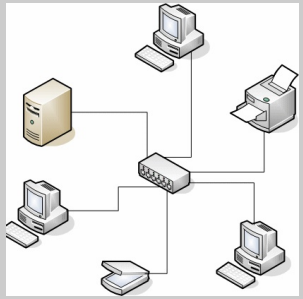
NETWORKS

Networks

- There are many types of networks and network effects
  - Physical: computers, railways
  - Social: online, family
  - Network externalities: value depends on # users
- Different fields, different (overlapping) refs, focus
- Economics is interested in
  - structure and dynamics of networks as graphs
  - implications of network externalities for firm strategy and market performance



Network externalities

- Definition: *each consumer's valuation is increasing in the number of other consumers*
- Direct NE: telephones, email, languages
- Indirect NE: computer operating systems (software), automobiles (servicing); virtual networks
- Tariff-mediated NE: bank ATMs, cell phone plans

The restaurant problem

- Yogi Berra re Ruggeri's (a St. Louis restaurant): "Nobody goes there anymore; it's too crowded"
- Seriously, it should be either
  - Nobody wants to go there because it's always empty
  - Everybody wants to go there because it's always full of people
- Network effects may imply multiple fulfilled-expectations equilibria: some restaurants are "in", some are "out"

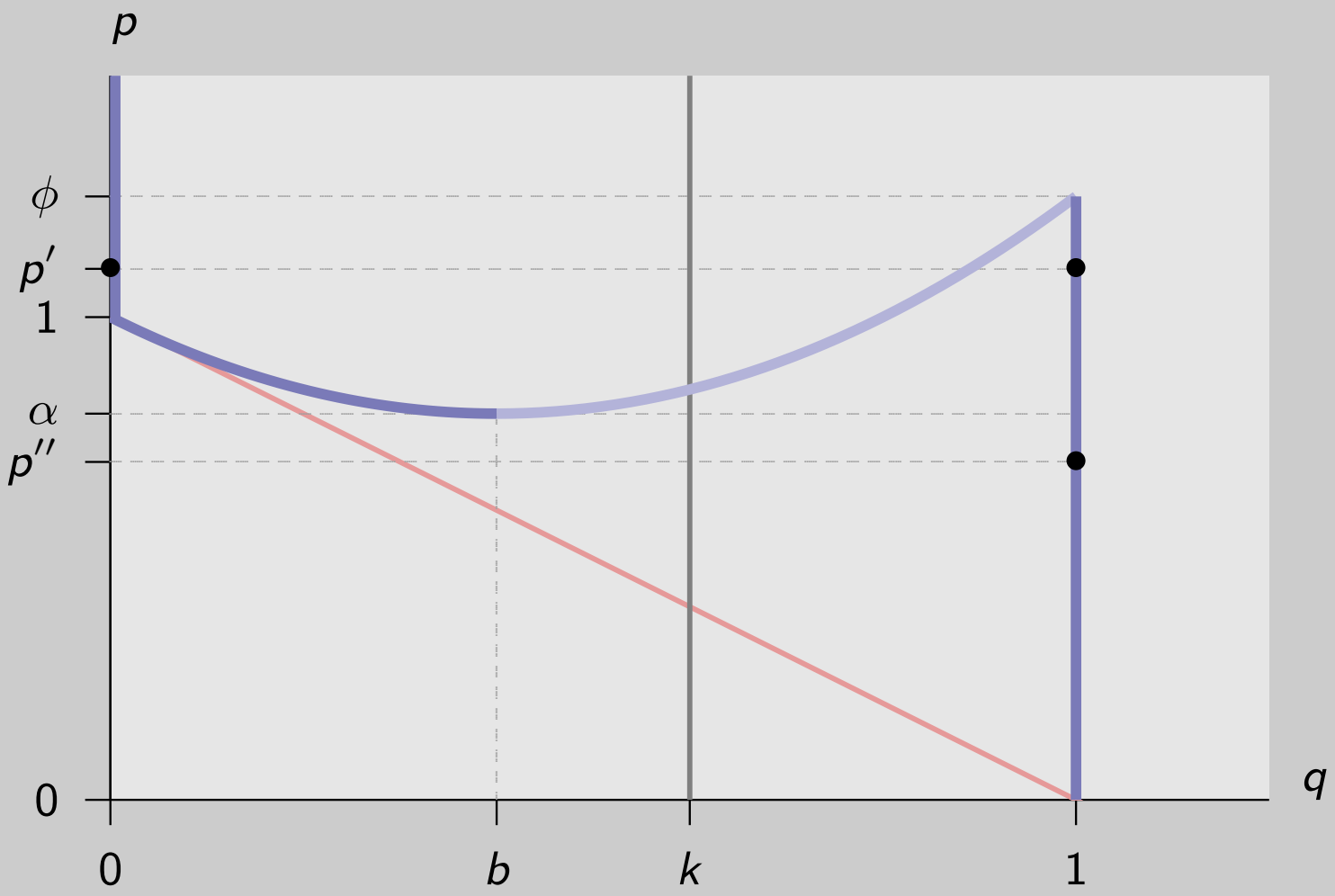
The restaurant problem

- consumer valuation: $v = u + \phi\, e^2$, where
  - u uniformly distributed in [0,1]
  - e: expectation regarding # consumers
- If u' is lowest u who goes to restaurant, $q = 1 - u'$ go.
- Fulfilled expectations: $e = 1 - u'$
- Indifferent consumer: $u' + \phi\, e^2 = p$, or $u' + \phi\,(1 - u')^2 = p$
- Since $q = 1 - u'$,

