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, gaming, social networks, cloud computing, live video-conferences, etc
  - constantly increasing bandwidth demand

- **Positive impact of broadband deployment on economic growth / employment**
  - e.g. Röller/Waverman (2001), OECD (2009), Czernich et al. (2011)

- **But,**
  - high investment to upgrade copper lines to fibre technology („Next generation access" - NGA) and high risks for investing 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?
  - infrastructure-based competition / existing broadband infrastructures?
  - dynamics of the adjustment process?

- **Wrt the firm level we ask if there are**
  - strategic interactions bw incumbent and ∑entrants?
  - differential effects on (regulated) incumbent and (non-regulated) ∑entrants investment?

Empirical evidence:
Related & recent literature

- **Impact of regulation & s-b competition on NGA investment/penetration**
  - Wallsten/Hausladen (2009, RNE): negative impact of unbundling on NGA lines
    - EU penetration data from an early stage (2002 to 2007)
  - Briglauer et al. (2013, IEP): s-b competition has negative impact on NGA deployment
    - NGA investment data for EU27 (2005 to 2011)
  - Briglauer (2014, JRE): broadband access regulation has negative impact on NGA penetration
    - NGA penetration data for EU27 (2004 to 2012)
  - Bacache et al. (2014, RIO): no support for LoI wrt last rung, i.e. from unbundling to NGA deployment
    - NGA 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 NGA investment / penetration
  - finding in line with majority of previous broadband literature
  - there are no firm-level studies using NGA specific invesment data so far …

HYPOTHESES

Regulation: Preliminary remarks

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

Regulation: testable hypotheses

- **Access charge regulation on old network**
  - wrt to investment incentives of the entrants we expect a positive relation with the height of relevant access charges (ULL)
  - wrt to relation between investment incentives of incumbents and the height of relevant access charges (ULL), the overall impact is indeterminate due to opposing effects

- **Service-based (s-b) competition**
  - we expect that the higher the extent of s-b competition is, the lower NGA investment of entrants; this gets reinforced to the extent that s-b competition also captures effects of access charges
  - to the extent that s-b competition captures effects of access charge regulation the overall effect on NGA investment of incumbents is indeterminate

Intramodal Competition: testable hypotheses

- **Replacement effect (Arrows, 1962) wrt 1stGen infrastructure**
  - 2ndGen NGA-investments cannibalize quasi-monopolistic rents on conventional 1stGen broadband services
    - copper-based infrastructure
    - coax cable-based infrastructure
- **Switching costs wrt 1stGen services**
  - Conventional broadband services enjoy broad consumer acceptance in most EU states, which establishes non-negligible switching costs and hinders migration to NGA services
- **Strategic interactions wrt 2ndGen infrastructure**
  - Incuments´ and entrants´ NGA investments as
    - strategic substitutes ??
    - strategic complements ??

Intermodal competition: testable hypotheses

- **Aghion et al. (2005): „inverted U-shaped“ relation**
  - At moderate levels of competition operators try to „escape competition“ to capture monopolistic rents by an innovation
  - At high levels of competition operators are not able to generate sufficient profits for investment/innovation (“Schumpeterian effect“)
  - NGA networks as “last chance” for traditional fixed-line operators to escape successfully broadband competition stemming from mobile broadband networks

EMPIRICAL SPECIFICATION RESULTS

Econometric specification:
Separate equations for NGA investment

$$\ln(Fttx\_inc_{it}) = \alpha_0^I + \beta_1^I reg\_bb_{i(t-1)} + \beta_2^I price\_ull_{i(t-1)} + \beta_3^I fms_{i(t-1)} + \beta_4^I fms^2{}_{i(t-1)}$$
$$+ \beta_5^I fixed\_legacy_{i(t-1)} + \gamma'^I \mathbf{Z}_{i(t-1)} + \theta_i^I + \lambda_t^I + \alpha_1^I \ln(Fttx\_inc_{i(t-1)}) + \alpha_2^I \ln(\sum Fttx\_ent_{it}) + \varepsilon_{it}^I$$

$$\ln(\sum Fttx\_ent_{it}) = \alpha_0^E + \beta_1^E reg\_bb_{i(t-1)} + \beta_2^E price\_ull_{i(t-1)} + \beta_3^E fms_{i(t-1)} + \beta_4^E fms^2{}_{i(t-1)} +$$
$$+ \beta_5^E cable_{i(t-1)} + \gamma'^E \mathbf{Z}_{i(t-1)} + \theta_i^E + \lambda_t^E + \alpha_1^E \ln(\sum Fttx\_ent_{i(t-1)}) + \alpha_2^E \ln(Fttx\_inc_{it}) + \varepsilon_{it}^E$$

