

## **The Adoption of Network Goods**

Evidence from the Spread of Mobile Phones in Rwanda

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Brown University

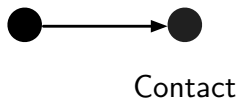
# Network Goods

- Facebook, Yelp, Waze, NetFlix, ...
- Mobile phones
- Mobile internet
- Mobile money

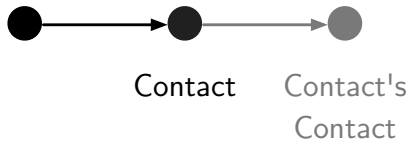
## Benefits from adopting a network good



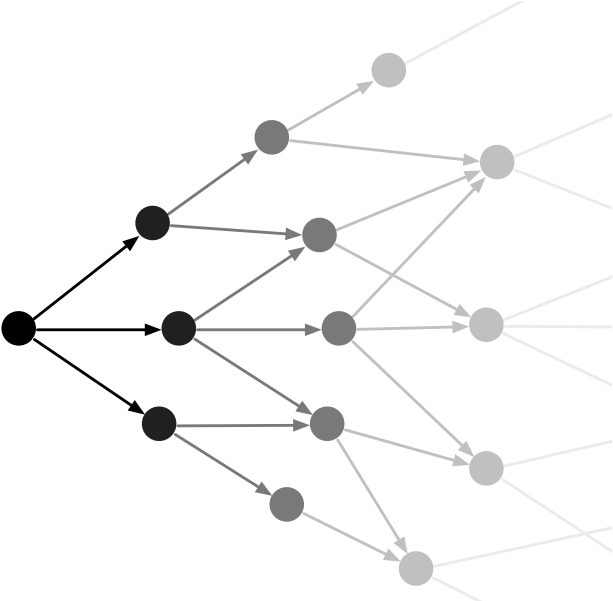
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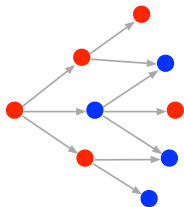
## Benefits accrue beyond adopter



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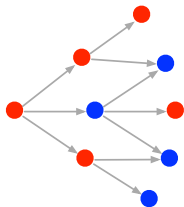
## Firms may not fully internalize network effects



Competitive

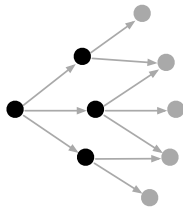
Benefits of expansion  
may spill over into  
competitor's network

## Firms may not fully internalize network effects



Competitive

Benefits of expansion  
may spill over into  
competitor's network



Monopolistic

May underprovide if  
there are limits to  
price discrimination



# Achieving efficient adoption of network goods

Careful policies needed by both firms and governments

## 1. Substantial theoretical work

- Rohlfs 1974, Katz and Shapiro 1986, Farrell and Saloner 1985

## 2. Little empirical work

- Difficult to gather **data** on entire network
- Difficult to **identify** network effects
- Difficult to **simulate** effects of policies

# The Spread of Mobile Phones

Mobile phone subscriptions in developing economies:

250 million (2000)

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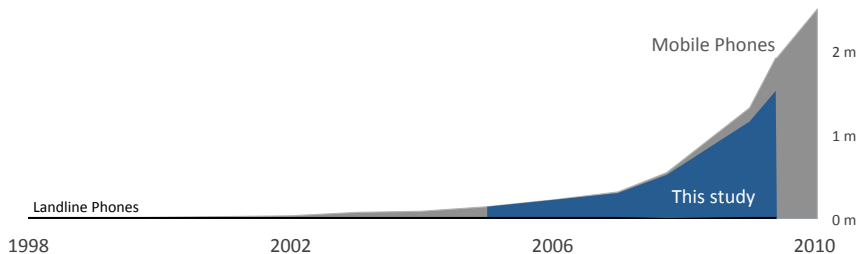
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Mobile: 7% of government revenues in sub-Saharan Africa

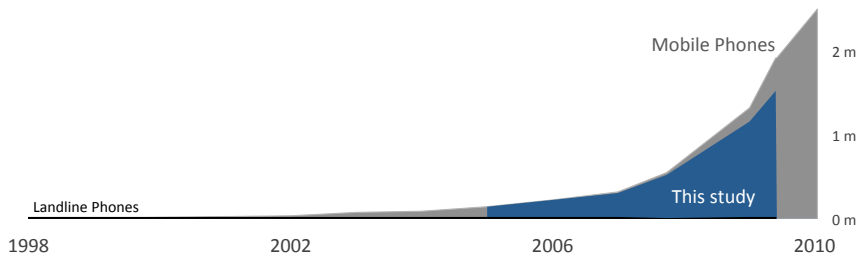
Simulate:

