Advanced Producer Theory: Notes on Technology

Sunding & Zilberman (2001). The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector. In B. Gardner & G. Rausser (Eds.), Handbook of Agricultural Economics, Volume 1 (pp. 207-261). Elsevier Science B.V.

What are *innovations*?

Ways of categorizing innovations:

- *embodied*

- *disembodied*

- *process* vs *product*

- Form:
  - mechanical
  - biological
  - chemical
  - agronomic (management practices)
  - biotechnological
  - informal (e.g. computer programs for management)
- Impacts:
  - yield-increasing

- cost-reducing
- quality-enhancing
- risk-reducing
- environmental-protection increasing
- shelf-life enhancing

Innovation generation

Induced Innovation Models

Background on Induced Innovation:

- First conceptualized by Hicks (1932): “A change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind — directed to economizing the use of a factor which has become relatively expensive.”
- First formalized and empirically verified by Hayami & Ruttan (1985) - new innovations emerge with economic conditions; New innovations are more likely to emerge in response to scarcity and economic opportunities
  - e.g. labor saving technologies will likely arise when….
- According to the induced innovation theory, what drives innovation?

Note that this is supported in many contexts:

- When and where population densities increased we witnessed transitions to more intensive farming systems and the development of crop rotation systems and fertilizer application (Borserup 1965; Binswager and McIntire 1987)
- Increased demand for fish led to a depletion of ocean populations, increasing harvesting costs, and leading to the development of alternative aquaculture systems to provide seafood.

But the technology development also requires technical feasibility and adequate scientific knowledge.

- Olmstead & Rhode (1993) argue that demand considerations posed by the induced innovation hypothesis cannot fully explain new technological innovation. Sometimes innovation occurs from the expansion of scientific knowledge, expansion of input manufacturing industries, and the synergistic relationships between farmers and machinery providers.
- This is still captured in “induced innovation” models, but rather than being induced by economic factors, innovation is induced by scientific knowledge or the identification of a new product through listening to the needs of farmers.

Evenson & Kisev (1976) - optimal experimentation or investment in experimentation for one line of research.

- Expected value of returns to research is increasing in the number of experiments conducted.

- Each experiment produces a random outcome and the outcome of the experiment is equal to the highest value of the outcomes.

- Expected value of research is increasing (at a decreasing rate) in the number of experiments

- A policy-maker can determine the optimal number of experiments to maximize expected gains within a given area:

- Implies that optimal research allocations are increasing in area (), decreasing in product scarcity (), and decreasing in marginal costs of experimenting ()
- Can incorporate risk as: adding an extra experiment reduces the risk associated with experimenting (as N increases, observed outcomes converge), so marginal benefits of experimenting are larger under risk aversion (normally). <- counterintuitive
- Decreasing marginal returns to experimentation imply that the greater the initial gain to experimentation (e.g. productivity gain), the smaller the investment in later periods if we hold C constant.
  - Technological change can enter as a shift in C -> reducing costs and increasing the optimal N

Binswanger (1974) - extend this model to multiple research lines over a set of inputs.

- More resources allocated to research lines with higher productivity effects that mostly impact inputs with higher expenditure shares that have a relatively lower cost.

- Limitations to induced innovation theory?

Publicly Funded Innovations

Partial Equilibrium Framework:

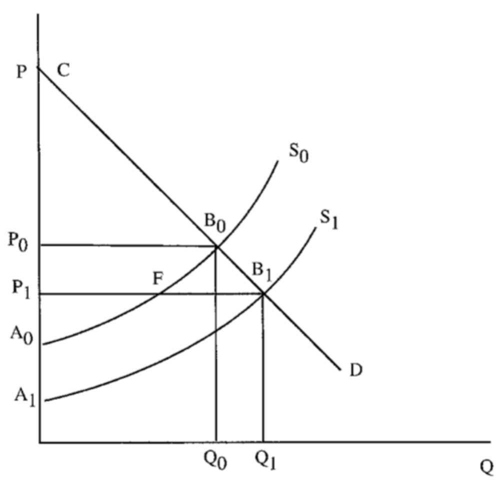


Figure 2.

- An innovation needs to be profitable for private companies to invest in it.
  - What types of innovation (above) lend themselves to private investment?

- Which do not?

- This is how political economy enters investment decisions

De Gorter and Zilberman (1990): simple model for analyzing political economic decisions of public spending on R&D.

- The social planner solves:

- FOC w.r.to investments implies that the marginal reduction in production cost because of R&D is set equal to the (marginal) cost of investment in equilibrium

- Then consider options for the investments to be funded by a combination of producers and consumers using a flexible parameter.
- If investments are fully funded by producers (give example of marketing orders) R&D will be under invested in compared with social optimum.

- reflects revenue loss due to decrease in equilibrium prices (note that comparing previous equation with this one is equivalent to comparing a situation where a firm invests in R&D only for itself
- Magnitude of under-investment increases as demand for final product becomes less elastic (think of perfectly inelastic case)
- On the other hand, if we set in the producer's maximization problem, this would be a case where consumers (taxpayers) pay for the innovation, but producers determine the level of the innovation -> similar relation to demand elasticity.

- When demand is highly elastic this leads to over-investment compared to social optimum. But as long as , this will lead to under-investment in R&D (and remember that is determined by shape of demand curve.

Rausser & Zussman (1991): Model of cooperative game between producers and consumers, designed so that both parties benefit from the action they agree upon.