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

Dynamic model:

$ln(Fttx\_{i(t-1)})$:	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

Econometric specification:
Aggregate analysis

$$\ln(Fttx\_total_{it\boldsymbol{j}}) = \alpha_0^{total} + \beta_1^{total} reg\_bb_{i(t-1)} + \beta_2^{total} fms_{i(t-1)} + \beta_3^{total} fms^2{}_{i(t-1)} + \beta_4^{total} cable_{i(t-1)} + \beta_5^{total} cable^2{}_{i(t-1)}$$
$$+ \beta_6^{total} bb\_lines\_hh_{i(t-1)} + \beta_7^{total} \ln(bb\_lines)_{i(t-1)} + \gamma'^{total} \mathbf{Z}_{i(t-1)} + \theta_i^{total} + \lambda_t^{total} + \alpha_1^{total} \ln(Fttx\_total_{i(t-1)\boldsymbol{j}}) + \varepsilon_{it}^{total}$$

$$\ln(Fttx\_sub_{it\boldsymbol{j}}) = \alpha_0^{sub} + \beta_1^{sub} reg\_bb_{i(t-1)} + \beta_2^{sub} fms_{i(t-1)} + \beta_3^{sub} fms^2{}_{i(t-1)} + \beta_4^{sub} cable_{i(t-1)} + \beta_5^{sub} cable^2{}_{i(t-1)}$$
$$+ \beta_6^{sub} bb\_lines\_hh_{i(t-1)} + \beta_7^{sub} \ln(bb\_lines)_{i(t-1)} + \gamma'^{sub} \mathbf{Z}_{i(t-1)} + \theta_i^{sub} + \lambda_t^{sub} + \alpha_1^{sub} \ln(Fttx\_sub_{i(t-1)\boldsymbol{j}}) + \varepsilon_{it}^{sub}$$

- j = *I* (incumbent), *E* (entrant)
- Increasing number of obs (~2*210 obs for dep.var)
- Estimating aggregate impact on total NGA investment (*Fttx_total*)
- Estimating aggregate impact on NGA adoption (*Fttx_sub*) => better welfare approximation?

Identification/Endogeneity - GMM

- **Dynamic panel GMM estimators**
  - We employ GMM-DIFF (Arellano and Bond (1991)) one-step estimates which control for the dynamic bias and provide sufficient internal instruments (*T*=9) for all potentially endogenous variables
    - in GMM-DIFF all main variables are defined as endogenous
    - no GMM-Sys: to avoid too many instruments /more efficient for models with high persistency

Identification/Endogeneity - LSDVC

- For robustness checks we also employ a bias-corrected LSDVC estimator (Bruno (2005)) designed for unbalanced panels and equations with lagged dependent variable when *n* is small (*n*=27)
  - estimator, however, requires strict exogeneity of regressors
  - we include period and fixed effects (no omitted time-invariant vars)
  - we consider 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 the incumbent (Dep.var.: *log_inc_fttx*) without controls and year dummies

	(1) Full_inc_ GMM	(2) Final_inc_ GMM	(3) Full_inc_r_ GMM	(4) Full_inc_ LSDVC	(5) Final_inc_ LSDVC
L.log_inc_fttx	0.4120***	0.4271***	0.4155***	0.5228***	0.5382***
	(6.47)	(6.69)	(7.09)	(6.91)	(7.14)
l_ms_reg_bb	1.4913	1.2374		1.5621	0.7082
	(0.80)	(0.69)		(0.67)	(0.39)
l_llu_price	0.0491	0.0459	0.0007	0.0229	0.0193
	(0.47)	(0.42)	(0.01)	(0.28)	(0.23)
l_rdi_bb			1.0252		
			(0.62)		
log_ent_fttx	0.3694***	0.3229***	0.3297***	0.2573***	0.2552***
	(4.12)	(3.23)	(3.64)	(2.75)	(2.81)
l_fms	-2.7695	-3.1192**	-2.8750*	-2.4182	-2.5569
	(-1.61)	(-2.11)	(-1.68)	(-1.42)	(-1.61)
l_fms2	0.2018	0.2252*	0.2029	0.1847	0.1936*
	(1.40)	(1.74)	(1.44)	(1.49)	(1.66)
l_fixed_legacy	-0.2577**	-0.2395***	-0.2904***	-0.2763**	-0.2686***
chi2	81916.9979	8142.5042	18462.5986		
arm1	-3.4681	-3.5246	-3.5677		
arm2	0.4510	0.8119	0.2709		
Sargan-test (p-value)	(1.000)	(1.000)	(1.000)		
#Observations	212	212	212	239	239

