Innovation diffusion and network externalities

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Issues

- Adoption of innovations (diffusion) slow and gradual
- Diffusion = share of adopters on total population of potential adopters
- Sigmoid (S-shaped) paths of diffusion
- Different innovations diffuse at different rates
- Similar innovations diffuse at different rates (in different regions)

⇒ We focus on process innovations (capital goods)

Diffusion models

1) Approach based on <u>information</u> → epidemic models

2) Approach based on <u>incentives</u> → 'threshold' (probit) models

3) Competition among alternative technologies → increasing returns to adoption models

1) Approach based on information

- *Non-economic studies* (marketing, psichology, sociology, anthropology)
- non-industrial innovation (agricultural, medical, cultural)
- innovation superior to existing alternatives
- question: 'why it is not adopted immediately?'
- answer: 'because not all potential adopters are aware of its existence / performance'
- diffusion = information (on existence/performance)

⇒ diffusion path depends on the source of information

Source of information

INTERNAL – Epidemic models

Inter-personal communication (word-of-mouth) between adopters and non-adopters (non-codifiable knowledge)

Epidemic process: probability of being 'informed' increases with the number of adopters… ….but less and less 'non-informed' subjects remain as diffusion proceeds

EXTERNAL – Other models

External source of information (media, government, suppliers)

(codifiable knowledge)

Information not dependent on the number of adopters (level of diffusion)

What's wrong with this approach?

LACK OF MICROFOUNDATIONS

- profitability of adoption differs from firm to firm – need to model individual choices of adoption
- in epidemic models, slowness of diffusion not dependent on lags of individual adoption – "WHO ADOPTS FIRST and WHY"?
- profitability of adoption changes over time (learning, incremental innovations, etc.)

Probit models

1) LESS EMPHASIS on INFORMATION and MORE ON INCENTIVES

- Diffusion 'slow' not because lack of information, but because innovation not necessarily better (profitable) than existing alternatives
- Diffusion process not as dissemination of information, but as process in which innovation and competitive conditions change in ways that make adoption profitable

2) FIRMS AS RATIONAL (OPTIMISING) AGENTS

- At any time t all firms for which adoption is profitable have actually adopted
- Firms that have not yet adopted the innovation are not 'ill-informed', but are simply waiting for the optimal adoption date

3) EMPHASIS ON FIRMS' HETEROGENEITY

- Size
- Specific needs

Probit ('threshold') model (David, 1969)

('Mechanical reaper' USA XIX° century)

Adoption benefits:

'Labour-saving' innovation: [$a = L/S$ input coefficient]

a_0: old (hand) technique --- a_1: mechanical reaper
where $a_0 > a_1$

- Given wage rate w, savings per unit of land:

$$w\,(a_0 - a_1)$$

- Given the size of farm (land extension) Si, total savings for farm i:

$$S_i\, w\,(a_0 - a_1)$$

Adoption costs:

(price of mechanical reaper + installation) = p
cost of adoption = p

Further assumptions:

a) price of output given (the innovation does not increase output, constrained by available land) ;

b) 'myopic' expectations

→ each firm decides to adopt if adoption benefits are greater than adoption costs

$$p \leq [S_i\, w\,(a_0 - a_1)]$$

Critical (threshold) size:

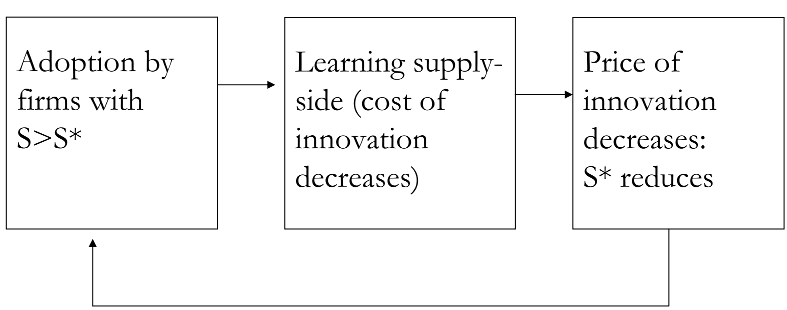
$$S_i \geq \frac{p}{w(a_0 - a_1)} \equiv S^*$$

- Why is diffusion slow? Because at time t, only few firms reach the 'critical' size. Larger firms are the first to adopt.

- What determines diffusion?
- Reduction of critical size ($p\downarrow$, $w\uparrow$, $a\downarrow$)
- and/or shift of firm size distribution ($S_i\uparrow$)

$w\uparrow$ $S_i\uparrow$ (exogenous) -- $a\downarrow$ $p\downarrow$ (endogenous → **supply-side**)

Diffusion, critical size and learning



Implications

- **Importance of firm heterogeneity**: the more similar are firms, the faster the diffusion process. Firms heterogeneity is the key variable explaining the slow (non instantaneous) process of diffusion
- **Importance of technological expectations**: expectations of improvements in capital good will slow down the diffusion process and learning on the supply-side
- **Importance of market structure and strategies of suppliers**:

Competition among alternative technologies with increasing returns to adoption

Some technologies/products/services become more attractive- more developed, more useful- the more they are adopted:

- *Direct effects* (e.g. telecom networks, fax, e-mail, internet)
- *Indirect effects*: Complementary assets, post-sale services, assistance etc.