1. Government requirement to serve rural areas
2. Alternate tax policies

# The Spread of Mobile Phones in Rwanda



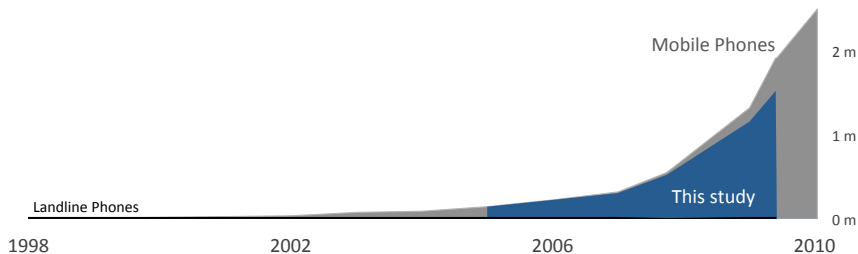
# The Spread of Mobile Phones in Rwanda



- **Handset prices** \$70 (2005) → \$20 (2009)



# The Spread of Mobile Phones in Rwanda



- **Handset prices** \$70 (2005) → \$20 (2009)
- **Operators adapted to reach poorer consumers:**
  - Coverage expanded: 60% → 95% of country
  - Calling prices reduced by over 50%

# Data

## Call Detail Records - with Nathan Eagle (Jana Inc.)

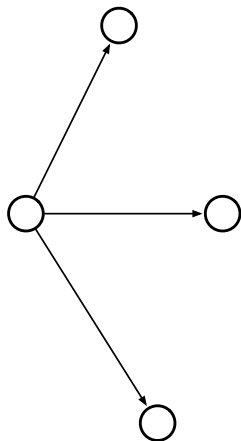
Anonymous transaction records from dominant operator,  
2005-2009

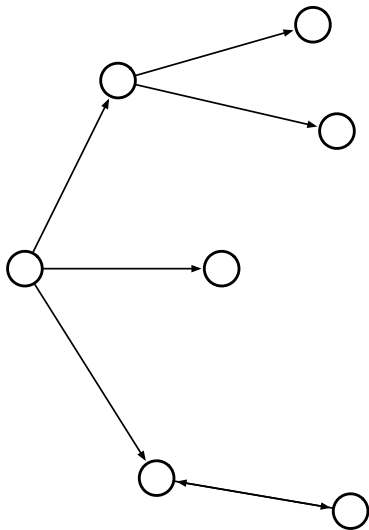
Transaction	Amount	ID.From	ID.To	Tower	Timestamp
Call					
Call attempt					
SMS					

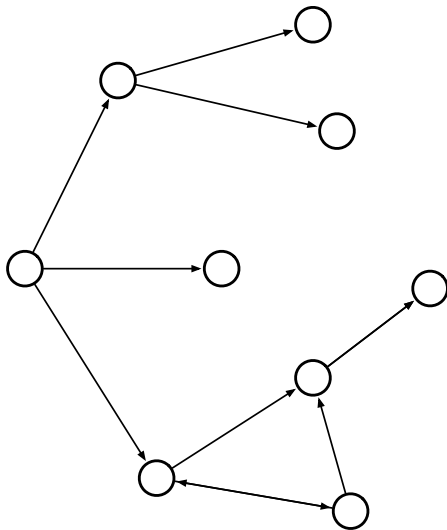
IDs map to account and handset for sender and recipient.

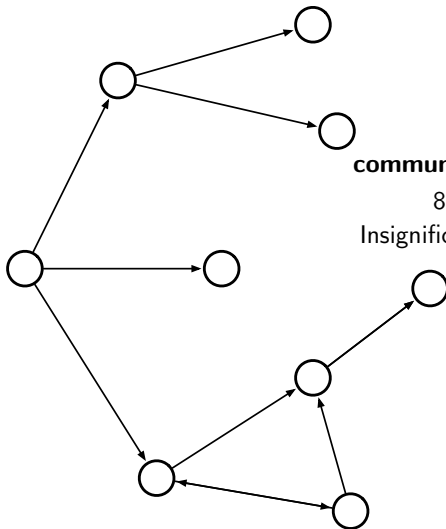
No other characteristics on subscribers.

