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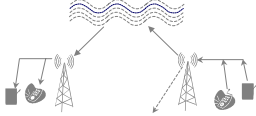
Competition in Wireless Telecommunications

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(joint work with Miguel Angel Campo-Rembado)   1

Background and motivation

Massive capital investments in wireless
- 2000-2004: About $100B annually in the US
- Total of over $100B on European spectrum alone
- Significant entry barriers (spectrum, fixed costs)

Flat/declining revenues and quality
- US ARPU flat as service features, traffic increased
- Declining revenue per MOU across all carriers
- Declining measured service quality

Questionable viability of 3G, UMTS upgrades

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Research agenda

Model competition in wireless telecom
- Capture interdependence between traffic, spectrum, transmission technology, infrastructure and service quality
- Incorporate congestion, minimum infrastructure needs
- Relate profits, revenue, return on assets and market share to changes in demand and transmission technology

Based on this model
- Explain some revenue and CAPEX trends
- Prescribe pricing, quality and migration strategies
- Examine industry concentration and policy issues

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Summary of some key results

Externalities and pricing power
- Increases the slope of profit functions, equilibrium prices
- Mediates the need for quality differentiation
- However, their extent depends critically on average traffic

Revenue and investment trends
- ARPU is flat over a range of traffic levels, then declines
- Profits are occasionally lower for the higher quality firm, ROI is often lower

Strategy for providers
- Low infrastructure, similar quality (early-stage)
- Aggressive quality differentiation (mature market)
- Migration to a new transmission technology

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Related literature (briefly)

Wireless telecom and service quality
- Rieffen, Shumann and Ward (2000)
- Valetti (1999)
- Sweet, Viehoff, Linardatos and Kaloutsids (2001)

Congestion pricing
- Levhari (1976), Levhari and Luski (1977), Reitman (1991), Dewan and Mendelson (1990), Lederer and Li (1997), Armony and Haviv (2003),…

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Overview of model
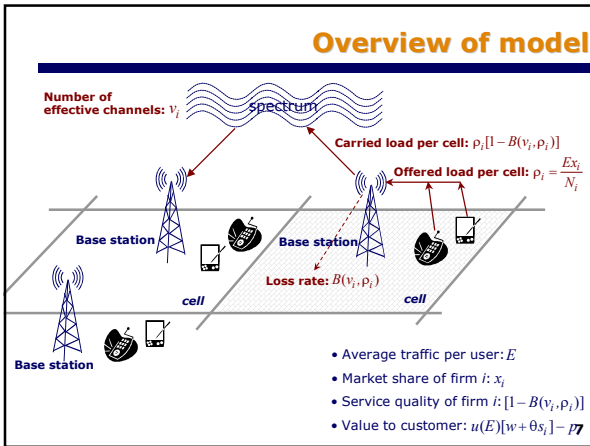
Competition between two wireless providers

Service quality determined by
- Effective channels per cell v_i (spectrum, transmission technology)
- Number of base stations N_i per unit area (cell size), with a minimum deployment constraint N_{min}
- Market share (negative externality demand imposes on quality)

Customer characteristics
- Homogeneous demand for E erlangs of traffic per unit time
- Heterogeneous valuation of service quality

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Overview of model

Number of effective channels: v_i

spectrum

Carried load per cell: $\rho_i[1 - B(v_i, \rho_i)]$

Offered load per cell: $\rho_i = \dfrac{Ex_i}{N_i}$

Base station

Base station

Loss rate: $B(v_i, \rho_i)$

cell

cell

Base station

- Average traffic per user: E
- Market share of firm i: x_i
- Service quality of firm i: $[1 - B(v_i, \rho_i)]$
- Value to customer: $u(E)[w + \theta s_i] - p_i$