Heteroscedasticity-robust t **statistics in parentheses; * *p* < 0.10, ** *p* < 0.05, *** *p* < 0.01**

Estimation results for the entrants (Dep.var.: *log_ent_fttx*) without controls and year dummies

	(1) Full_ent_ GMM	(2) Full_ent_r1_ GMM	(3) Full_ent_r2_ GMM	(4) Final_ent_ GMM	(5) Full_ent_ LSDVC	(6) Full_ent_r_ LSDVC
L.log_ent_fttx	0.3652***	0.4472***	0.4695***	0.3972***	0.5523***	0.6115***
	(5.12)	(6.52)	(6.97)	(6.20)	(7.49)	(8.29)
l_ms_reg_bb	-4.2243**			-3.5357**	-2.7417*	
	(-2.21)			(-2.03)	(-1.68)	
l_llu_price	-0.1021	-0.1019		-0.0890	-0.0645	
	(-1.25)	(-1.20)		(-1.01)	(-1.33)	
l_rdi_bb		-1.8381**	-2.1372***			-2.0125**
		(-2.15)	(-2.62)			(-2.04)
log_inc_fttx	0.1338**	0.1163*	0.0978*	0.1082	0.0791*	0.0694
	(2.14)	(1.91)	(1.69)	(1.60)	(1.68)	(1.48)
l_fms	1.2636	0.5485	0.1324	0.3628	0.1180	0.3607
	(1.01)	(0.49)	(0.13)	(0.30)	(0.15)	(0.42)
l_fms2	-0.0923	-0.0408	-0.0103	-0.0270	-0.0232	-0.0366
	(-0.96)	(-0.47)	(-0.13)	(-0.29)	(-0.36)	(-0.53)
l_cable_entr_sh	2.8151	2.5039	1.4005	3.8511	4.1350**	3.2967*
	(1.17)	(0.98)	(0.45)	(1.30)	(2.37)	(1.92)
arm1	-3.1114	-3.1733	-3.2723	-3.0736		
arm2	-0.5158	-0.0135	0.2417	-0.3736		
Sargan-test (p-value)	(1.000)	(1.000)	(1.000)	(1.000)		
#Observations	212	212	212	212	239	239

Heteroscedasticity-robust t **statistics in parentheses; *** ***p*** **< 0.10, **** ***p*** **< 0.05, ***** ***p*** **< 0.01**

Estimation results for the aggregate GMM models without controls and year dummies Dep.var.: *log_total_fttx* (1-3) *log_total_fttx_w* (4) *log_fttx_sub* (5-6)