5.3 billion transactions



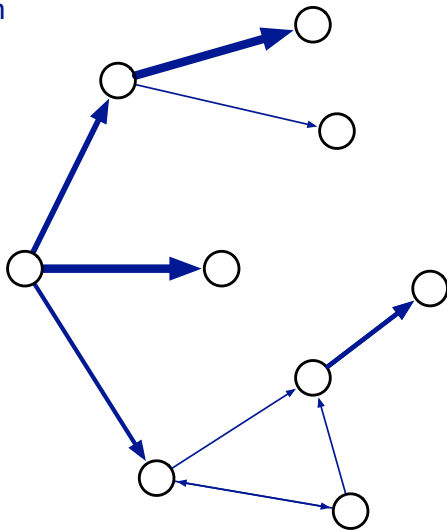




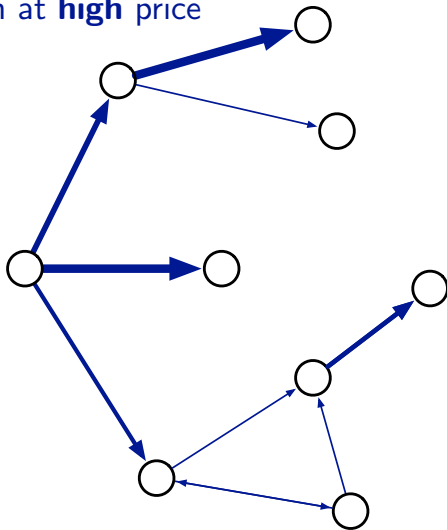


**Nearly all remote  
communication in Rwanda:**  
88% of mobile phones  
Insignificant landline network

## Duration



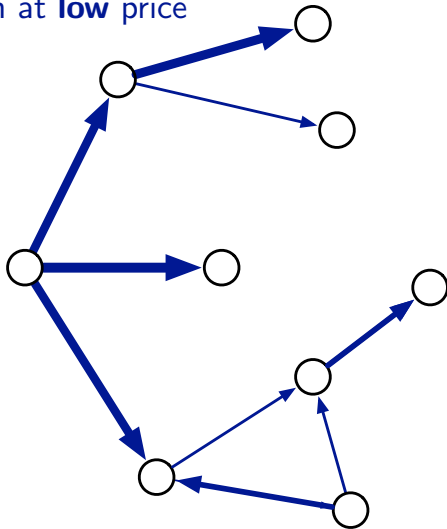
Duration at **high** price



$$\frac{\Delta \text{Duration}}{\Delta \text{Price}}$$

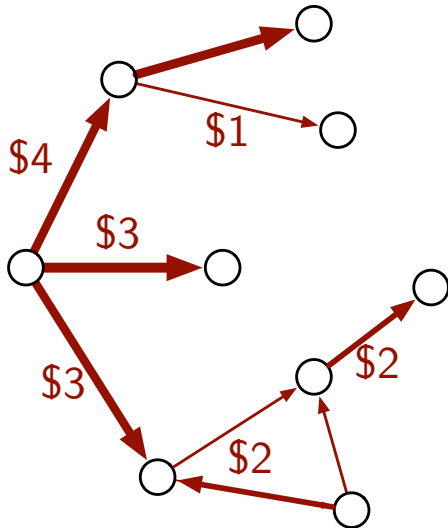


Duration at **low** price

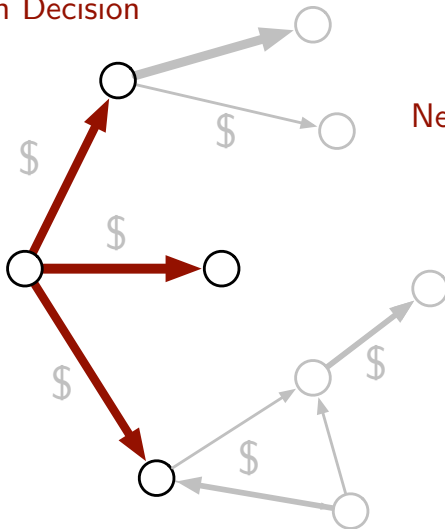


$$\frac{\Delta \text{Duration}}{\Delta \text{Price}}$$

How much value do people get from communicating?