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Equilibrium prices

Timeline $\qquad\qquad\qquad\qquad\qquad\qquad \theta$

Market share for Firm B	Market share for Firm A

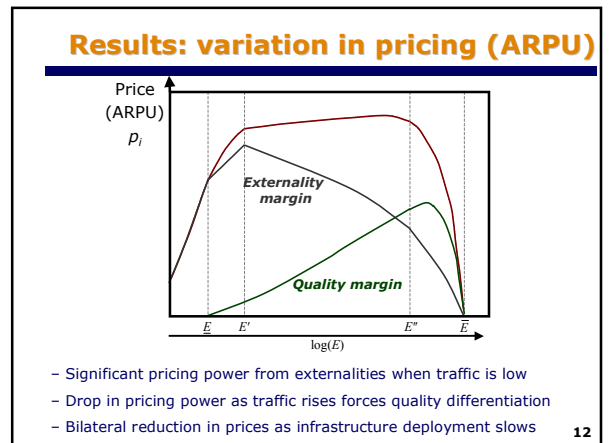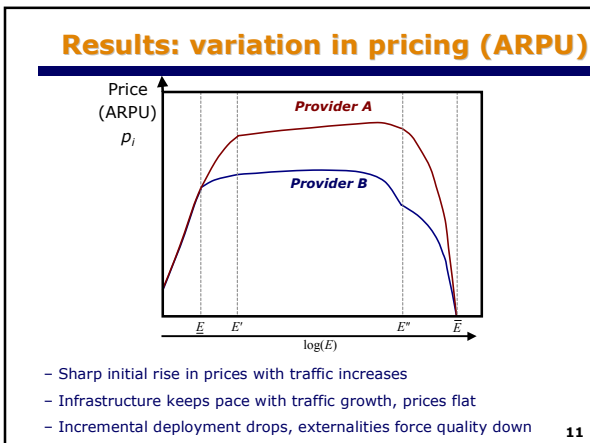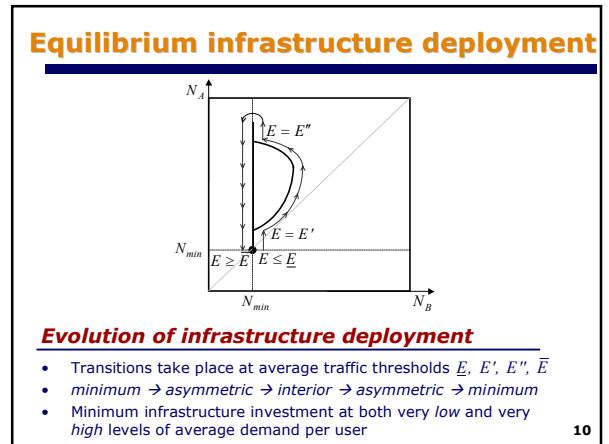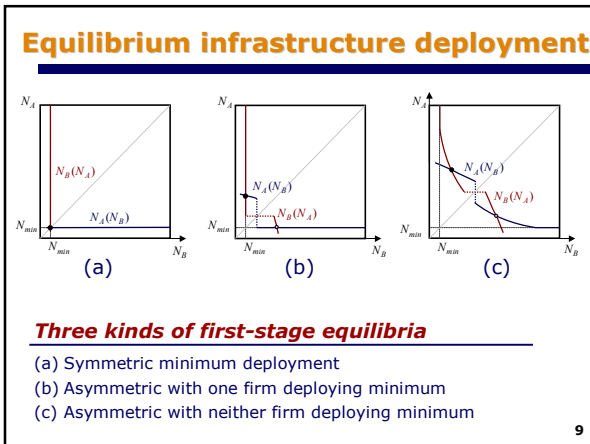$0 \qquad\qquad\qquad\qquad y \qquad\qquad\qquad\qquad 1$

(fulfilled) expectation of relative market share
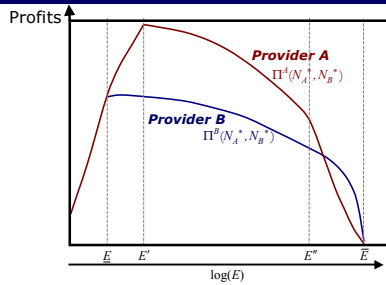
$$p^A(N_A, N_B) = u(E)(1 - y)\varphi(y)$$

$$p^B(N_A, N_B) = u(E) y \varphi(y)$$

$$\varphi(y) = \underbrace{\left(B\left(v, \frac{Ey}{N_B}\right) - B\left(v, \frac{E(1-y)}{N_A}\right) \right)}_{\textit{quality margin}} + \underbrace{yE\left(\frac{1}{N_B} B_2\left(v, \frac{Ey}{N_B}\right) + \frac{1}{N_A} B_2\left(v, \frac{E(1-y)}{N_A}\right) \right)}_{\textit{externality margin}}$$

