An Empirical Analysis of Fixed and Mobile Broadband Diffusion

> Sangwon Lee & Mircea I. Marcu University of Florida

> > 15th ANACOM Seminar Lisbon, Portugal 26 May 2008

Outline

- 1. Introduction
 - Motivation
 - Main Results
- 2. Fixed Broadband
 - Logistic Model of Diffusion
 - Empirical Specification and Results
- 3. Mobile Broadband
- 4. Discussion and Further Research

1. Introduction

- Importance of broadband diffusion
 - General consensus: broadband diffusion encourages innovation, contributes to productivity and growth, and attracts foreign investment
 - Magnitude of effects is difficult to gauge and still a matter of research
 - Broader impact on society and democracy

Introduction

- Broadband definition
 - Different definitions (FCC, ITU, OECD)
 - Differences between narrowband and broadband:
 - Higher speed data transfer
 - "Always on" connection
 - Low latency (ability to send and receive data packets with little or no noticeable delay)
 - Variety of applications (e.g. VOIP, online games, MP3 music download, IPTV, mobile TV)

Introduction

- Fixed Broadband
 - We use OECD data to study fixed BB
 - The OECD defines broadband as a network offering a speed ≥ 256 kbit/s in one or both directions
 - Fixed broadband technologies: DSL, cable modem, FTTH, BPL
- Mobile Broadband
 - We use ITU data to study mobile broadband
 - Mobile broadband technologies (3G Wireless): W-CDMA, CDMA 2000

Fixed Broadband Deployment OECD Countries, Dec 2006



Global Mobile Broadband Deployment

- Global mobile broadband penetration rate: 0.93 per 100 inhabitants (ITU, 2005).
- 2.8% of total mobile subscribers were mobile broadband users (ITU, 2006).
- Top Mobile Broadband penetration countries in 2004:

0	1. Korea	57.3%
0	2. Israel	27.8%
0	3. Canada	23.31%
0	4. Japan	20.1%
0	5. New Zealand	18.7%
0	6. USA	16.7%

Purpose of the Study & Research Questions

- Purpose: determine what factors influence the diffusion of fixed and mobile broadband
 - Economic and demographic variables?
 - Income, population density
 - ICT (Information and Communication Technology) variables?
 - PC penetration, Internet content
 - Policy variables?
 - Unbundling policy, platform competition (fixed broadband)
 - Standardization policy (mobile broadband)

Policy Variables

- Unbundling policy (LLU)
 - Some argue it is necessary to create competition
 - Bottleneck local loop
 - Entrants need to overcome network effects, economies of scale
 - "Stepping stone theory"
 - Unbundling reduces the incumbent's investment incentives and may reduce facilities based entry
 - Does unbundling speed up diffusion by promoting entry and competition?

Policy Variables

- Single vs. multiple standard(s) for 3G mobile
 - Tradeoff:

Economies of scale & network effects

VS.

differentiated products, reduced prices & increased quality

 Fixed broadband: similar tradeoff for inter-platform competition (cable modem vs. DSL)

Main Findings of Previous Studies

- Effect on fixed broadband diffusion:
 - Population density (+)
 - Depending on the study: income, teledensity (+)
 - Most studies: Inter-platform competition speeds up fixed broadband diffusion
 - Unbundling: the most controversial, mixed results

Limitations of Previous Studies

- Less data, so only linear models
 - Exception Denni & Gruber (2005)
- To our knowledge:
 - No study of mobile broadband yet
 - No study of relation between fixed and mobile broadband
 - Complements can increase BB penetration
 - Substitutes ambiguous effect on BB penetration

DSL Penetration - Portugal



13

Cable Modem Penetration - Portugal



14

Our Main Findings

- Fixed BB:
 - local loop unbundling, PC penetration, population density, and Internet content are associated with faster fixed broadband diffusion.
 - Platform competition is a significant driver of cable modem broadband, but not DSL diffusion.
- Mobile BB:
 - Multiple standards, higher PC penetration, and lower previous generation (1G & 2G) mobile penetration are associated with higher mobile broadband penetration.
 - Fixed broadband is neither a complement nor a substitute for mobile broadband yet.

