Economics of Networks
Network Effects: Part 1

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Agenda

Externalities

Network effects and markets

- Tipping Points
- Competition and Lock-in
- Labor markets

Suggested Reading: EK Chapter 17

What is an Externality?

A consequence of economic activity that is not reflected in market prices

- Typically spillover effects on third parties

Classic Example: Pollution

- Refinery takes oil, makes finish petroleum products
- Generates air pollution
- Pays for oil, not social cost of pollution

Absence of pricing is key: Rival goods $\neq$ externalities

- If I buy a can of coke, you cannot drink it
- If I paid what it costs to replace the can, there is no externality

What is an Externality?

Another Example: Traffic Congestion

- Equilibrium routing inefficient because players do not internalize cost of congestion they produce

Others?

What about positive externalities?

- Vaccines
- Education
- Research

Problems with Externalities

Supply and Demand

- If not paying full cost, get too much of bad things
- If not reaping full benefit, get too little of good things

Policy responses:

- Taxes and subsidies (“internalize” the externality)
- Direct regulation
- Selling/auctioning pollution rights (allow secondary market)

Good policy needs to anticipate how people respond

- Think about congestion pricing plans

Network Effects

Some products are more valuable when more people use them

Classic examples:

- Fax machine
- Telephone

Contemporary examples:

- Operating Systems
- Messaging Apps
- Social Media

Others?

Types of Network Effects

Direct network effects

- Communication/collaboration technologies

Two-sided network effects

- Marketplaces

Indirect network effects

- Learning spillovers
- Research/improvement of existing product
- Development of complementary goods

Artificial network effects

- Referral programs

Markets for Network Goods

Unit mass of potential customers

Suppose customers have "types" v distributed uniformly on $[0, 1]$

- Higher types value the product more

If mass $q \in [0, 1]$ purchase the product, type v values it at qv

- Network effect: more valuable if more people buy
- At price p, net benefit $qv - p$