$$p = 1 - q + \phi\, q^2$$

- Contrast $\phi = 0$ with $\phi > 0$

The restaurant problem



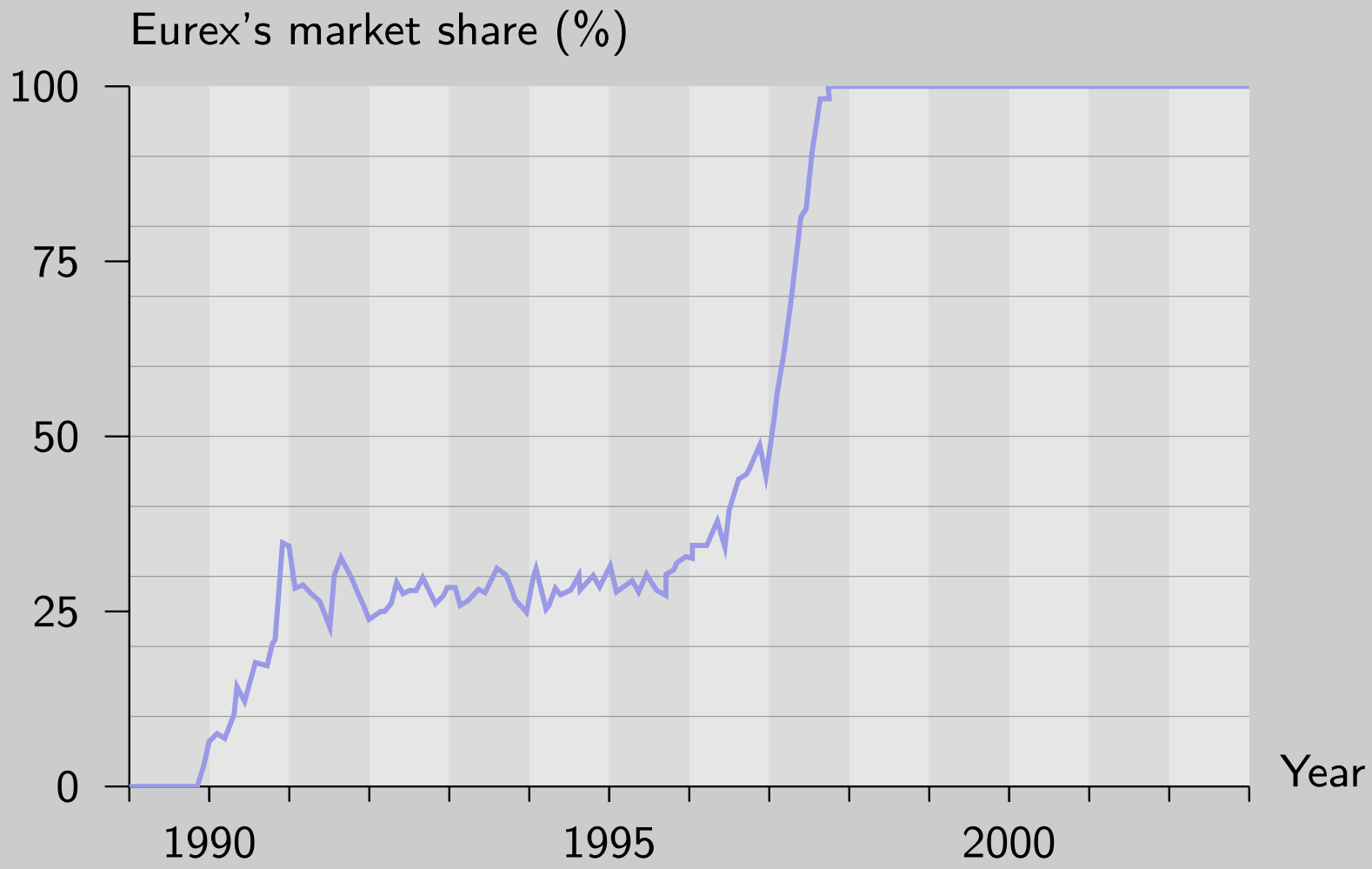
Fulfilled-expectations equilibrium

- Network effects may imply multiple demand levels for a given price
- Which value takes place depends on consumers' expectations regarding network size
- Unstable equilibria and tipping
- Pricing and capacity decisions with multiple equilibria

The Battle of the Bund

- London International Financial Futures and Options Exchange (LIFFE): derivatives exchange est. 1982
- Items traded include future contracts on the Bund (German government bonds)
- Deutsche Terminbörse (DTB): based in Frankfurt, established January 1990; also trades Bund contracts
- Liquidity creates net effects, favors LIFFE (70% share)
- DTB follows aggressive strategy; market share gradually increases
- Once "tipping point" is crossed, DTB snowballs into monopoly