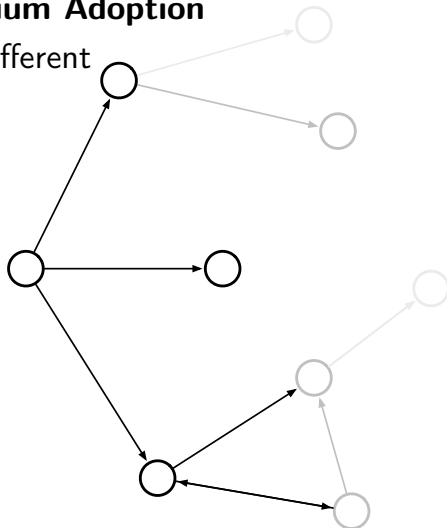
## Adoption Decision



**Consider:**  
Handset price  
Network benefits

## Equilibrium Adoption

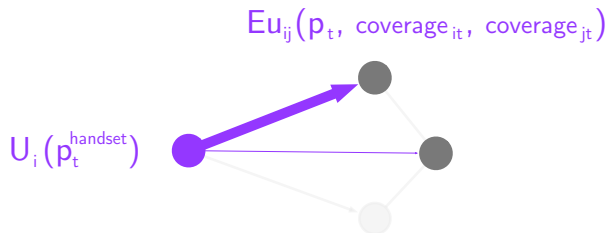
Under different  
policy



# Model

Adoption Decision

Call Decision

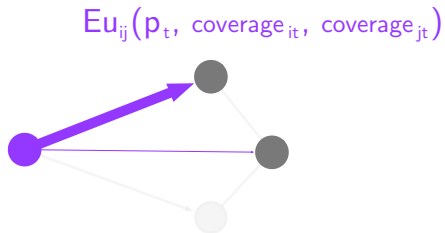


# Model

Adoption Decision

Call Decision

$$U_i(p_t^{\text{handset}})$$



**Identification:**

Geographical and policy instruments

Within-link changes in price and coverage

# Adoption Equilibrium

Compute new equilibrium based on change to the environment.

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**Equilibrium**  $\Gamma(\eta)$ : function of individuals' unobserved benefits  $\eta_i$   
Each  $i$  adopts at  $\tau_i = \arg \max_t U_i^t(\eta_i, \hat{\tau}_{G_i})$



## Multiple Equilibria

Obtain a set of equilibria  $\Gamma(\eta)$  due to uncertainty in  $\eta$  and coordination.

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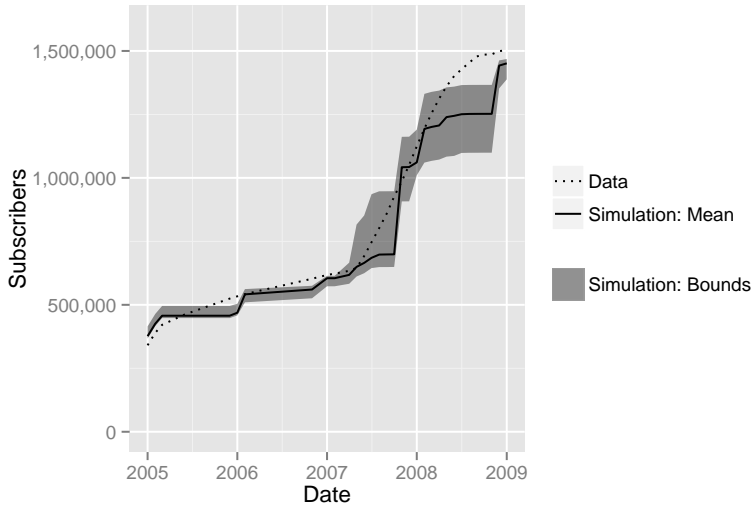
Game has strategic complements; equilibria form a lattice.

Individual bounds  $[\underline{\eta}_i, \bar{\eta}_i]$  and bounds on expectations  $\hat{\tau}_j \in [0, \bar{T}]$  imply bounds on set of equilibria:

$$\underline{\Gamma}(\underline{\boldsymbol{\eta}}) \leq \Gamma(\boldsymbol{\eta}) \leq \bar{\Gamma}(\bar{\boldsymbol{\eta}})$$

