Diffusion of Environmentally Beneficial Technology

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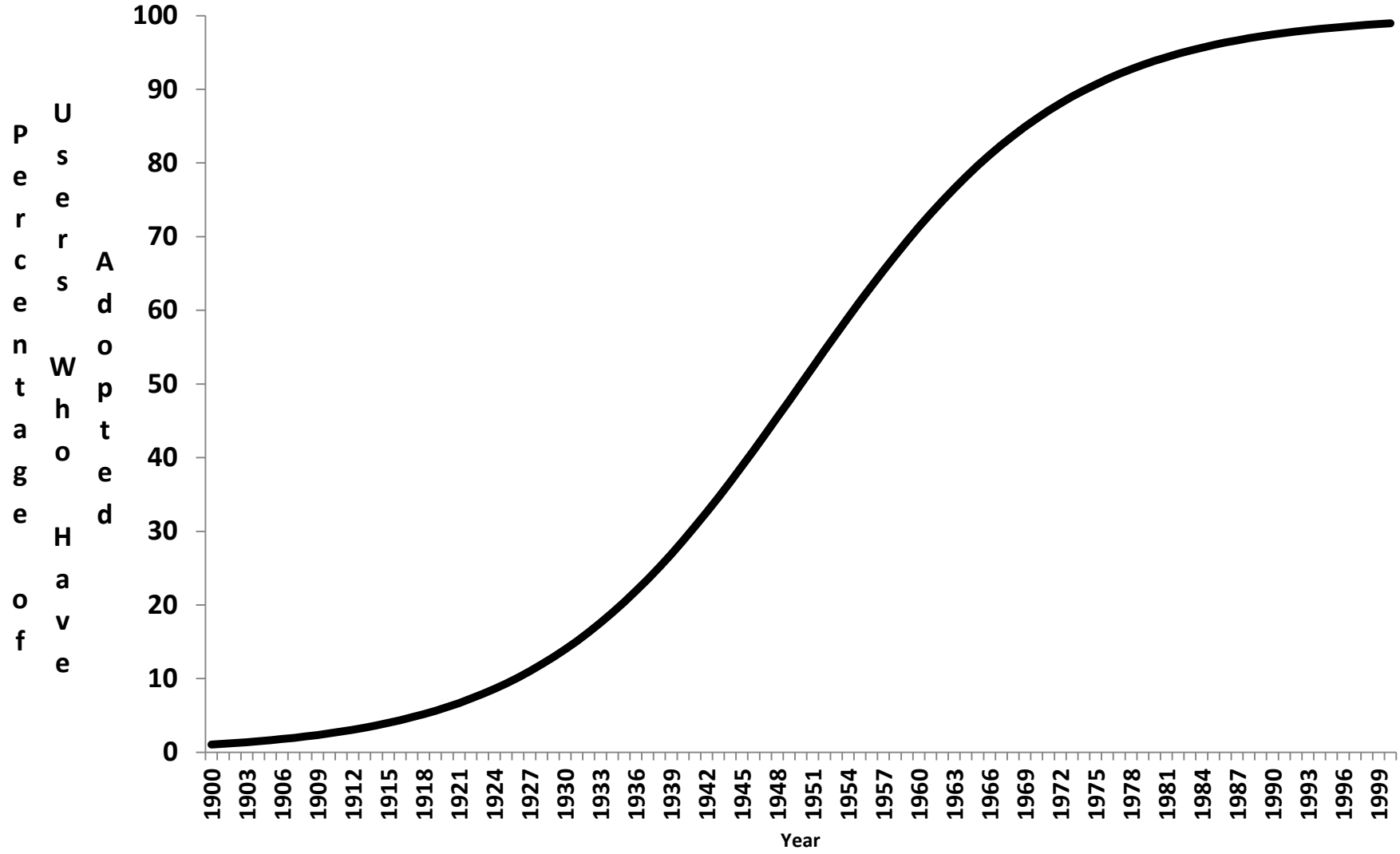
Motivation