The Battle of the Bund



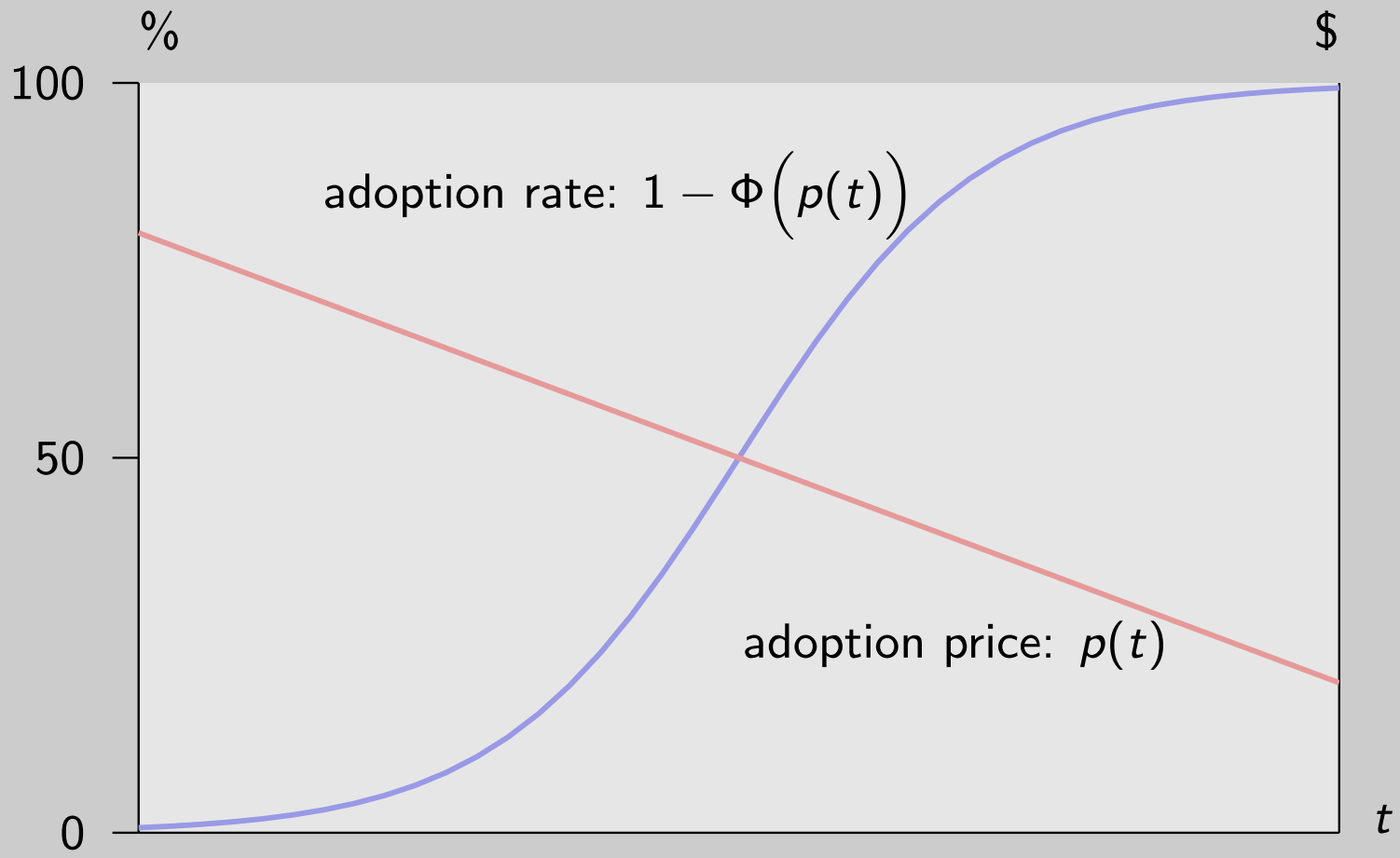
Theories of innovation adoption

- Most innovations follow an S-shaped path
- Theory 1 (**diffusion**): agent heterogeneity
  - High valuation users go first; S curve from cdf
  - Example: hybrid corn
- Theory 2 (**epidemic**): word of mouth, social networks
  - matching informed, uninformed users; logistic S
  - Example: Google mail
- Theory 3 (**catastrophe**): networks externalities
  - value increasing in # other users; S from discontinuity
  - Example: fax machines

Innovation diffusion

- Benefit from adoption: $u \sim \Phi(u)$
- Cost from adoption: $p(t)$
- Adoption by time t: $x(t) = 1 - \Phi\big(p(t)\big)$
- As $p(t)$ declines, additional users adopt innovation
- If $p(t)$ is approximately linear, then $x(t)$ follows an S-shaped path — just like $\Phi(\cdot)$

Adopter heterogeneity and nnovation diffusion



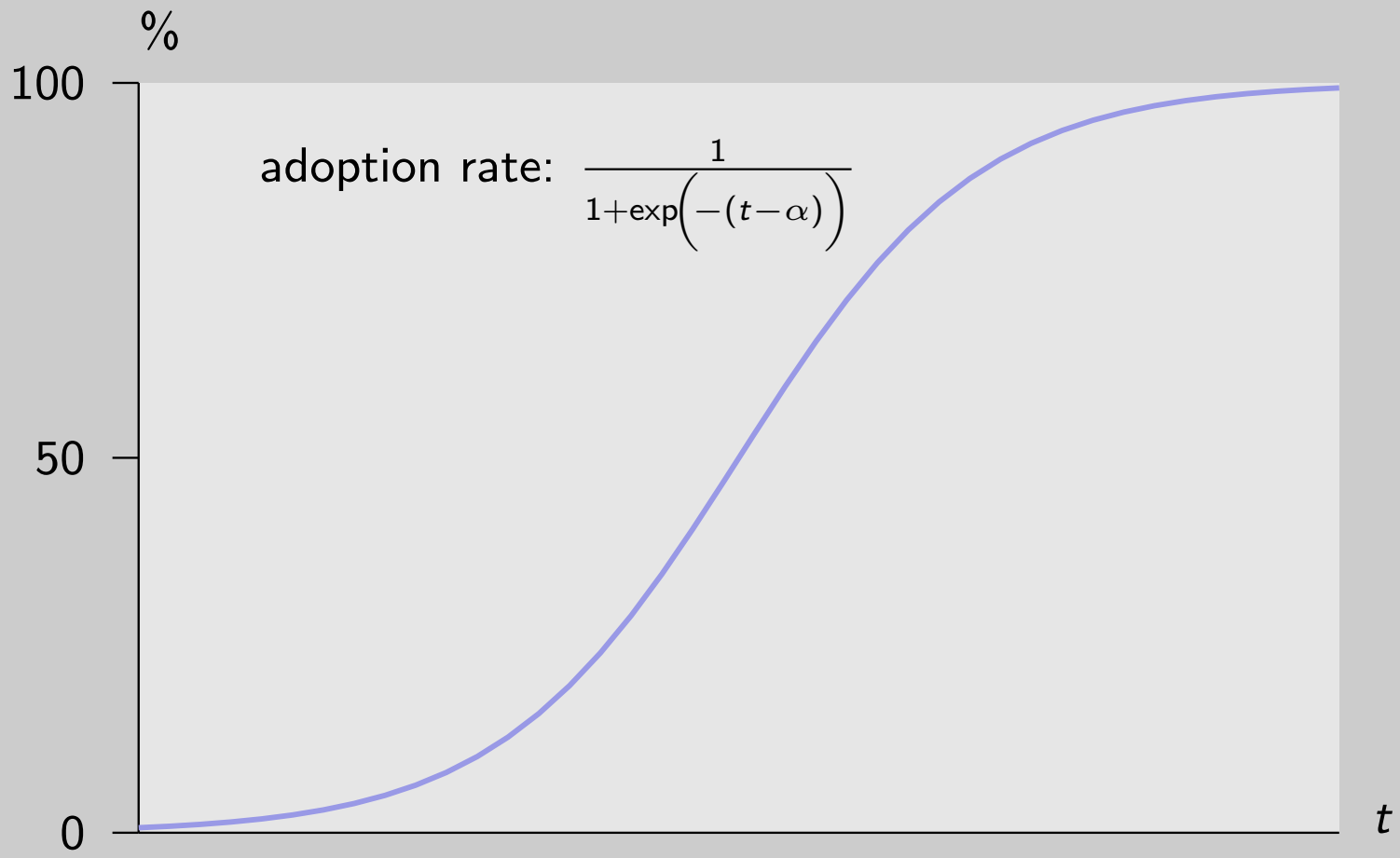
Word of mouth and innovation adoption

- Gmail is available but very few potential users know about it: at time t_0, a fraction x_0
- Each period, two email users meet
  (a) one know Gmail, the other does not: new "convert" to Gmail
  (b) neither knows about Gmail: nothing happens
  (c) both know Gmail account: nothing happens
- This implies

