** to NGA services
- There is clear evidence for an **autonomous growth process** towards a **long-run equilibrium** infrastructure stock

THANK YOU FOR YOUR ATTENTION!

APPENDIX

Relevant FTTx deplyoment scenarios

- Main broadband technology today in Europe: xDSL via copper wire (and coax) lines with bandwidths from 8 to 25 Mbit/s
- Next Generation Access Networks:
  - VDSL/FTTC: „fibre to the curb" – copper wires from the curb to the household: bandwidth up to 50 Mbit/s
  - FTTB: „fibre to the building" – only in-house-wiring by copper wires: speeds up to 100 Mbit/s
  - FTTH: „fibre to the home" – nearly unlimited bandwidth, today up to 1 Gbit/s

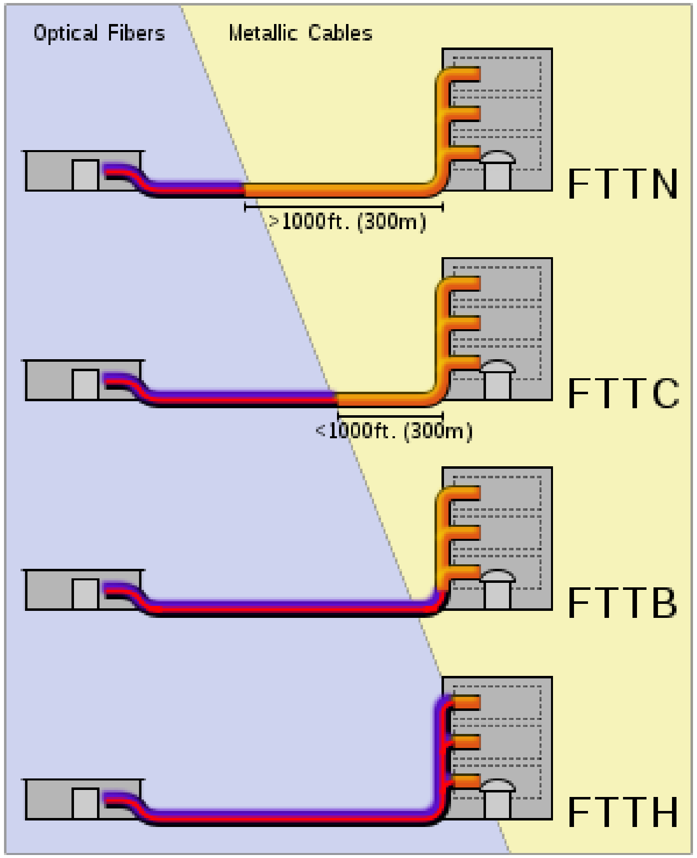

Figure 1. Different NGA scenarios

Modeling the invest dynamics – partial adjustment

- Partial adjustment = lagged dep + adjustment equation (ADL 1,0)
- long-run optimal infrastructure (equilibrium) stock is given by:

$$Fttx_{it}^{*} = X_{it}\beta' + \theta_i + \varepsilon_{it}$$

- adjustment process towards this stock is:

$$Fttx_{it} - Fttx_{i,t-1} = \alpha'(Fttx^{*}_{it} - Fttx_{i,t-1}) + \mu_{it}$$

- substituting yields estimating equation (short run relationship):

$$Fttx_{it} = \alpha Fttx_{i,t-1} + X_{it}\beta + \alpha'\theta_i + u_{it}$$

$$\alpha = 1 - \alpha'; \quad \beta = \alpha'\beta'; \quad u = \alpha'\varepsilon; \quad 0 < \alpha < 1$$

Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
NGN_total	270	2072843	4706856	1	3.75e+07
ln(NGN_total)	270	10.63032	5.608084	0	17.43946
NGN_total_w	270	.1315215	.1648317	1.21e-08	.7351943
ln(NGN_total_w)	247	-5.789674	5.302496	-18.22869	-.4238326
NGN_adop	270	316400.6	668623.5	1	5144100
ln(NGN_adop)	270	9.32781	4.685692	0	15.45336
bb_lines	267	3723236	5769546	13738	2.80e+07
bb_lines_w	267	.1904645	.0973223	.0023487	.4044925
cable	254	.2157732	.1649066	0	1
sbc_bb	239	.194315	.197063	0	.9705678
price_ull	239	11.72037	4.383839	5.34	42
ms_ull	239	.1014437	.1406279	0	.6772212
i_ull_price_sh	254	1.112611	1.496397	0	7.07019
legacy	243	40.88424	12.98943	15.98503	66.38055
fms	269	3.375306	1.669958	1.2819	10.9396
rdi_bb	243	.6995885	.322663	0	1
bus_use_lan	270	.7118741	.1566787	.231	.996
int_user	270	.6368203	.1846024	.1500006	.951
edu	243	68.96461	13.13021	26	86.6
gdp_pc_ppp	243	29783.69	13548.51	8730.803	89055.8
mdwell_perm	243	161.4842	134.003	12.54	913.39
wage	269	11.06208	7.875111	.8	38.7
labcost_con	243	95.7	14.85244	39.8	134.7
urban	270	72.43043	11.89043	49.4118	97.4945