Competition and Quality

Evidence from the Entry of Mobile Network Service

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Entry of a new mobile network in France

Mobile network service market in France before 2010

- Shares highly concentrated on 3 incumbent networks
- Failed efforts of competition authority to mitigate their market power
- 3G spectrum license (nation-wide) set aside for new entrant
- But no one applied.

A new entry by **Free Mobile** in 2012

- Facilitated by competition authority through various protection measures
- Substantial consumer gains from lowered prices
- But the overall welfare impact less clear when considering product responses in the long run

Did the entry induce competition enough or too much? The answer lies on

- product quality
- cost of quality supply

Determinant of network quality

Quality of network service

- Generated by cellular base stations supplying network traffic bandwidth in local area
- Output quality experienced through the speed of data transmission

Cellular base stations

- Key input for enhancing wireless spectrum bandwidths
- Require a stream of large-scale sunk investments to meet growing demand
- Investment pace accelerating over time

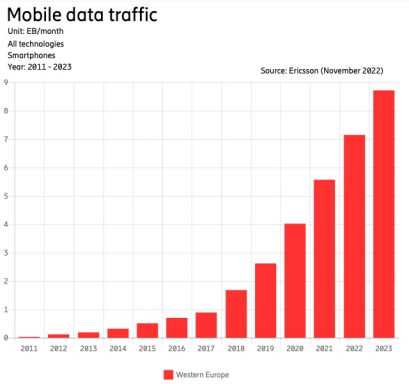


Figure 1: Mobile data traffic growth

Fueled by accelerated growth of mobile network bandwidth (nearly doubling every two years)

Research questions

Quality impact of market structure

- Market entry: Does it spur the investment race?
- Coordinated investment: how does it affect the quality supply?
- Competition vs merger: oversupply or undersupply?

Welfare impacts of market structure

- Welfare outcome of the entry
- Duplication of investment costs
- Positive net gain in the long run?

Literature

Quality supply/competition

- Spence (1975), Gaynor (2006)
- Crawford, Shcherbakov & Shum (2019)

Empirical studies of mobile markets

- Genakos, Valletti & Verboven (2018)
- Elliot, Houngbonon, Ivaldi & Scott (2023)

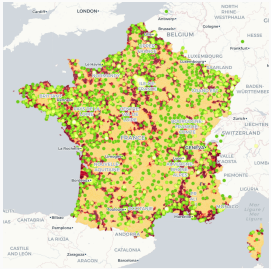
Innovation dynamics

- Schumpeter (1942), Arrow (1962), Aghion et al (2005), Vives (2008)
- Goettler & Gordon (2011), Hashmi & Van Biesebroeck (2016)
- Igami & Uetake (2019), Yang (2020)

Merger impact

- Motta & Tarantino (2017), Federico, Langus & Valletti (2018), Bourreau, Jullien & Lefouili (2021)
- Federico, Scott Morton & Shapiro (2019)

Data



Mobile service demand panel (2011–2014)

- 4 mobile network operators in 21 geographic markets
- Unit: product-region-quarter
- Product demand & price from Kantar

Network supply panel

- Cellular base stations (antennas) from ANFR
- measured by number of active stations in each region

Change of market structure

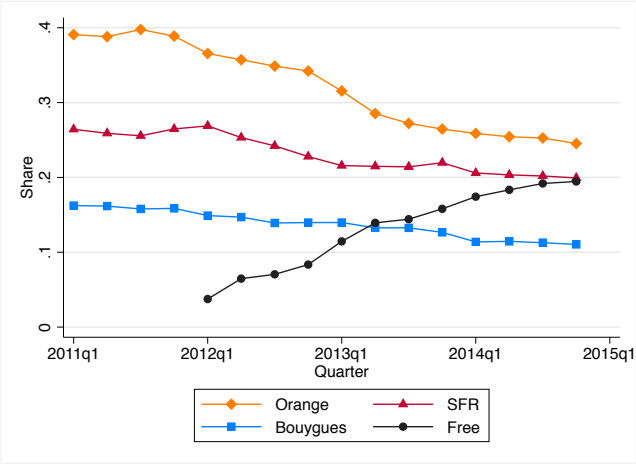
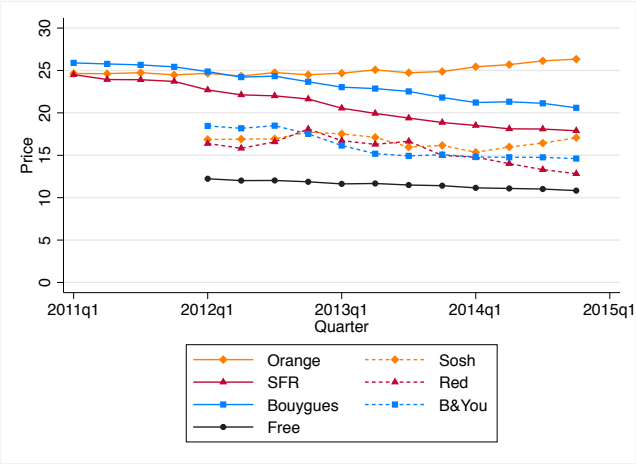