$$x_t = \frac{1}{1 + \exp\big(-(t - \alpha)\big)}$$

where $\alpha = t_0 + \ln(1 - x_0) - \ln(x_0)$

Word of mouth and innovation diffusion



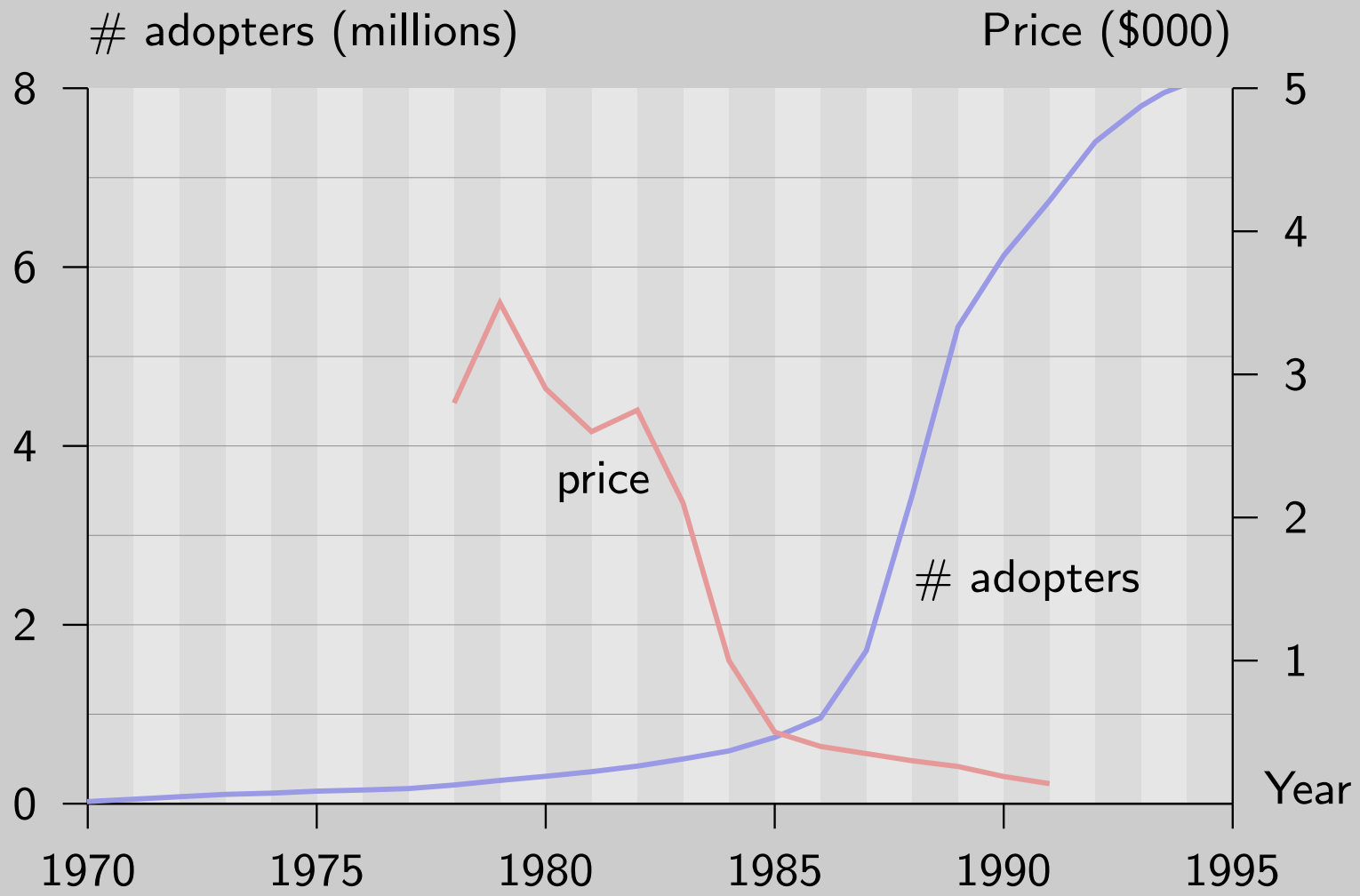
Technology adoption as a coordination game

- It's only worth having a fax machine if others have a fax machine too (before Internet)
- In game theory terms, this is equivalent to the coordination game