	(1)	(2)	(3)	(4)	(5)	(6)
	Full_total	Full_total_r	Final_total	Final_total_w	Full_sub_B	Full_sub_r
Lagged dependent var.	0.3751***	0.4025***	0.4142***	0.3299***	0.3378***	0.3632***
	(8.27)	(9.52)	(9.80)	(8.14)	(4.33)	(3.94)
l_ms_reg_bb	-1.5719**		-1.5665*	-3.0296**	-2.3110**	-2.4204**
	(-2.03)		(-1.94)	(-2.56)	(-2.27)	(-2.06)
l_llu_price	0.0054	0.0014	-0.0489	-0.0056		0.0153
	(0.09)	(0.02)	(-0.87)	(-0.08)		(0.34)
l_rdi_bb		-1.9096***				-0.0007
		(-2.86)				(-0.00)
l_fms	-1.3152*	-1.1435	-1.4573*	-1.3004	-1.4494***	-0.8625
	(-1.71)	(-1.57)	(-1.93)	(-1.18)	(-2.66)	(-1.38)
l_fms2	0.0666	0.0632	0.0794	0.0871	0.0629**	0.0258
	(1.36)	(1.35)	(1.57)	(1.28)	(2.10)	(0.71)
l_cable_entr_sh	-6.4694	-7.2950*	2.7985*	1.3004	1.9997	-2.4592
	(-1.40)	(-1.67)	(1.72)	(0.60)	(1.06)	(-0.60)
l_cable_entr_sh_2	8.5428***	8.3089***				4.9203*
	(3.15)	(3.16)				(1.65)
l_fixed_legacy	-0.1399**	-0.1013*	-0.1491***	-0.1590**	-0.0694	-0.0444
	(-2.26)	(-1.89)	(-3.08)	(-2.12)	(-1.42)	(-0.83)
lw_bb_lines	-21.0973***	-18.1162***	-19.5532***	-17.5572***	-10.3747*	-14.6078***
	(-3.89)	(-4.27)	(-3.46)	(-3.34)	(-1.94)	(-2.65)
log_l_bb_lines	1.2984***	1.2870***	0.8152**	0.7881*	0.4257	0.7765*
	(5.60)	(5.78)	(2.40)	(1.95)	(1.14)	(1.67)
chi2	1.1170e+11	10340942.657	8495.6987	1896.1474	799.5056	729.7733
arm1	-3.8475	-3.8177	-3.8319	-3.6144	-1.6815	-1.8673
arm2	-0.9840	0.0485	-1.1719	-1.2130	-1.4311	-1.2170
Sargan-test (p-value)	(1.000)	(1.000)	(1.000)	(1.000)	(1.000)	(1.000)
#Observations	428	428	428	428	422	422

***Heteroscedasticity-robust t* statistics in parentheses; * *p* < 0.10, ** *p* < 0.05, *** *p* < 0.01**

Prelimnary results and conclusions

- **s-b competition** variable is significantly **negative throughout** all estimations **for entrants** (insignificant for incumbents) and **in total**
  - → more intense s-b competition has substantially negative impact on NGA investment of entrants and in total
  - Picks-up effect of *llu_price* and *rdi_bb*
- wrt the **replacement effect** we find strong evidence that existing **legacy infrastructure** of incumbents exerts a **negative effect on NGA investment**
- there is clear evidence that incumbent´s and entrants´ NGA investments are **strategic complements**
- **significant lagged dependent** variable implies
  - substantial **adjustment costs** to reach long-run desired infrastructure stock
  - **switching costs** on consumers´side underlying the diffusion process
  - on average around 50% (individual est.) / 60% (aggregate est.) of the gap to the desired long-run target are closed each period

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

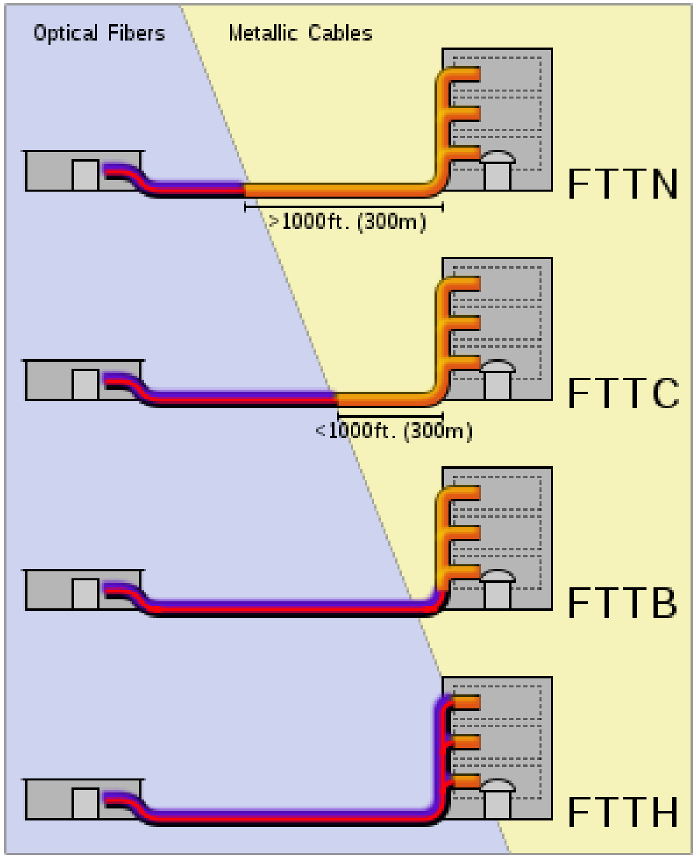

Figure 1. Different NGA scenarios

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):

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

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