Figure 2: Market share of network operators (aggregated)

Low variation in price over time



Price elasticity identified from change in choice set

Impact of entry on network quality supply

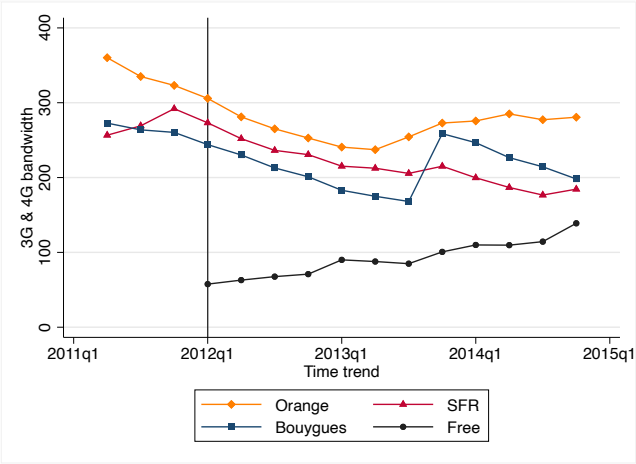


Figure 3: Supply of mobile network bandwidths (normalized by mobile traffic growth)

Incumbents' investment slightly lower after entry, but far from conclusive.

Model

Supply of network service

Network i's period profit from supplying quality q_i at price p_i:

$$\Pi_i = (p_i - c_i)D_i(q, p) - C_i(a_i)$$

for $q = (q_1, ..., q_N)$ and $p = (p_1, ..., p_N)$, where

- c_i: marginal cost of supplying each consumer
- D_i: demand for network i
- a_i: new investment in network stations
- C_i: sunk cost of investing specified as

  $$C(a_{it}) = (\lambda - \nu_{it})a_{it}^2,$$

  where ν_{it} is i.i.d. random cost shock.

Quality production and investment

Quality index q_i:

Quality of network i is indexed to the accumulated investment capital A_i as

$$q_i = q(A_i),$$

where A_i is the cumulative stock of network stations in each region.

Capital accumulation process:

New investment a_i adds to A_i, producing in the next quarter A_i':

$$A_i' = \frac{1}{\delta^d}(A_i + \delta^s a_i),$$

where A_i is normalized to the 2011 Q1 level by growth rate factors (δ^d and δ^s) of mobile traffic and spectral efficiency, respectively.[1]

[1] They are calibrated from ARCEP database and Real Wireless (2011).

Competition on investment in quality

Each firm i's investment strategy $\sigma_i^*(s_t) = a_{it}$ is Markov perfect equil.(MPE):

The MPE strategy maximizes its net present value of future profit flows

$$V_i(s) = \max_{a_i} \left\{ R_i(s) - C_i(a_i) + \beta E\left[V_i(s')|s, a_i, a^*_{-i}\right] \right\} \qquad i = 1, ..., N.$$

given industry state s_t and optimal strategies $\sigma^*_{-i} = \{\sigma_j^*\}_{j \neq i}$ of rivals.

Price competition

Network i sets prices $\{p_j\}_{j \in \mathcal{J}_i}$ to maximize net revenue

$$R_i = \sum_{j \in \mathcal{J}_i} (p_j - c_j) D_j(p, q),$$

given marginal cost c_j and expected demand D_j.