		Player 2: Old	Player 2: New
Player 1	Old	1, 1	0, 0
	New	0, 0	2, 2

- Strong network externalities imply multiple equilibria

Adoption of fax machines in US



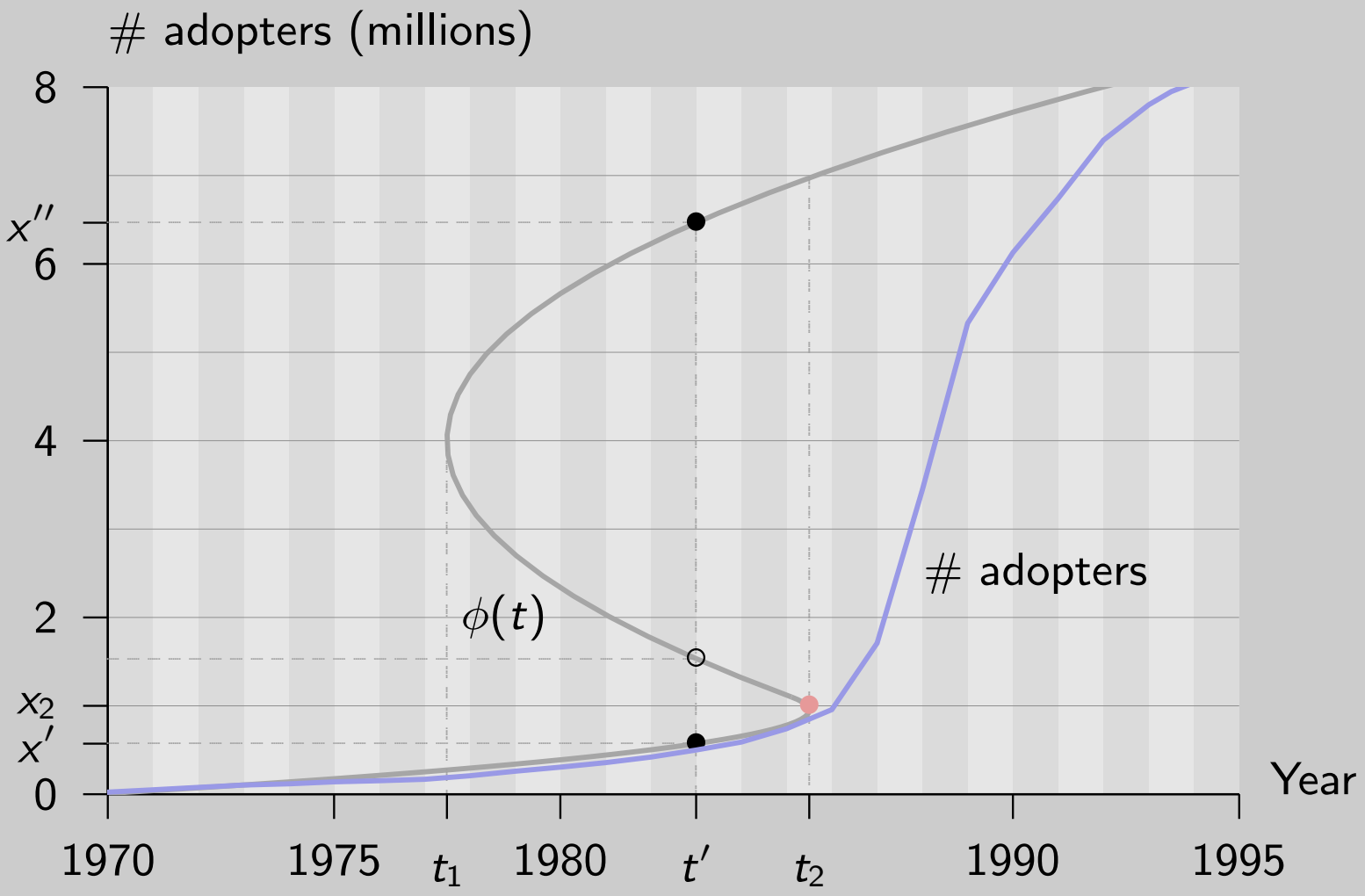
Innovation adoption with network effects

- Adoption benefit: $u + \psi(x)$
- $u \sim$ cdf $\Phi(u)$
- $p(t)$: adoption price
- A: # potential adopters
- $x(t)$: # actual adopters at time t
- u': indifferent adopter's value of u; all with $u > u'$ adopt

$$u' + \psi\big(x(t)\big) = p(t)$$
$$x(t) = A\left(1 - \Phi(u')\right)$$

- $\phi(t)$: equilibrium values of x at time t

Adoption of fax machines in US



Fax machines in US: summary

- From about 1980 to about 1987, there are two fulfilled-expectations equilibria (chicken and egg)
- If expectations are given by latest observation, then up to about 1987 industry follows low equilibrium
- At about 1987, a critical mass (tipping point) is achieved
- For a brief period of time, system in disequilibrium (snow-ball): buyer expectations exceeded
- New, higher adoption equilibrium is eventually reached

Inertia and tipping

- Consider a new product or technology: will it be adopted too quickly or too slowly?
- Excess inertia: nobody buys it because nobody buys it (multiple equilibria)
- Excess momentum: market tips very quickly towards new product even when it does not represent a great improvement

Excess inertia

- Users 1 and 2 simultaneous choose old or new version
- Old version worth a_i $(i = 1, 2)$, New version worth b_i
- Switch from Old to New costs c_i
- Network effects: each version useless unless other player chooses same version

Excess inertia

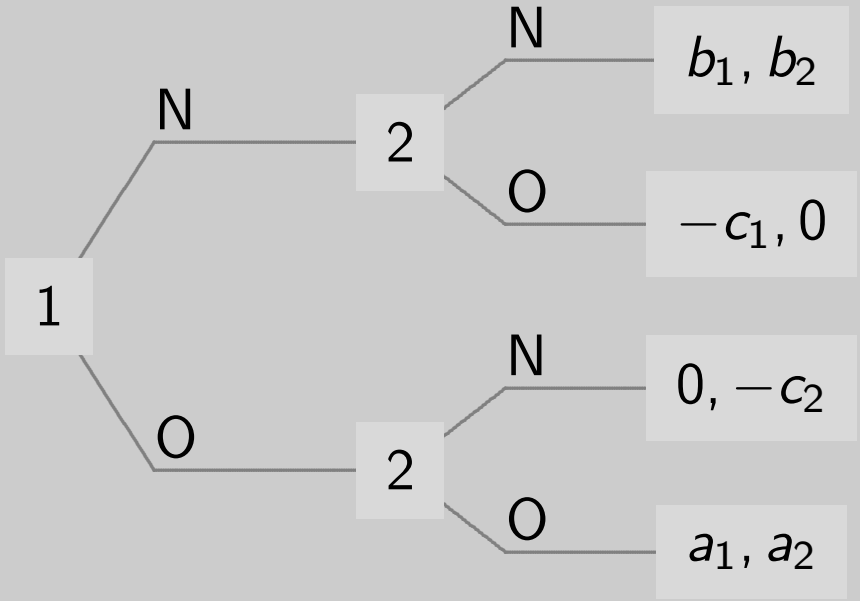
User 1 \ User 2	O	N
O	a_2 a_1	$-c_2$ 0
N	0 $-c_1$	$b_2 - c_2$ $b_1 - c_1$

Excess inertia

- $b_i - c_i > a_i \Rightarrow (N, N)$ eq'm Pareto dominates (O, O) eq'm
- Suppose $b_i = 2\,c_i$ and that c_i is very large
- Switching from O to N = "lottery" yilding $-c_i$ or $+c_i$ (depending onother player's choice)
- Reasonable to assume (O, O) eq'm will play out