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Equilibrium infrastructure deployment

(a)   (b)   (c)

Three kinds of first-stage equilibria

(a) Symmetric minimum deployment
(b) Asymmetric with one firm deploying minimum
(c) Asymmetric with neither firm deploying minimum

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Equilibrium infrastructure deployment

Evolution of infrastructure deployment

- Transitions take place at average traffic thresholds $\underline{E}$, E', E'', $\overline{E}$
- minimum → asymmetric → interior → asymmetric → minimum
- Minimum infrastructure investment at both very *low* and very *high* levels of average demand per user

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Results: variation in pricing (ARPU)

Price (ARPU) p_i

Provider A

Provider B

$\underline{E}$ E' E'' $\overline{E}$

$\log(E)$

- Sharp initial rise in prices with traffic increases
- Infrastructure keeps pace with traffic growth, prices flat
- Incremental deployment drops, externalities force quality down

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Results: variation in pricing (ARPU)

Price (ARPU) p_i

Externality margin

Quality margin

$\underline{E}$ E' E'' $\overline{E}$

$\log(E)$

- Significant pricing power from externalities when traffic is low
- Drop in pricing power as traffic rises forces quality differentiation
- Bilateral reduction in prices as infrastructure deployment slows

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Variation in profits

Profits

Provider A
$\Pi^A(N_A^*, N_B^*)$

Provider B
$\Pi^B(N_A^*, N_B^*)$

$\underline{E}$ E' E'' $\bar{E}$

$\log(E)$

– Pricing power and low infrastructure drives up profits initially
– Flat prices, increasing infrastructure reduce profits, decline accelerates as prices fall
– Zero-profit threshold suggests necessary migration point

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Technology migration cycles

Profits

Higher number of channels v

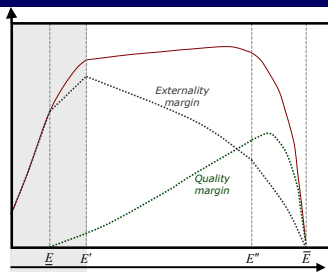Lower number of channels v

$\bar{E}_{lower}$ $\bar{E}_{higher}$
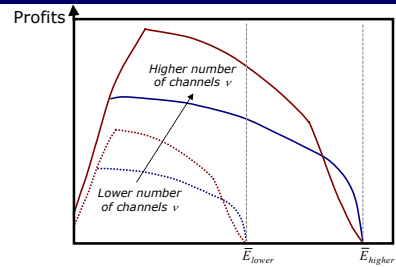
– Technology migration increases number of effective channels
– Pricing and profit trends are similar, but 'expanded'
– Suggests cycle of

migration → pricing power → flat ARPU → next migration
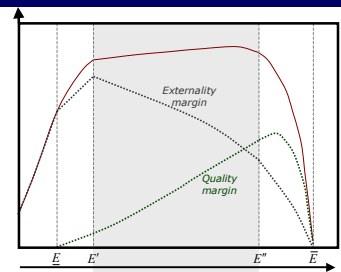
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Implications for provider strategy

Externality margin

Quality margin

$\underline{E}$ E' E'' $\bar{E}$

Early-stage wireless markets

– Choose similar quality, low infrastructure
– Leverage pricing power from externalities

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Implications for provider strategy

Externality margin

Quality margin
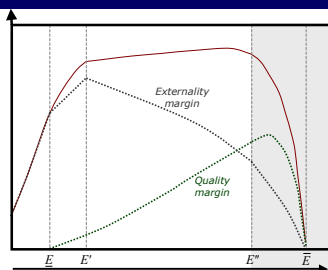
$\underline{E}$ E' E'' $\bar{E}$

Mature wireless markets

– Pursue aggressive quality differentiation
– Expect flat/declining revenue per user

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Implications for provider strategy

Externality margin

Quality margin

$\underline{E}$ E' E'' $\bar{E}$

Late-stage wireless markets

– Slow/cut back on infrastructure deployment
– Actively plan and implement next migration

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Ongoing work

Market power and relative concentration

- Welfare implications of recent mergers
- Herfindahl-Hirschman index may understate market power

Oligopoly and spectrum policy

- Multiple providers and equilibrium market structure
- Calibrated guide to profitability of additional spectrum

Technology migration games

- Stage-payoffs in multi-period adoption game
- Optimal timing of migration

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