- Environmental challenges cannot be addressed at achievable cost without new technology (broadly defined)
- Frequent discussion of “paradox” of low uptake of cost-effective technologies
- Double externality:
  - Adoption of new technology constrained by information
  - Act of adoption generates information for other users, hence a positive externality
- Very salient in agriculture
- At the heart of sustainable development

Background

- Define: Adoption; Diffusion; Technology transfer
- S-shaped (logistic) diffusion curve
- Diffusion typically slow: electric motor; computer
- Two complementary models:
  - Heterogeneous adopters
  - Spread of information
- Market failures: information; principal/agent; capital market imperfections; network/lock-in effects
- Uncertainty; option value of waiting
- Behavioural effects: framing; “irrational” treatment of future costs and benefits

Typical Diffusion Curve



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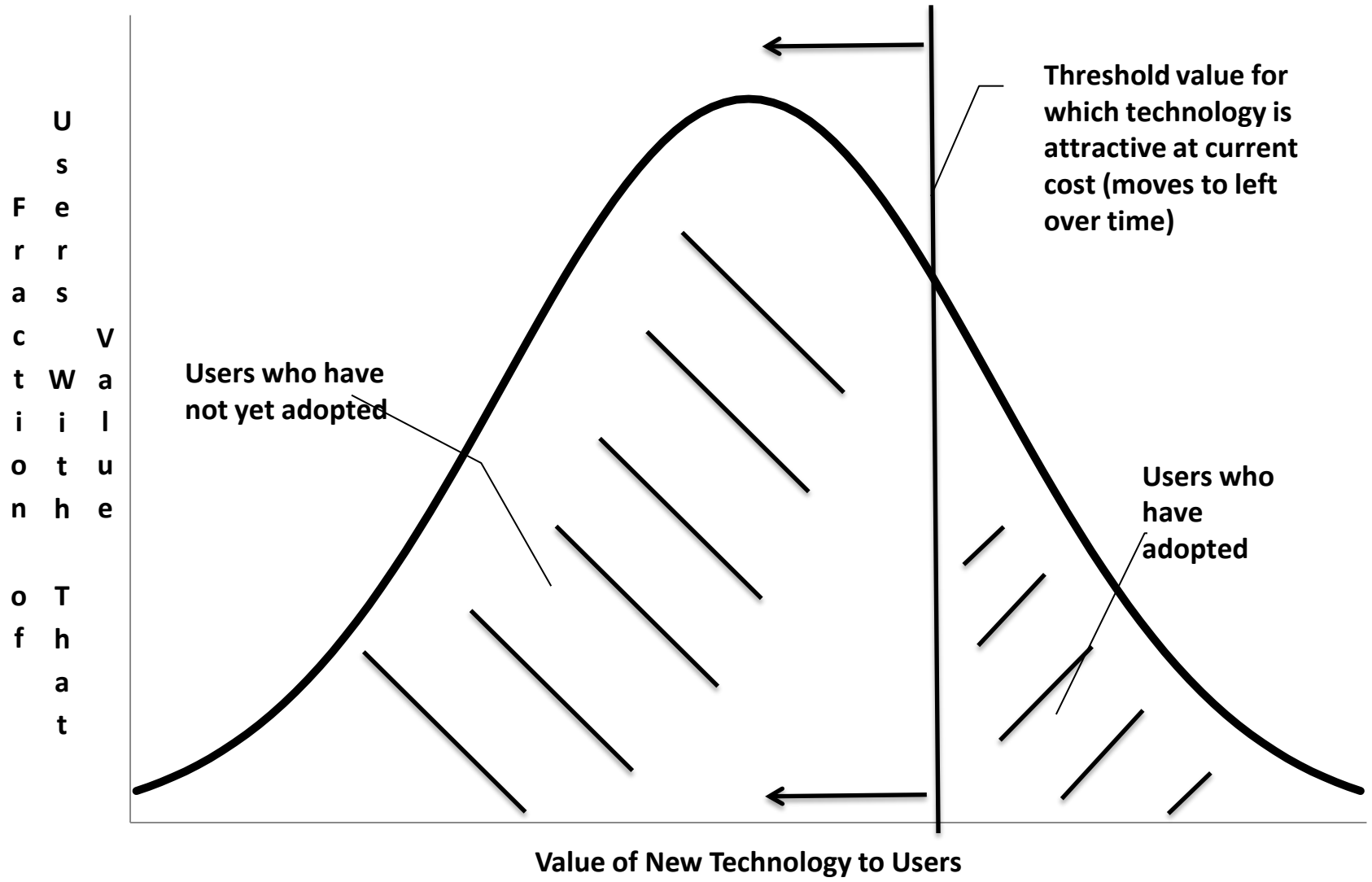
Heterogeneous Adopter Model