Excess momentum

- Sequential game; $b_1 \gtrsim a_1$; $b_2 \gtrsim 0$
- Subgame perfect eq'm: choose version b
- Since $b_1 \approx a_1$ and $b_2 \approx 0$, $b_1 + b_2 < a_1 + a_2$



Excess momentum

- Equilibrium: both switch to new technology
- Total payoff before switch $= 2\,v_0$
- Total payoff after switch $\approx v_0$
- Intuition:
  - Lead adopter has small benefit, imposes huge loss on second adopter
  - Second adopter is better off with new technology *given that* first adopter adopts new technology
- Terminology: bandwagon effect, domino effect, snow-ball effect

Inertia and tipping

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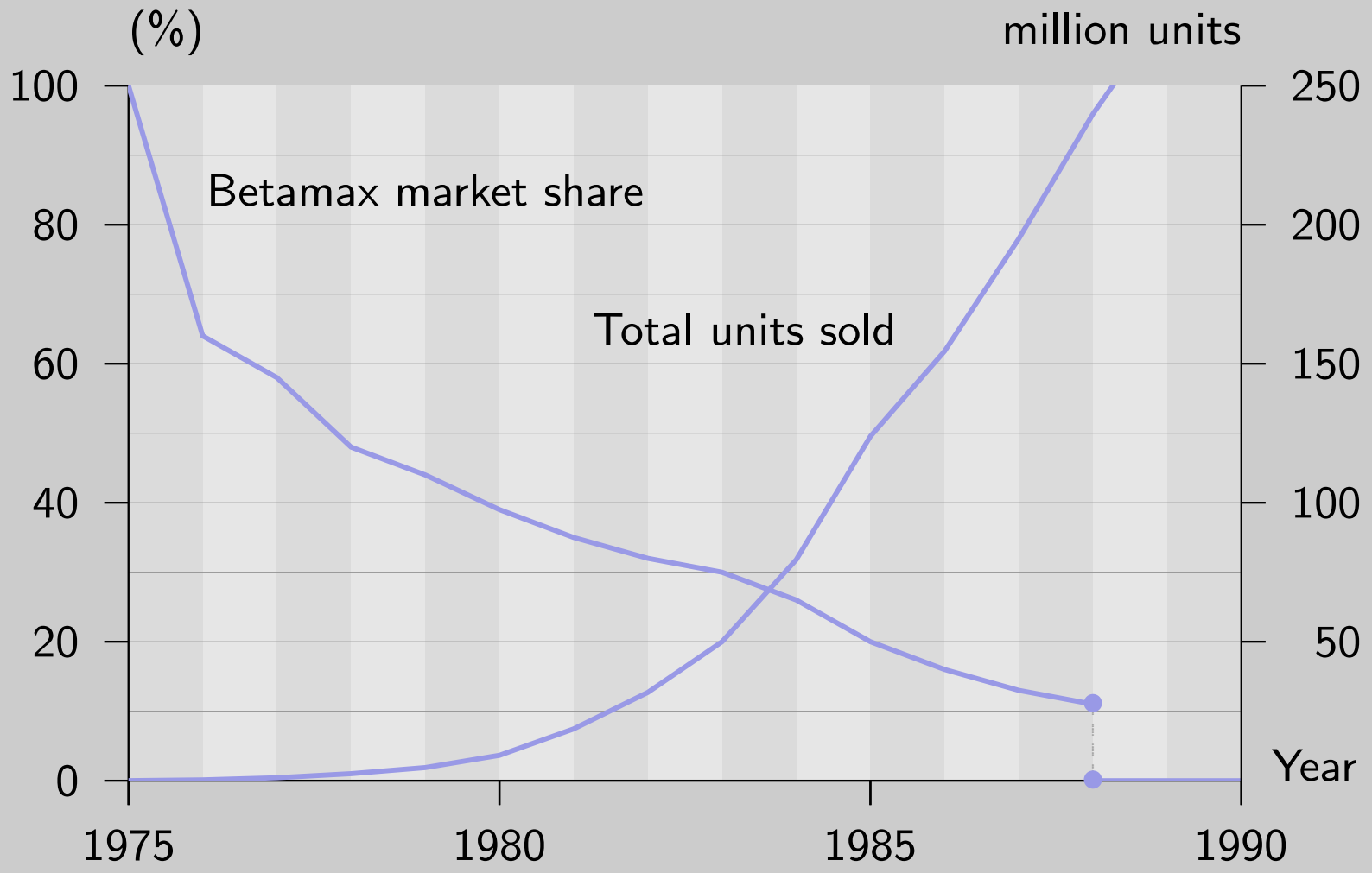
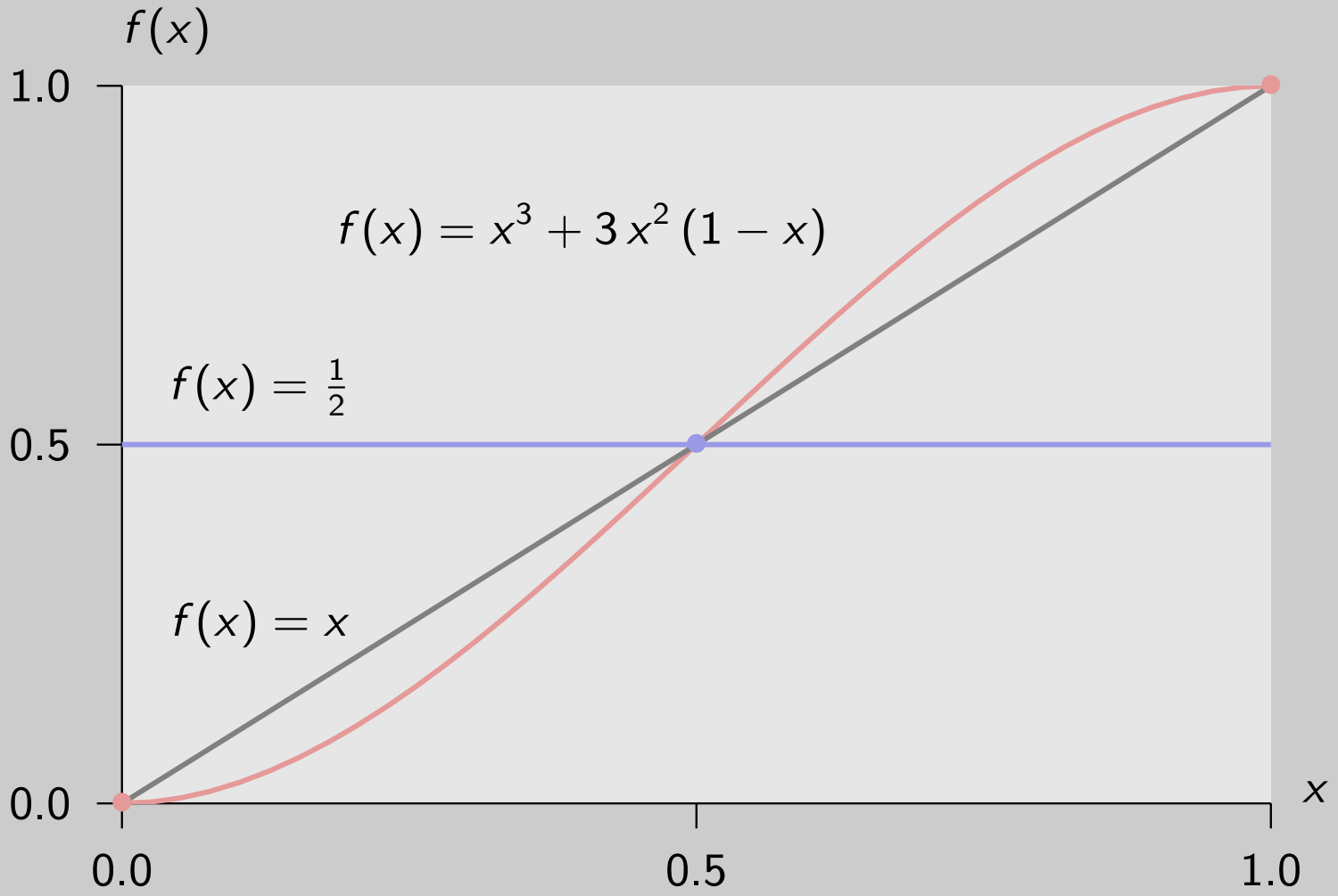
VHS v Betamax