Equilibrium Demand

Unlike standard consumer theory, choice to buy is strategic

- Value depends on others' behavior

If price is p, consumers of type higher than

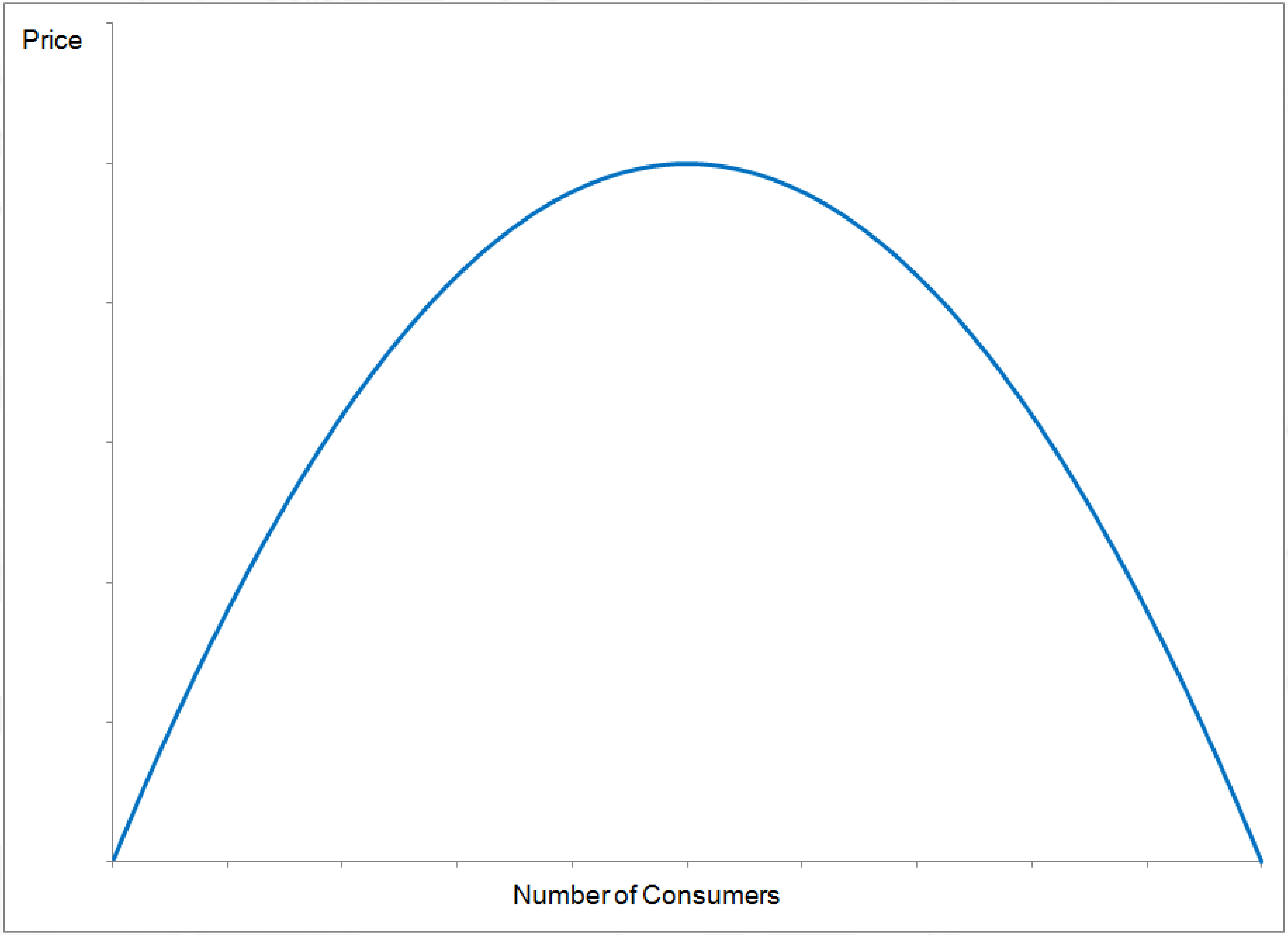
$$\overline{v} = \frac{p}{q}$$

want to buy

Uniform values imply there is a mass $\hat{q} = 1 - \overline{v}$ such consumers