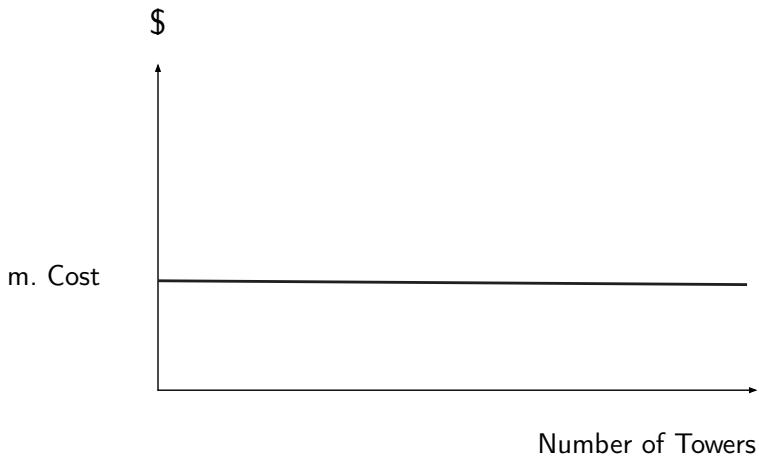
(Topkis 1978, Milgrom and Shannon 1994)

# Simulation Fit

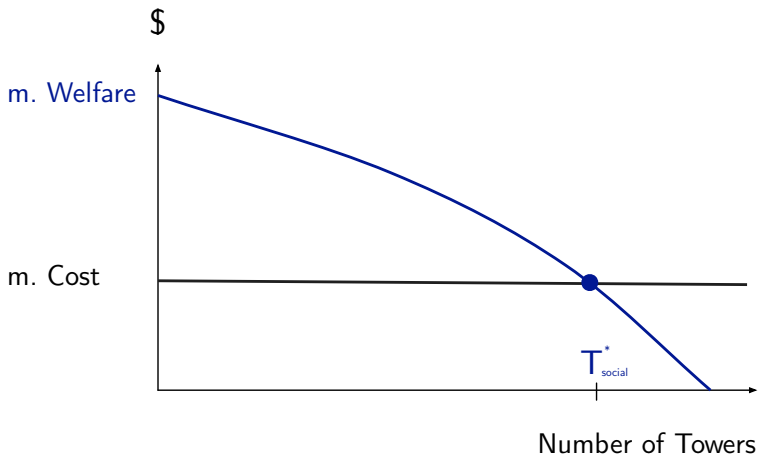


(Bounds result from uncertainty in  $\eta_i$  and the span of equilibria.)