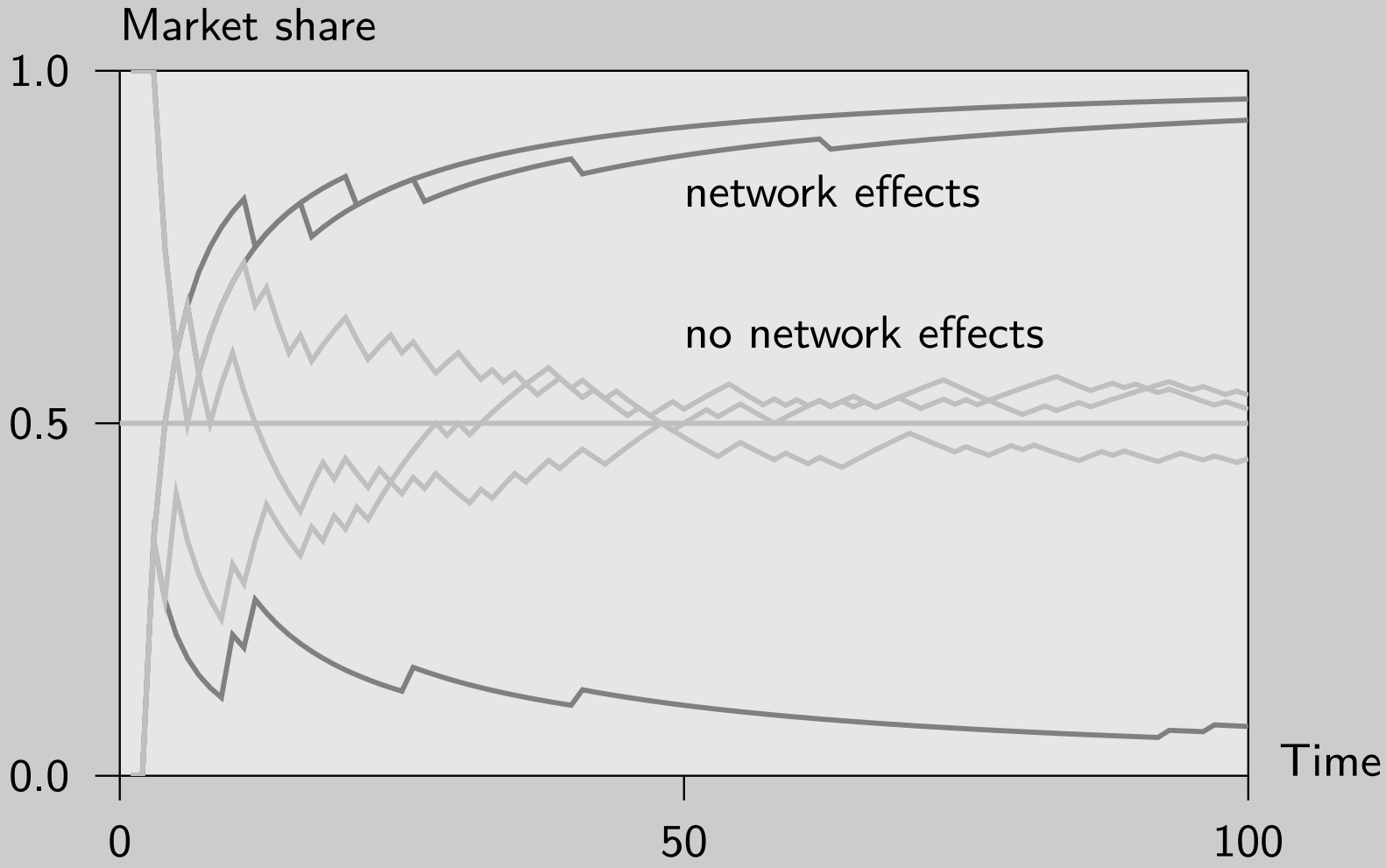
Standards wars

- Two versions of a new technology: blue and red
- Adopters arrive sequentially
  - No network effects: flip a coin
  - Network effects: poll 3 of the past adopters; follow majority
- What happens to the fraction $x(t)$ of blue adopters?
- Theorem: converges almost surely to a stable fixed point of $f(x)$, the probability next ball is blue given current fraction of blue balls