2. Fixed Broadband Logistic Model of Diffusion

$$y_{it} = \frac{y_{it}^{*}}{1 + \exp(-a_{it} - b_{it} t)}$$

y_{it} is the number of subscribers per capita

- y_{it}^{*} is the market potential (ceiling)
- a_{it} determines initial penetration
- b_{it} captures speed of diffusion and varies with country characteristics X_{it} and policy decisions D_{it}^{j}

$$b_{it} = \beta_i^0 + \sum_{j=1}^J \beta^j D_{it}^j + X_{it} \beta$$

Fixed Broadband Logistic Model of Diffusion

- Why logistic? Appealing because:
 - supported by previous studies of telecommunications diffusion
 - fits data well (recall S shaped graph)
 - can account for:
 - > network externalities
 - prevailing stages of adoption

 Importance of Prevailing Stages of Adoption: Diffusion Process y=1/[1+exp(0.8-(0.9+b*D_t)t)] Linear Instead of Logistic Regression

No unbundling, $D_t = 0$ Unbundling from year 4, $D_4 = 1$



Linear regression including a dummy for unbundling would find a positive effect even if unbundling had no effect (b=0).

Fixed Broadband Empirical Specification 30 OECD countries, 1999-2005

Variables	Measurement	Source
 Fixed broadband penetration 	 Fixed broadband subscribers per 100 inhabitants 	OECD
 Cable modem penetration 	 Cable modem subscribers per 100 inhabitants 	OECD
 DSL penetration 	 DSL subscribers per 100 inhabitants 	OECD
• Income	Real GDP per capita	ITU
 PC Penetration 	 Estimated PCs per 100 inhabitants 	ITU
• LLU	 Dummy (1 for unbundling of local loop) 	OECD
 Population density 	 Inhabitants per km² 	ITU
 Urban population 	 Percentage of urban population 	Euromonitor
 Internet content 	 Internet hosts per 10000 inhabitants 	ITU
 Platform Competition 	• Dummy (1 if both DSL and cable modem)	OECD
 Education 	UNDP Education Index	UNDP ¹⁹

Fixed Broadband Diffusion Logistic Regression Results (NLLS)

	Fixed BB Pe	enetration	Cable Penetration		DSL Penetration	
Variable	Coefficient	t	Coefficient	t	Coefficient	t
Ceiling	22.25231	11.8***	9.918326	9.00***	13.70388	6.35***
Initial level parameter	-3.54919	-7.09***	-2.02251	-4.73***	-4.61221	-5.8***
Natural speed	-1.92986	-1.49	-4.03646	-2.66**	-1.50823	-0.88
Income	-2.22E-06	-0.5	-9.43E-06	-2.22**	2.19E-06	0.39
PC Penetration	0.517512	2.03*	0.861724	3.06***	0.367589	1.06
LLU	0.189548	2.86***	0.28127	1.82*	0.1359	2.48**
Population density	0.000933	2.06**	0.000966	2.21**	0.000886	1.74*
Urban population	0.000411	0.13	-0.0008	-0.23	0.00175	0.39
Internet hosts	8.12E-05	2.2**	5.13E-05	1.70*	9.76E-05	1.56
Platform competition	0.040566	0.64	1.699292	3.93***	-0.02958	-0.29
Education index	1.926459	1.33	1.966175	1.31	1.706803	0.86
Adjusted R-square	0.8871		0.7473		0.8483	20
Number of obs.	205		205		205	

Fixed Broadband Results and Analysis

- Unbundling, higher population density, PC penetration, and Internet content are associated with faster fixed broadband diffusion.
- Platform competition is a significant driver of cable modem broadband, but not DSL diffusion.
 - Perhaps cable was successful in stealing business from DSL

Fixed Broadband Results (continued)

- Income is insignificant, except in cable equation (-!)
 Income and PC penetration are highly correlated
- Urban population is insignificant
 - Theoretically both population density and urban population are drivers of cost. There is less variation in urban population among OECD countries, and more variation in population density.
- Education is insignificant
 - there is little variation in education levels among OECD countries

Fixed Broadband Results (continued)

- Additional variable:
 - Government ownership share in incumbent operator (may lead to regulatory capture): no significant effect
- Nonlinear model, so marginal effects are not equal to the coefficients.