In equilibrium: $1 - q = \frac{p}{q}$

Equilibrium Demand



A Funny Demand Curve

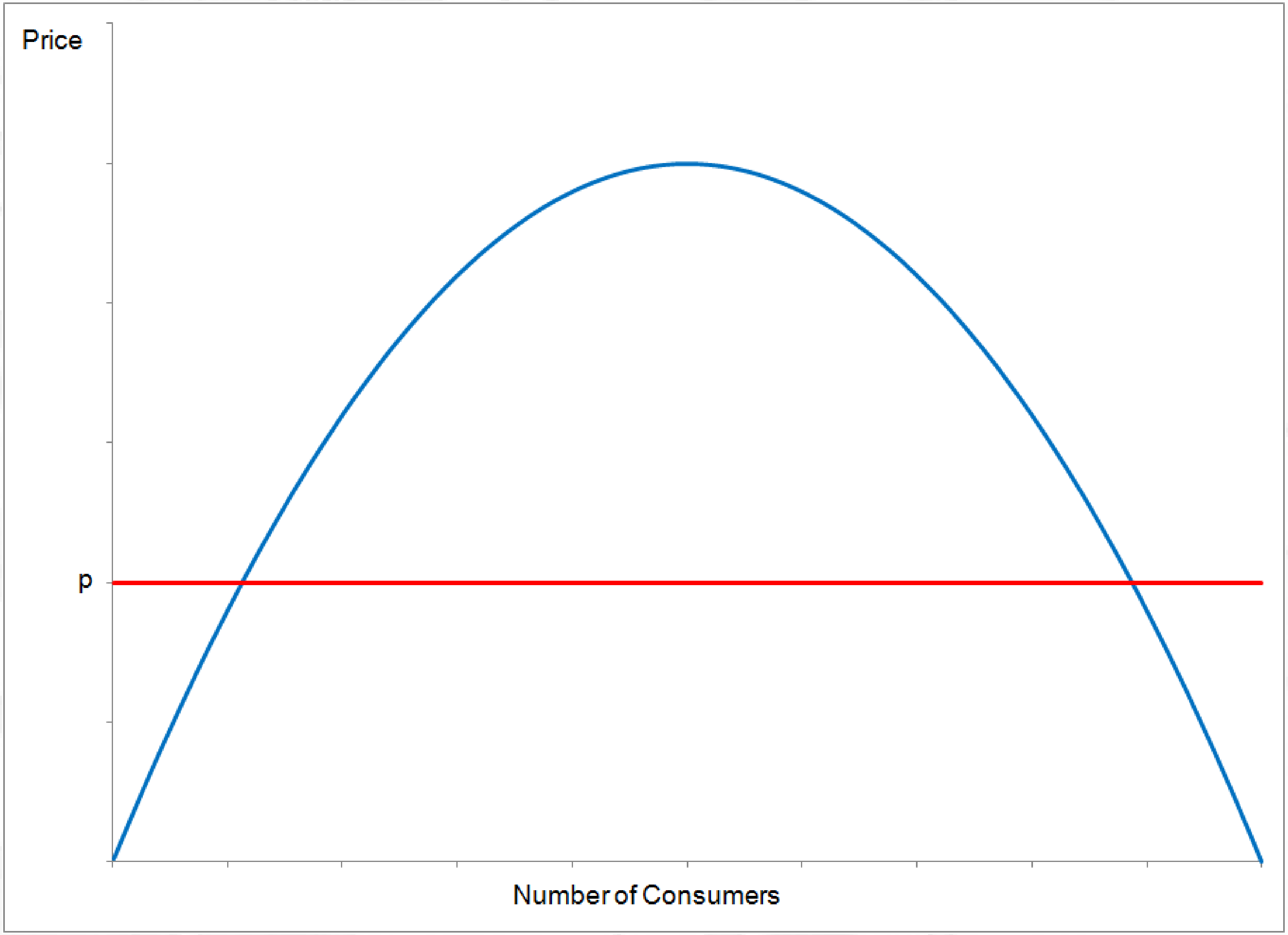
Initially upward sloping (why?)

Value of more users outweighs decrease in marginal v

At high q, the curve looks more normal

Implication: multiple equilibria

Multiple Equilibria



Multiple Equilibria

Three distinct equilibria:

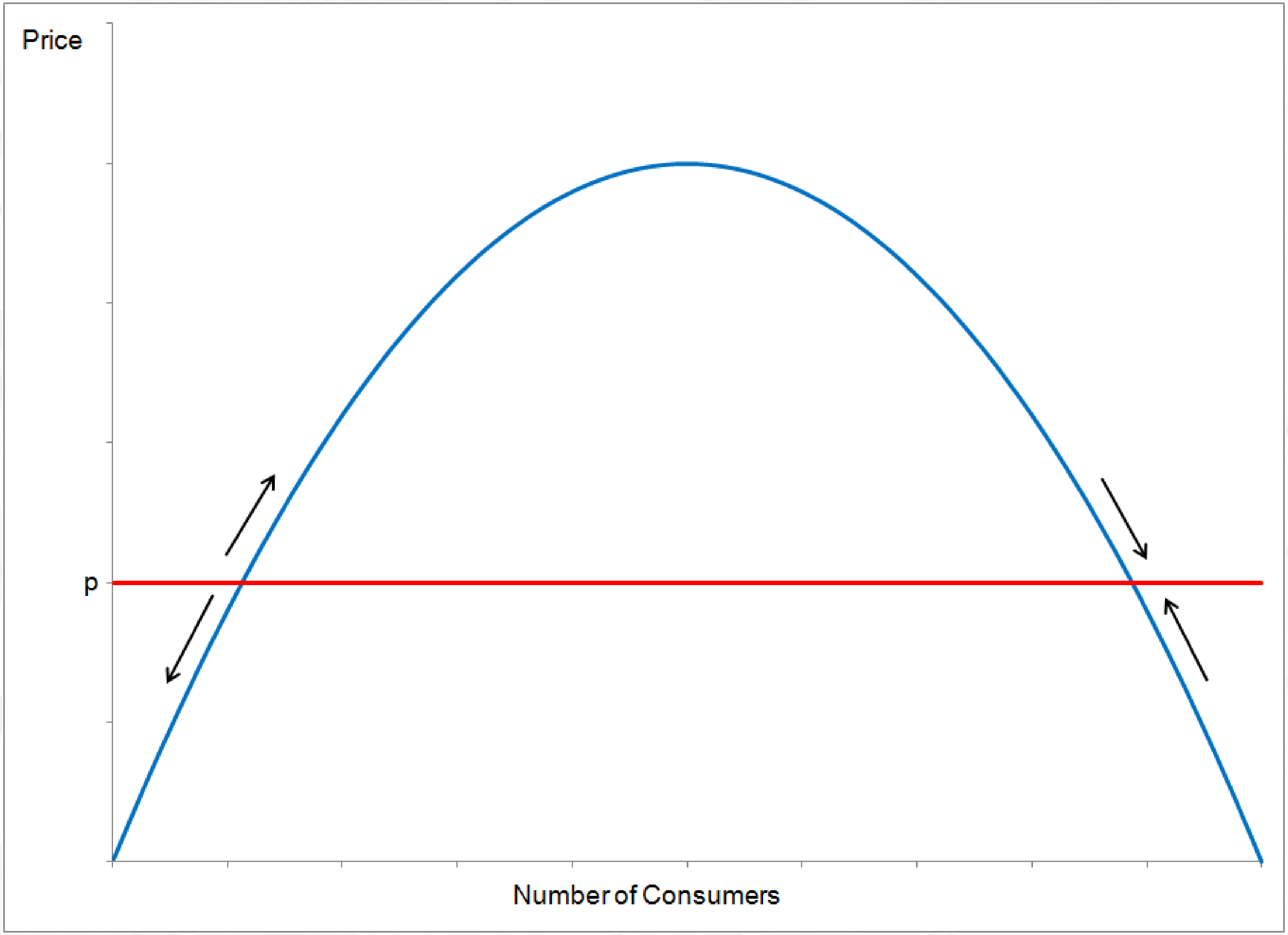
- Non-adoption equilibrium
- Middle equilibrium on upward sloping part
- High equilibrium on downward sloping part

Are any of these equilibria more “reaonsable” than others?

Let’s think about myopic best response dynamics

- Consumers buy in each of many periods
- Observe how many bought last period
- Which equilibria are stable?

A Dynamic Adjustment Process



Stable and Unstable Equilibria

High equilibrium and non-adoption are stable

- Return to same place after a shock
- Middle equilibrium is "tipping point"

Pure network goods face barriers to adoption

- Cold-start problem
- Examples?

A Simple Market with Competition

Two products, A and B, compete for adoption

Customers arrive sequentially and choose one of the two

Value to the next customer depends on previous adopters

When customer t arrives, $N_A(t)$ chose A and $N_B(t)$ chose B

A Simple Market with Competition

Two types of customers

- Type a prefer product A
- Type b prefer product B

If customer t is type a:

- Value product A at $1 + cN_A(t)$
- Value product B at $cN_B(t)$

If customer t is type b:

- Value product A at $cN_A(t)$
- Value product B at $1 + cN_B(t)$

Type of customer t is random

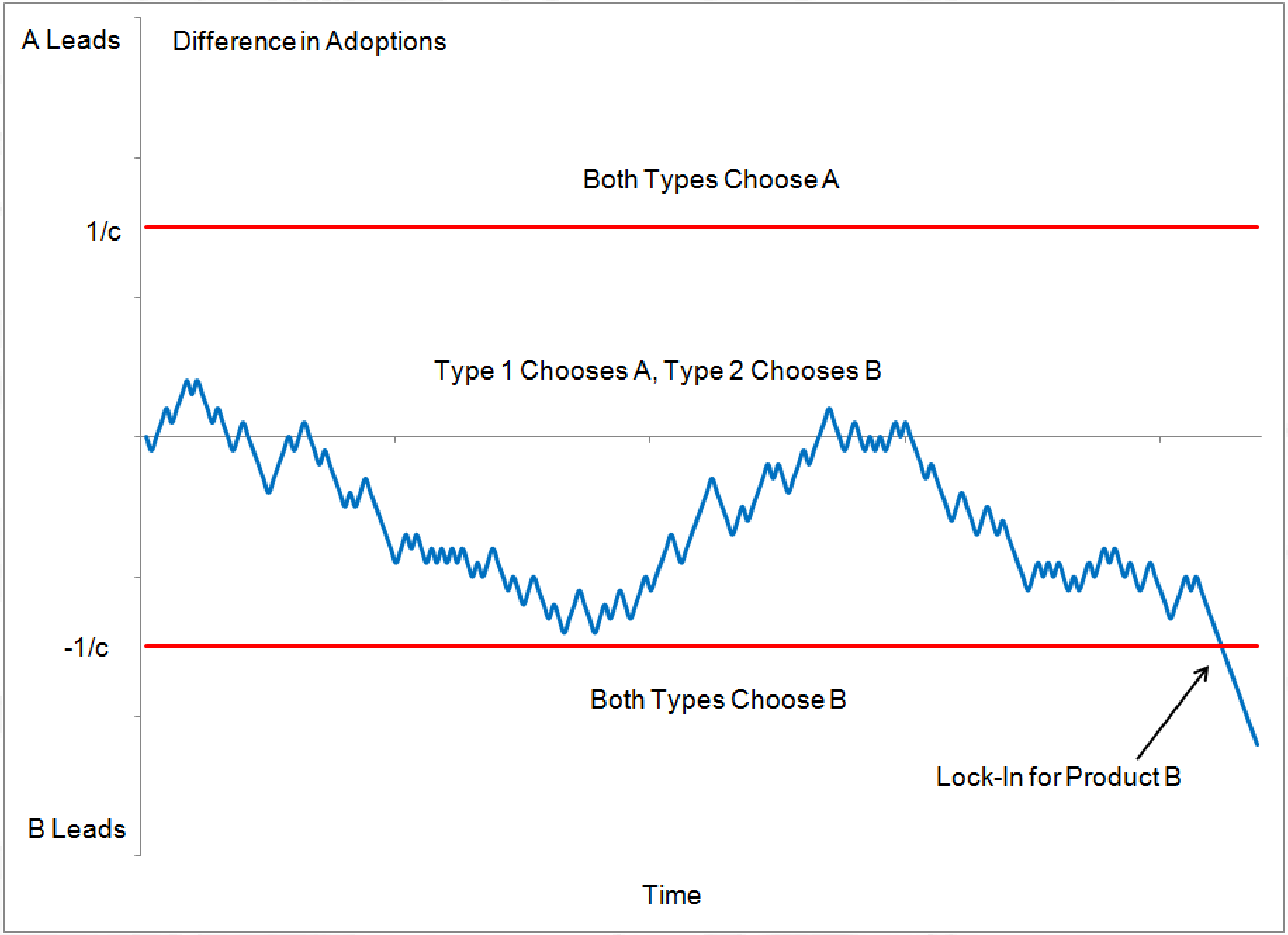
A Simple Market with Competition

Suppose the first 30 customers happen to be type a...

Which product do they choose?

What does the next customer do?

Lock-In


A Leads
Difference in Adoptions
Both Types Choose A
1/c
Type 1 Chooses A, Type 2 Chooses B
-1/c
Both Types Choose B
Lock-In for Product B
B Leads
Time

Lock-In

Product A has large lead $\implies$ both types prefer A

Historical examples:

- The QWERTY keyboard
- Microsoft Windows
- Facebook

Network effects can lead to "winner-take-all" markets

- Best technology doesn't always win

Network Effects in the Labor Market

Old idea in economics: geographic concentration of firms related to geographic concentration of skills

- Why would we have a geographic concentration of skills?