Adoption probability

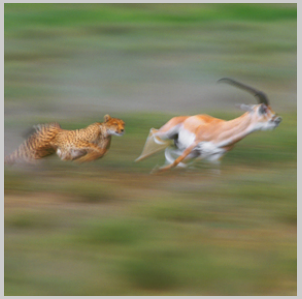


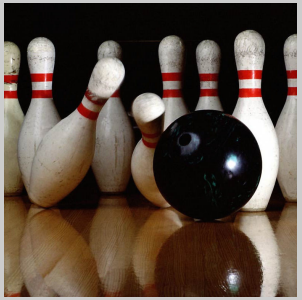
Standards wars



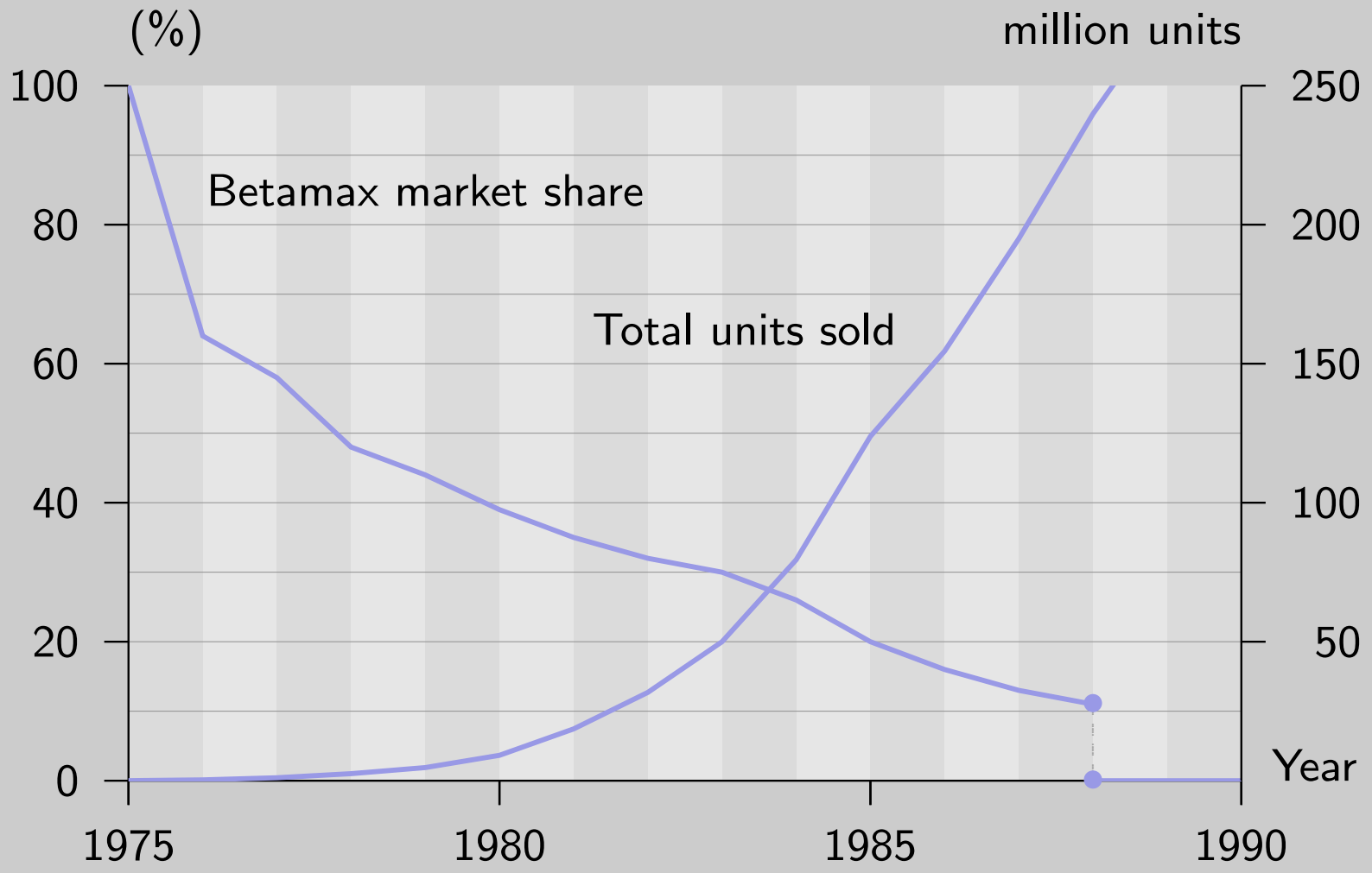
Standards wars

- Eventually, one design takes over the entire market, while the other is "orphaned:" self-reinforcing dynamics, snow-ball effects.
- The winning technology is not necessarily the best or the one preferred by most consumers; the fittest does not necessarily survive.
- The ultimate outcome of the battle depends on a series of "small historical events;" the outcome is path dependent.





VHS v Betamax

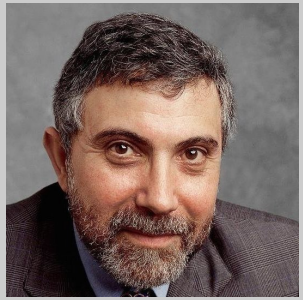


Examples

- Videocassette recorder
- gasoline engine
- QWERTY keyboard
- NB: interpretation of these examples highly controversial

Viral processes and superstars

- Vanishing middle: feature of the "new economy"
- Improved search cheaper production: embarrassment of niches (a.k.a. the long tail)
- At opposite end: supermegablockbusters: combination of social networks, globalization
  - Media (music, movies, books, newspapers)
  - Some professions (CEOs, medicine)
- How do superstars emerge?



Network externalities and social networks

- So far, assumed very simple network structure: each user is equally likely to connect to any other user
- In practice, networks has very specific structure
- Example #1: video game standards have different shares of different demographics
- Exmaple #2: diffusion of Facebook shows that it's not just # users that matters

Takeaways

- Network effects crop up everywhere; they can lead to excess inertia, and may allow small seemingly random events to influence ultimate outcome