Estimation strategy for marginal cost c

- Static Bertrand competition
- Ex ante demand shock

Conditional demand for network

Consumer ι's indirect utility of service j at time t:

$$u_{\iota jt|k} = \delta_{jkt} + \epsilon_{\iota jkt},$$

for service k chosen at last period $t-1$, and

$$\delta_{jkt} = \gamma q_{jt} - \alpha p_{jt} + x'_{jt}\theta_x + \chi_{jkt} + \xi_{jt},$$

- $q_{jt} = \log A_{jt}$: quality index
- $\chi_{jkt} = \chi \cdot \mathbb{1}\{j = k\}$: SW costs forgone when not switching
- $\epsilon_{\iota jkt}$: extreme value utility shock when switching from k to j (partially known to networks)

Consumer demand switching from network k to j:

$$S_{jt|k} = Pr(d_{\iota t} = j | d_{\iota t-1} = k)$$

Demand for network operator

Demand quantity:

$$D_{jt} = M \cdot S_{jt},$$

where M is market size, and S_{jt} is share of network j such that

$$S_{jt} = \sum_{k \in \mathcal{J}} S_{jt|k} S_{kt-1}$$

- $S_{jt|k}$: share of network j among consumers switching from k
- S_{kt-1}: share of existing customers of network k at time $t-1$

Minimal state space

How to minimize the set of state variables without affecting the value function?

$$\begin{aligned} R_i(p_t, A_t; c_t, x_t, \xi_t, S_{t-1}) &= (p_j - c_j) M \sum_k S_{jt|k}(p_t; A_t, c_t, x_t, \xi_t) S_{kt-1} \\ &= m_j M \sum_k S_{jt|k}(m_t; A_t, \tilde{\xi}_t) S_{kt-1} \end{aligned}$$

- $m_j = p_j - c_j$: margin
- $\tilde{\xi}_{jt} = -\alpha c_{jt} + x'_{jt}\theta_x + \xi_{jt}$, therefore $\delta_{jt} = \gamma \log A_{jt} - \alpha m_{jt} + \tilde{\xi}_{jt} + \chi_{jkt}$

Markov transition of industry states

1. Investment stock:

$$A_{it+1} = \frac{1}{\delta^d}(A_{it} + \delta^s a_{it})$$

2. Captive consumers:

$$S_{jt} = \sum_{k \in \mathcal{J}} S^{\epsilon}_{jt|k} S_{kt-1}$$

3. Exogenous quality:

$$\tilde{\xi}_{jt+1} = \rho_{0j} + \rho_1 \tilde{\xi}_{jt} + \zeta_{jt},$$

where $\tilde{\xi}_{jt}$ is an index of exogenous quality adjusted for marginal cost c_{jt}.

Estimation is made tractable by continuous action & state spaces, even with heterogeneity in payoffs & state transitions at firm & product level.

Estimation results

Mobile network demand under switching costs

	Logit		IV		IV-SWC	
	Estimate	Std. err	Estimate	Std. err	Estimate	Std. err
Price	-0.004	(0.011)	-0.787***	(0.119)	-0.786***	(0.105)
SW cost					6.626***	(0.117)
Log 3G & 4G	0.159	(0.106)	0.611***	(0.118)	0.608***	(0.087)
Observations	12,863		12,863		12,863	
J test (p value)			0.454		0.447	

$*$: p<0.1; $**$: p<0.05; $***$: p<0.01. Market fixed effects omitted from the table.

Instruments for price: BLP IV (sum of rival networks 3G & 4G) + linear time trend

Market power

Service provider	Product group	Price (€)	M.C. (€)	Margin (€)
Orange	Orange	25.00	16.57	8.43
	Sosh	16.64	13.66	2.98
SFR	SFR	20.76	13.45	7.30
	Red	15.42	12.70	2.72
Bouygues	Bouygues	23.23	17.54	5.69
	B&You	15.86	13.48	2.38
Free	Free	11.54	9.14	2.39

Average across 21 regions for 2011Q2–2014Q4 based on 200 bootstraps

Overall results as expected

- Lower margins from subsidiaries (due to absent SW costs)
- The entrant has the least market power.

Transition of exogenous quality (ξ_{jt})

$$\tilde{\xi}_{jt+1} = \rho_0^j + \rho_1 \tilde{\xi}_{jt} + \zeta_{jt}.$$

Parameter	Estimate	Std. err
ρ_0	0.589	0.236
ρ_1	0.590	0.015
SFR	0.090	0.083
Bouygues	-0.574	0.069
Free	-0.284	0.104
Sosh	-0.890	0.074
B&You	-0.961	0.073
Red	-0.917	0.071
Observations	1,822	
R^2	0.871	

200 bootstrap estimates with robust error covariance. Market fixed effects included.

- Orange's fixed effect normalized to 0.
- Low-cost services converge to low quality in the long run.