Knowledge-based
vs.
traditional industries

- High sunk costs relative to unit production costs
- Network externalities and increasing returns to adoption
- Switching costs and consumers lock-in

→ Strong market selection and tendency towards concentrated market structures

Competition among technological systems
(e.g. DOS vs. Apple)

- Two *new* and *incompatible* technologies (A , B)
- Both technologies *unsponsored*
- *N* potential adopters
- Adopters *heterogeneous*: N/2 have *natural preferences* for technology A, N/2 have *natural preferences* for technology B
- *Sequential* adoption: $\forall$ t , only 1 agent ready to adopt
- Type of next adopting agent is random
- Myopic expectations

Returns to adoption

Adopter type "A":

$\alpha + \gamma n_A$ (if adopts A)

$\beta + \gamma n_B$ (if adopts B)

Adopter type "B":

$\alpha + \gamma n_B$ (if adopts B)

$\beta + \gamma n_A$ (if adopt A)

n_i = number of adopters of technology *i* so far

$\alpha > \beta \Rightarrow$ absolute benefit

$\gamma n \Rightarrow$ relative benefit

Adoption choice

Type "A" adopter at time *t* adopts technology A if:

$$\alpha + \gamma n_A > \beta + \gamma n_B$$

$$(\alpha - \beta) > \gamma(n_B - n_A)$$

else adopts technology B.

If at time *t*: $(\alpha - \beta) < \gamma(n_B - n_A)$

from then on all adopters, <u>indipendently on their type</u>, will adopt technology B

$\Rightarrow$ *self-reinforcing process*

Lock-in

- If at time *t* :

$(\alpha - \beta)/\gamma > (n_B - n_A)$ **<u>and</u>** $(\alpha - \beta)/\gamma > (n_A - n_B)$

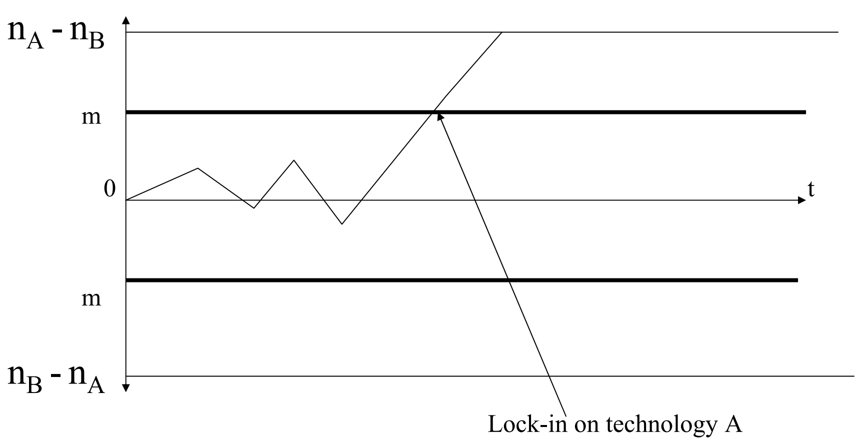
$m > (n_B - n_A)$ **<u>and</u>** $m > (n_A - n_B)$

$- m < (n_A - n_B) < m$

→ the next adopter will adopt will adopt "preferred" system

- If at time *t* , $m < (n_A - n_B)$, *lock-in* on technology A
- If at time *t* , $m < (n_B - n_A)$, *lock-in* on technology B

Adoption and lock-in



Outcome of competition

- One technology dominates the market (*lock-in* and *standardisation*)
- Which one dominates depends on the "path" of adoption (*path-dependence: history matters*)
- Multiple equilibria and unpredictability *ex-ante*
- Possibile inefficiencies of equilibrium (e.g. $\gamma_A > \gamma_B$)

❑ Cases: QWERTY, Ms-DOS, Betamax vs. VHS

Extensions of model

- Importance of consumers' expectations
- Importance of price to build a "critical mass" of users
- Problems of co-ordination on the demand side (*excess inertia* and *excess momentum*)
- Sponsorship: strategic interaction on the supply side (choice of compatibility)

Compatibility

- Increase consumers' welfare, solves problem of *angry orphans*
- For firms, compatibility implies trade-offs:

❍ Battle for proprietary standard: high profits (if success) vs. need to invest large resources and high probability of failing

❍ Compatibility: increases probability of adoption, but causes a more intense competition and therefore lower profits

⇨ Depending on the type of technology, we may expect firms either to agree upon a common standard or to engage in a battle for standards

Trade-off compatibility-competition

- Two-stages game:
- t_0: choice of compatibility → battle for standard → only one standard selected
- t_1: competition

- If at t_0 → compatibility: π^D
- If at t_0 → battle: π^W $\pi^L=0$

What strategy gives to firms the highest payoffs? – compatibility or battle?

Battle for standard

		Firm 1	
		Tecn. 1	Tecn. 2
Firm 2	Tecn. 1	8,12	5,4
	Tecn. 2	6,5	10,7

Strong network externalities. Benefits from compatibility offset by intra technology competititon. Expect firms to battle for own standard.

Compatibility

		Firm 1	
		Tecn. 1	Tecn. 2
Firm 2	Tecn. 1	10,10	5,4
	Tecn. 2	6,5	8,8

Strong network externalities. Benefits from compatibility higher than disadvantages from intra technology competition. Expect firms to agree upon a common standard.

Battle for standards

Importance of building an "installed base of users" and contrast growth of rivals (e.g. Netscape vs. Explorer)

- Heavy discounts initially
- Management of intellectual property rights
- Strategic alliances and partnerships (software, games)
- Vertical integration
- New products pre-announcements (*vaporware*)
- Importance of consumers' expectations

Implications of network externalities for public policy

1) Avoid lock-in and keep competition open
- support variety and alternative technologies (narrow windows)
- antitrust policy
- facilitate compatibility (e.g. adapters) (angry orphans)
- facilitate standard-setting organisations

2) Policy failures:
- public authorities are subject to private interests
- public authorities are blind giants