Epidemic Model of Diffusion

- Contact with previous adopter induces new adoption with some probability
- Instantaneous rate of adoption depends on "contagiousness," the number of previous adopters, and the number of remaining potential adopters:

$$dA/dt = C \bullet (A) \bullet (1-A)$$

Which can be solved to yield:

$$A = 1/[1 + \exp(-Ct)]$$

Which is the logistic (S-shaped) function

Empirical Estimation: Adoption Models

- Unit of observation is firm, household, farm
- LHS is adopt/not or time until adoption (hazard model)
- RHS has unit attributes (e.g size, organizational form)
- May include diffusion aspects (stock of adopters in “vicinity”)
- If pooled across technologies, can also include measures of intrinsic contagiousness

Empirical Estimation: Diffusion Models

- Unit of observation region, sub-market or some other group
- LHS is fraction adopting each period
- RHS has accumulated stock of adopters; other variables capturing information transfer (e.g. presence of public info program; characteristics of local social networks)
- May include adopter characteristics (e.g. firm size) as average for group
- If pooled across technologies, can also include measures of intrinsic contagiousness

Issues for Green Technologies

- Incentive effects: upfront costs versus annual savings
- Role of different information mechanisms
- Attributes of early adopters
- “End of pipe” technologies versus process change
- Image/preference effects
- Impact of different policy instruments

Incentive Effects

- Impact of up-front cost is proportionally larger than that of annual cost savings
- Effect is separate from question of magnitude of discount rate
- Interpretation:
  - Behavioural bias
  - Elasticity of expected future price wrt current price is less than one

Information effects

- Adoption of green technologies is correlated with self-reported knowledge about
  - Environmental impact of operations
  - Technologies themselves
- Use of one green technology correlated with use of others
- Participation in extension programs is positively correlated with adoption
- Presence of and participation in organizations and social networks is positively correlated with adoption
- Adoption by “neighbors” is correlated with adoption

Attributes of Early Adopters

- Larger firms (usually)
  - For cost-saving technology, spread fixed cost over more units
  - Capital constraints
- In farm sector: higher income; more capital have effect after controlling for farm size
  - Capital constraints
  - Managerial ability; information?
- Ownership versus tenancy has weak (positive) effect

End-of-pipe technologies versus process change

- Some evidence that economic incentives (market or regulatory) are more conducive to process change
- Management systems and better information more conducive to process change
- More stringent regulations may push towards end-of-pipe

Image/Preference effects

- Knowledge of and concern about environment is positively correlated with adoption
- Case study evidence of concern about consumers' perceptions driving change
- For adoption by households (hybrid cars), preferences are an important factor

Policy instruments

- Economic instruments are more conducive to technology diffusion than regulatory standards
- Subsidies can be effective, but also costly
- Openness to international trade fosters technology transfer
- Some evidence that “strong” intellectual property rights fosters technology transfer in middle income countries, but not for least developed
  - Other aspects of institutional environment (e.g. legal system) at least as important

Concluding Thoughts

- Very difficult to disentangle empirically
- Information failures, rational response to uncertainty and behavioural issues look quite similar
- Need more application of behavioural economics techniques to these problems
  - Study of “framing” effects can, in principle, distinguish behavioural effects from “pure” information and uncertainty effects
  - Given policy interest in this area, need more experimental and quasi-experimental research