Fixed Broadband - Potential Endogeneity Robustness Checks

- Potential endogeneity
 - Policy decisions like LLU may be endogenous (self selection)
 - ➤ EU mandated LLU: estimate the model only for EU countries → same qualitative results, the positive effect of LLU on the speed of diffusion persists
 - PC penetration and Internet content may be endogenous:
 - Results do not change when using lags

3. Mobile Broadband

Sample:

- 53 OECD and non-OECD countries
- cross-section for the year 2004

Linear regression:

3G Mobile Penetration = $\beta_0 + \beta_1$ (Dummy-Standardization Policy) + β_2 (PC Penetration) + β_3 (Mobile Price) + β_4 (Population Density) + β_5 (Education) + β_6 (Teledensity) + β_7 (Income) + β_8 (Fixed Broadband Price) + β_9 (Price of Mobile Application) + ϵ_t

Mobile Broadband Empirical Specification

Variables	Measurement	Data Sources
3G Mobile Penetration	3G subscribers per 100 inhabitants	ITU
Standardization Policy	Dummy (1 for multiple standards)	3gtoday.com, ITU
PC Penetration	Estimated PCs per 100 inhabitants	ITU
Mobile Service Price	Per minute local call (USD) peak	ITU
Population Density	Population density (per km ²)	ITU
Price of Mobile Application	Price of SMS service	ITU
Income	GDP per capita	ITU
Education	UNDP Education Index	UNDP
Urban Population	Percentage of urban population	Euromonitor
Fixed Broadband Price	USD per 100kbit/s	ITU
1G & 2G Mobile Penetration	1G & 2G subscribers per 100 inhabitants (lagged)	ITU 26

Mobile Broadband OLS Results

	Extended Model		Reduced Model	
Variable	Coefficient	t-stat	Coefficient	t-stat
Constant	-21.144	-1.274	-16.692	-1.383
Multiple Standards Policy	7.484**	2.982	7.397***	2.918
Mobile Service Price	-3.489	505	-	-
Income	-8.89E-6	-0.060	-	-
Population Density	.001	.573	-	-
Fixed Broadband Price	.001	.088	-	-
PC Penetration	.172*	1.805	.171***	2.938
Price of Mobile Application	-9.243	465	-	-
Education	32.161	1.596	24.309	1.662
Urban Population	012	152	-	-
Mobile Penetration (1G and 2G)	141**	-2.276	146***	-3.398
R-Squared	.515		.492	27
Number of observations	53		53	

Mobile Broadband Results and Analysis

- Multiple standards, higher PC penetration, and lower previous generation (1G&2G) mobile penetration are associated with higher mobile broadband penetration.
- Fixed broadband is neither a complement nor a substitute for mobile broadband yet.

4. Discussion and Further Reserch

- Fixed Broadband
 - Caution: further analysis is needed to understand the full impact of unbundling
 - Unbundling reduces the incumbent's investment incentives
 - May crowd out facilities based entry
 - What about long run penetration level? Tradeoff between speed and long run penetration level?
 - Different ways of implementing unbundling, more or less intrusive (UNE-P vs. LLU)
 - Access (leased line) prices & regulation

Discussion and Further Reserch

- Broadband prices
- What is the impact of competition and unbundling policies on quality / capacity / speed?
- Mobile Broadband
 - Path dependency? What is the legacy of single standards for future technologies/generations? Symmetry and collusion?
 - Are the adoption factors different for developing countries? Education? Move directly towards mobile broadband?
 - Nonlinear model of mobile BB diffusion when sufficient data becomes available

An Empirical Analysis of Fixed and Mobile Broadband Diffusion

> Sangwon Lee & Mircea I. Marcu University of Florida

> > 15th ANACOM Seminar Lisbon, Portugal 26 May 2008

> > > Thank you. 31