Estimating investment cost function

Two-step estimation (Bajari, Benkard & Levin, 2007)

- Find θ minimizing the violations of the optimality condition

$$V_i(s; \sigma_i^*, \sigma_{-i}^*; \theta) \geq V_i(s; \sigma_i', \sigma_{-i}^*; \theta)$$

- V_i forward simulated by reduced-form investment σ^*
- 40 future quarters simulated with discount factor β=0.975.
- One-period deviation: $\sigma_i' = \sigma_i^* \times (1 \pm 0.01)$

Investment policy σ^* estimation

Random forests regression

$$\log a_{it} = \hat{f}(s_t) = \frac{1}{B} \sum_{b=1}^{B} T_b(s_t)$$

- Random forests on states s_t with B=1,000 trees
- Robust prediction with high R^2 (0.871)
- Little tuning needed for forward simulation
- Flexible to accommodate nonstationary equil. before entry
- Weaker assumptions than parametric models (not the most efficient)

Investment cost function

	(1)		(2)	
	Estimate	Std. error	Estimate	Std. error
Invest	58,054	8,425		
Invest $\times \nu$	3,924	4,175		
Invest^2			330.21	40.16
Invest$^2 \times \nu$			138.34	16.98

Discount factor β=0.975; Based on 192 bootstrap samples & 100 simulation paths. Average investment: 22.74 (national), 51.47 (Île-de-france) in the basis unit of 2011 Q1.

Table 1: Estimation of investment cost

Marginal cost of investment (in 2011 Q1 unit) under Model 2

- €14,745 at the national average
- €33,071 in Île-de-france

$$C(a_{it}) = (\lambda - \nu_{it})a_{it}^2, \qquad \nu_{it} \sim N(0, \sigma^2).$$

Counterfactuals

Simulating counterfactual market

Long-run equilibrium

1. simulated for the largest market (Île-de-France) over 10 years starting from 2012 Q2 [2]
2. Continuous action & state spaces
3. Heterogeneity in payoff & state transition across firms & products

Continuous states & actions in high-dimensional dynamic game

- Sparse grids & basis functions for value function approximation
- slows the curse of dimensionality (Doraszelski & Judd, 2012)
- Judd et al (2014), Brumm & Scheidegger (2017)

[2] using 200 Monte Carlo simulation paths

Sparse grid for the curse of dimensionality

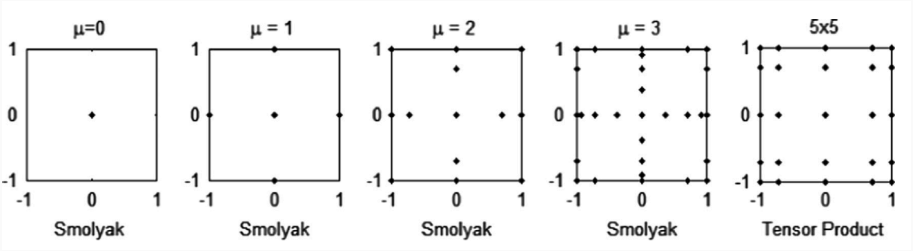


Figure 4: Smolyak vs tensor-product grid (Judd et al, 2014)

Number of grid points for 14-dim state space

- Tensor product with 5^d points: 6,103,515,625
- Smolyak: 4,117

Sparse basis similarly constructed

Value function approximated by values from neighboring grid points

Quality impact of entry

Network	(1) No entry	(2) + Free mobile		(3) + Fight brands	
Orange	1,150	1,140	-0.87%	1,050	-8.70%
SFR	1,084	1,089	0.46%	1,047	-3.41%
Bouygues	877	897	2.28%	818	-6.73%
Free	0	628		572	
Total	3,111	3,755	20.70%	3,487	12.09%

Network quality simulated simulated in *Île-de-France* for 10 years starting from 2012 Q2. Network quality measured in units of 2011 Q1 network quality. Column (2) for Free's entry. Column (3) for entry of Free and the incumbent's fighting brands.

Table 2: Long-run equilibrium supply of network quality

Entry alone did not reduce investment incentives for all incumbents.

Yet, investments decline driven by cannibalization of the incumbents' own services.

Optimal quality supply

	Quality comp.	Social plan.1	Social plan.2	Merger (all)	Back to 3 (Orange)	Back to 3 (Bouyg)
Long-run equilibrium with entry						
Orange	1,050	955	850	836	1,016	1,095
SFR	1,047	957	926	911	1,068	1,056
Bouygues	818	793	595	501	865	798
Free	572	723	438	219	246	350
Total	3,487	3,428	2,809	2,467	3,194	3,299

Column “Social plan.1” for social planner with price competition.
Column “Social plan.2” for social planner with first-best pricing.
Column “Back to 3 (mno)” for MNO acquiring Free.
Column “merger” for monopoly (Free’s quality increased at the bottom panel).