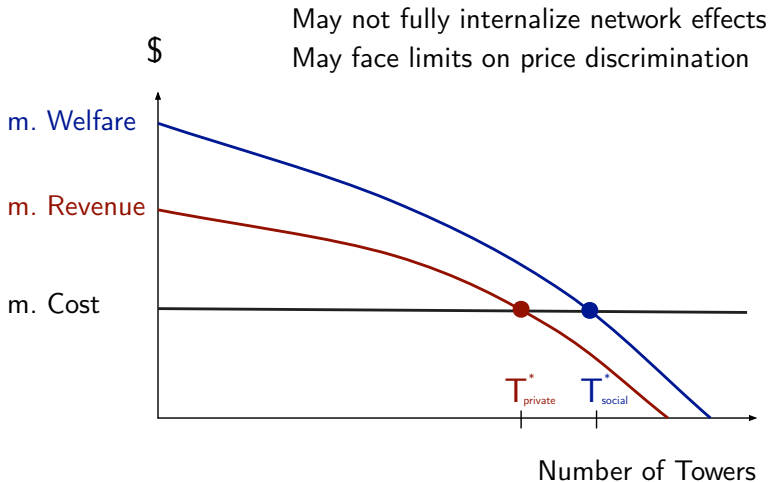
## Cost of expanding towers



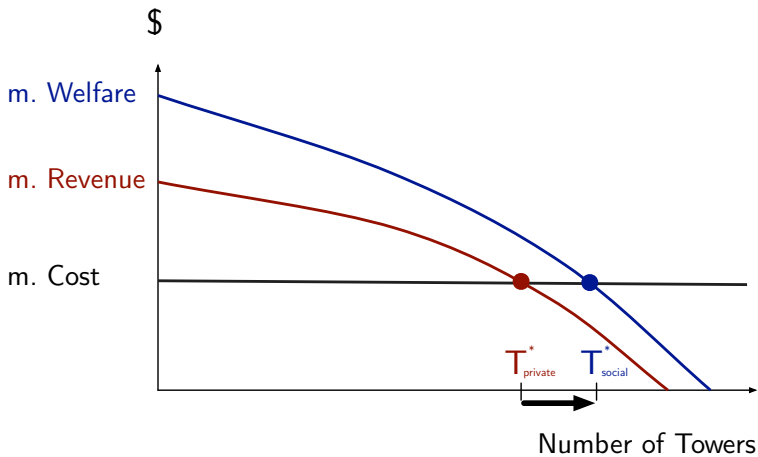
# Optimal coverage



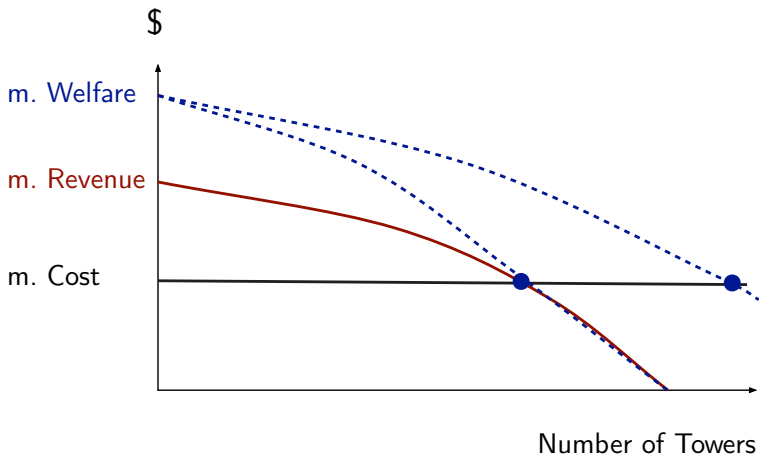
# Private returns from coverage may differ from social returns



# Coverage obligation

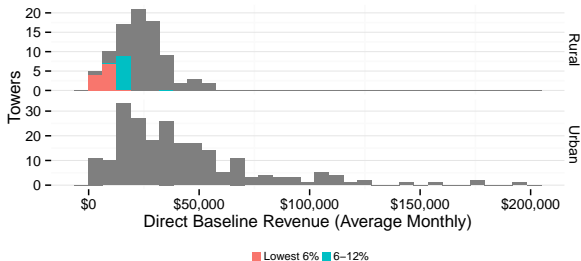


# Effect of policy depends on shape of welfare and revenue



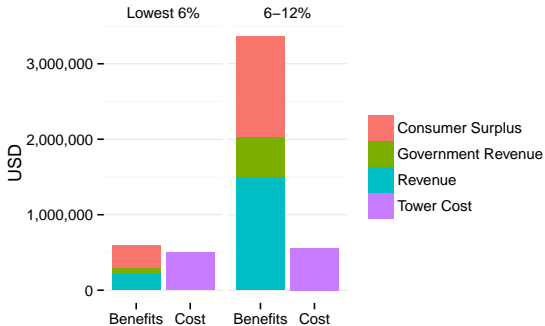


## Peel back tower construction (based on realized revenue)



- Don't build the lowest revenue rural towers (6%)
- Save \$496,660 in annualized build and operation costs

## Effect of Rolling Out Rural Coverage



Benefits dispersed: much of consumer surplus to individuals whose coverage was unaffected

## How, and how much to tax?

66% of government revenue from mobile from consumer taxes on handsets and usage.

Average tax rate in SSA (2007): 31% handsets, 20% airtime

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Simulate alternative tax policies

# Taxation

Tax Handset	Revenue (\$m)		Consumer
	Telecom	Government	Surplus (\$m)
<b>Baseline: 48%</b>	<b>[193, 210]</b>	<b>[78, 84]</b>	<b>[37, 44]</b>
48% until 2007, then 0%	[205, 217]	[67, 70]	[60, 62]
48% until 2006, then 0%	[207, 217]	[66, 69]	[63, 67]
0%	[208, 220]	[62, 65]	[65, 66]

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- When network effects are ignored, underestimate tax distortions (by up to 45% on firm revenue)
- Welfare cost of \$2.56 or \$1.62 per government dollar (vs. MCF in sub-Saharan Africa 1.21 (1.37 Rwanda), Auriol and Warlters 2012)

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...above Q90 usage		[105, 110]	[46, 48]	[29, 32]
...below Q90 usage		[76, 83]	[36, 39]	[23, 27]

Q90 usage  $\approx$  1.6 minutes/day.

Shifting from adoption to usage taxes would dramatically increase consumer surplus accruing to 90% of users

# The Spread of Mobile Phones

Method to estimate and simulate adoption of a network good

Use data from nearly the entire Rwandan cell phone network:

- **Estimate structural model of adoption**  
as a function of each individual's social network, coverage, and prices
- **Simulate policies**  
Government requirement to serve rural consumers: improved welfare  
Alternate tax policies  
Paper: Adoption subsidies: high return, large fraction of effect due to spillovers