Labor market model based on “Training and Innovation in an Imperfect Labor Market,” (Acemoglu, 1997)

Consider a two-period model with a large population of workers and firms

- Assume one worker per firm

Network Effects in the Labor Market

Each worker initially matched with a firm, per period output y

At start of game, each firm can adopt new technology

- Investment cost k
- Worker retraining cost c
- Return α per period

Wage is fixed fraction $\beta \in (0, 1)$ of total output

With probability $q \in [0, 1)$, each worker and firm separate after period 1

- Separated firms and workers rematch at random for period 2

Network Effects in the Labor Market

First, assume no separation ($q = 0$)

Unique equilibrium in which all firms adopt new technology as long as

$$\beta < 1 - \frac{k + c}{2\alpha}$$

Non-adoption payoff over two periods: $2(1 - \beta)y$

Adoption payoff over two periods: $2(1 - \beta)(y + \alpha) - k - c$

Network Effects in the Labor Market

What if $q > 0$?

Adoption by other firms creates spillovers

- More likely to rematch with qualified worker

Non-adoption payoff unchanged: $2(1-\beta)y$

Adoption payoff if no other firms adopt:

$$(1-\beta)\left[2y + (2-q)\alpha\right] - k - c$$

Adoption payoff if all other firms adopt:

$$2(1-\beta)(y+\alpha) - k - c$$

Network Effects in the Labor Market

If we have

$$1 - \frac{k+c}{(2-q)\alpha} < \beta < 1 - \frac{k+c}{2\alpha}$$

then there exist two pure strategy equilibria

Multiplicity driven by firms' expectations about whether they can fill vacancies with qualified workers

- Expectations are self-fulfilling

Consider an extension with two regions in different equilibria

- A new entrant that wants to use the new technology will choose the region with more adopters

Network Effects in Residential Choices

Large literature studying the role of network effects on neighborhood segregation

Tipping point phenomena: even with very weak preferences to live near own-type individuals, best response dynamics can result in strong segregation over time

- See Thomas Schelling's work on "neighborhood tipping"

Originally studied in the context of black-white racial segregation, but the central insight applies along other dimensions too

Consider academic peer effects: children's education is affected by their classmates

- Parents who care about education may move for a more desirable peer group

Network Effects in Residential Choices

Consider another example, based on Benabou (1992), "The Workings of a City"

We have a population of ex ante identical agents, each of whom can invest in skill

- End up either high-skill or low-skill

Utility of agent i is $U_i = w_i - c_i - r_i$

- Wage w_i
- Cost of education c_i
- Cost of rent in chosen neighborhood r_i

Network Effects in Residential Choices

Cost of education depends on fraction x of high-skill agents in one's neighborhood

- Cost $c_H(x)$ to become high skill, cost $c_L(x)$ to become low skill
- Both are decreasing in x, with $c_H(x) > c_L(x)$, and $c'_H(x) < c'_L(x)$

Last condition means that living near more high skill agents has a larger effect on the cost of becoming high-skill

Since agents are ex ante identical, we have the equilibrium condition

$$U_i(L) = U_i(H)$$

Agents are indifferent between becoming high-skill or low-skill

Network Effects in Residential Choices

Assume the labor market is city-wide, perfectly competitive, and exhibits constant returns to scale

- If ratio of high to low skill workers H/L is high, then ratio of wage rates w_H/w_L will be low
- Ensures equilibrum will include a mixture of types

Assume there are two neighborhoods in the city of equal size

- Individuals compete in the housing market to locate in one neighborhood or another

Network Effects in Residential Choices

Two types of equilibria: integrated and segregated

Integrated equilibrium: both neighborhoods contain same fraction $\hat{x}$ of high-skill agents, rents are equal

- Assuming individuals are small, no incentive to deviate since neighborhoods are identical

Segregated equlibrium: one neighborhood is homogeneous

- Could either have $x = 1$ and $\tilde{x} < 1$, or $x = 0$ and $\tilde{x} > 0$

Key observation: only segregated equilibrium is stable under myopic best response dynamics

- Starting from an integrated equilibrium, what happens if we move a fraction ϵ of high-skill agents from neighborhood 1 to neighborhood 2?

Network Effects in Residential Choices

The change reduces the cost of education in neighborhood 2

Increases incentive of high-skill agents to live in neighborhood 2

- Will pay higher rents and willing to outbid low-skill agents to live there

Segregation arises as unique stable equilibrium because of complementarities

- Recall the agents were identical to start

Next time: local network effects