Table 3: Long-run equilibrium supply of network quality

Long-run supply of quality

- Quality investment spurred by competition
- Quality suppressed under coordination, due to internalized cannibalization effects
- Acquisition lowers investment. Non-merged firms escalate quality supply.

Welfare impacts of entry

	(1)	(2)	(3)
Entry	Yes	No	No
Quality	Equil	Fixed	Equil
Consumer surplus			
NPV (10 years)	7.341	5.953	5.970
1st year	1.099	0.908	0.910
10th year	1.157	0.931	0.934
Producer surplus	4.087	5.488	5.460
Total surplus	11.427	11.441	11.430

Consumer surplus in billion euros.
Quality of Column (2) fixed to the equilibrium in Column (1).

Table 4: Long-run equilibrium consumer surplus

Welfare impacts of entry

- Gain from price & variety changes: (1) – (2)
- Loss from quality: (2) – (3)

Consumer gains from product-market competition $\gg$ Loss from reduced quality

Summary

Market entry

- Eventually slowed down incumbents' investment in quality
- Primarily through cannibalization from their own new products
- Surplus reallocated from producers to consumers

Investment externality

- Spurs investment in quality competition
- Negative externality internalized under coordinated investment
- Positive externality to firms not merged

Both entry & merger diminish quality supply incentives.

- It's not simply about market shares concentration.

Thank you!

https://sites.google.com/site/yutecsun

Full demand estimation table

	Logit		IV Logit		IV Logit-SWC	
	Estimate	Std. err	Estimate	Std. err	Estimate	Std. err
Price	-0.004	(0.011)	-0.787***	(0.119)	-0.786***	(0.105)
SW cost					6.626***	(0.117)
Log 3G & 4G	0.159	(0.106)	0.611***	(0.118)	0.608***	(0.087)
Log 2G	0.059	(0.442)	1.826***	(0.446)	1.842***	(0.350)
Orange	0.690	(0.808)	-0.833	(0.796)	-2.487***	(0.555)
SFR	0.692	(0.748)	-2.900***	(0.844)	-4.554***	(0.663)
Bouygues	0.345	(0.744)	-0.771	(0.752)	-2.419***	(0.447)
Free	1.114	(0.751)	-9.643***	(1.570)	-9.639***	(1.491)
Sosh	-0.303	(0.827)	-7.514***	(1.160)	-7.510***	(1.079)
B&You	-0.345	(0.712)	-6.352***	(1.084)	-6.334***	(0.906)
Red	-0.439	(0.733)	-7.307***	(1.148)	-7.293***	(1.014)
Observations	12,863		12,863		12,863	
J test (p value)			0.454		0.447	

$*$: p<0.1; $**$: p<0.05; $***$: p<0.01. Market fixed effects omitted from the table.

Correlated exogenous quality shock (ζ_{jt})

	Orange	SFR	Bouygues	Free	Sosh	B&You	Red
Orange	1.000	0.378	0.467	0.052	0.105	-0.034	-0.206
SFR	0.378	1.000	0.477	0.121	-0.019	0.119	0.283
Bouygues	0.467	0.477	1.000	0.060	-0.085	0.221	0.175
Free	0.052	0.121	0.060	1.000	0.151	0.045	0.058
Sosh	0.105	-0.019	-0.085	0.151	1.000	0.170	-0.209
B&You	-0.034	0.119	0.221	0.045	0.170	1.000	0.288
Red	-0.206	0.283	0.175	0.058	-0.209	0.288	1.000

Based on 200 bootstrap estimates

Table 5: Correlation matrix of quality shock ζ_t

Why allow for correlation?

- To simulate future path of exogenous qualities that jointly evolve over time

Quality and welfare impacts of switching costs

	SW cost changes				
	-20%	-10%	0%	10%	20%
Long-run equilibrium without entry					
Total quality	2.24%	5.65%	3,131	-10.22%	-20.73%
Consumer (€mil)	37.69%	15.63%	934	-14.35%	-28.80%
Producer (€mil)	34.51%	22.93%	881	-26.11%	-51.99%
Long-run equilibrium with entry					
Total quality	-2.83%	-1.46%	3,431	-5.88%	-14.31%
Consumer (€mil)	49.87%	24.03%	1,156	-20.92%	-38.03%
Producer (€mil)	-3.24%	2.16%	652	-13.71%	-37.60%

SW cost changes compensated by change of marginal cost of serving each consumer.

Table 6: Long-run equilibrium impacts of switching costs