- There is one level of investment in R&D that is socially optimal. Political weights determine the distribution of the gains -> if producers have 70% of political weight, they receive 70% of benefits.
- Generally does not align with what we observe in reality

Institutional Policies

Wright (1983): Compare patents, prizes, and contracts in terms of optimal investments in R&D (when privately invested)

- patents and prizes result in "Tragedy of the Commons" and lead to under-investing
- Contracts can lead to social optimum.

Alston, Norton, and Pardey (1995): Because of commercialization (and the large fixed and variable costs associated with this upscaling and development process), private and public sector research can actually be complements - an increase in public sector research leads to patentable discoveries, and when private companies obtain rights to patents, invest in commercialization research.

Perfect Competition versus Monopsonist

Hamilton and Sunding (1998): Under a monopolist processing sector, the introduction of a cost-reducing technology can reduce societal welfare.

- The social welfare of R&D (or innovation) come from: (1) welfare increasing effect of farm cost reduction and (2) welfare effect of changes in market power in the processing industry.

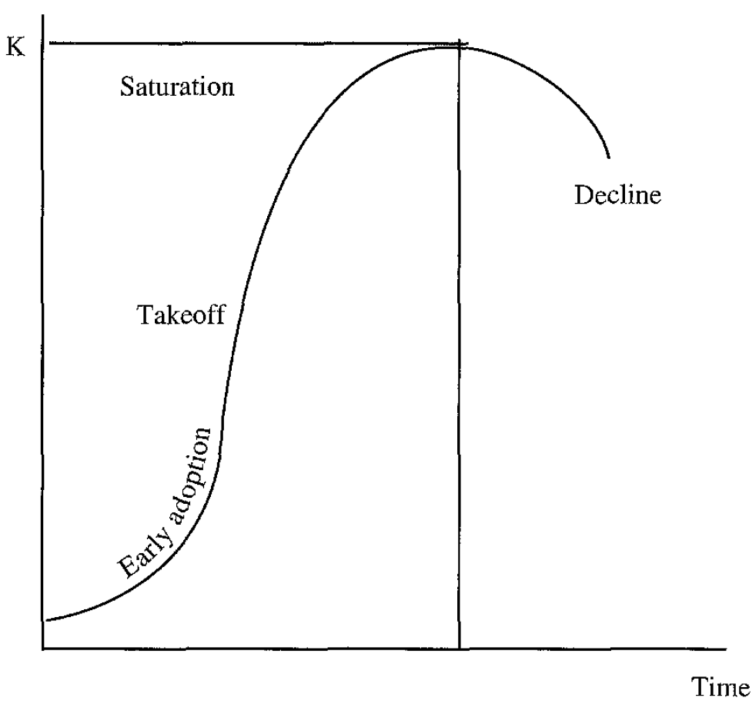
Wright (1983) - the benefits to research can often be larger to firms than to social welfare (depends on slope of supply and demand curves). Under asymmetric information, both patents and prizes CAN yield pay-outs to the firms that are too large, but they can also yield pay-outs that are too small. There are two mechanisms - 1 the value of the innovation is not realized until a later period, and 2 even if the value of patents and prizes are adjusted by a fraction that is optimal ex ante, this does not eliminate the inferiority to contracts due to the common pool/tragedy of the commons problem They do walk through optimal contracts under a bunch of different scenarios, and contracts are not necessarily always the winners (particularly in terms of inducing innovation).

Technology Adoption & Diffusion

Technology Adoption

Technology Diffusion

S-Shaped Diffusion Curves



Rogers (1962)

- developed by rural sociologists with emphasis on diffusion across geographic space, where tech spreads over time to those who are geographically further away (starts in city centers and spreads out)

- Despite the initial geographic argument, initial models did now account for determinants of heterogeneity in the timing of adoption.
- Enter Griliches:

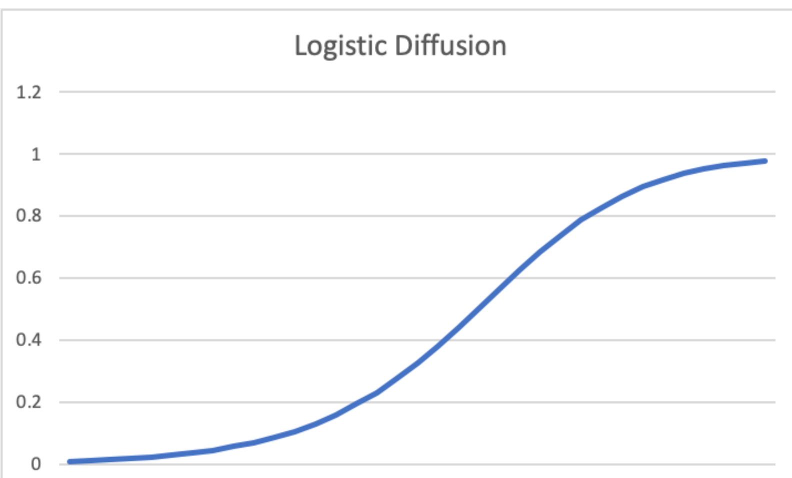
Griliches (1957, 1958) found that rates of farm profitability within a geographic area (and other economic variables) positively affect K (upper limit of diffusion curve), positively affect rates of initial adoption, and positively affect the diffusion rate over time.

Diffusion as Imitation

- This starts with Griliches conceptual framework and attempts to develop models that can estimate the dynamic relationship empirically using time series data

Mansfield (1963) - logistic diffusion

- marginal rate of diffusion is proportional to diffusion level times the un-utilized diffusion potential:

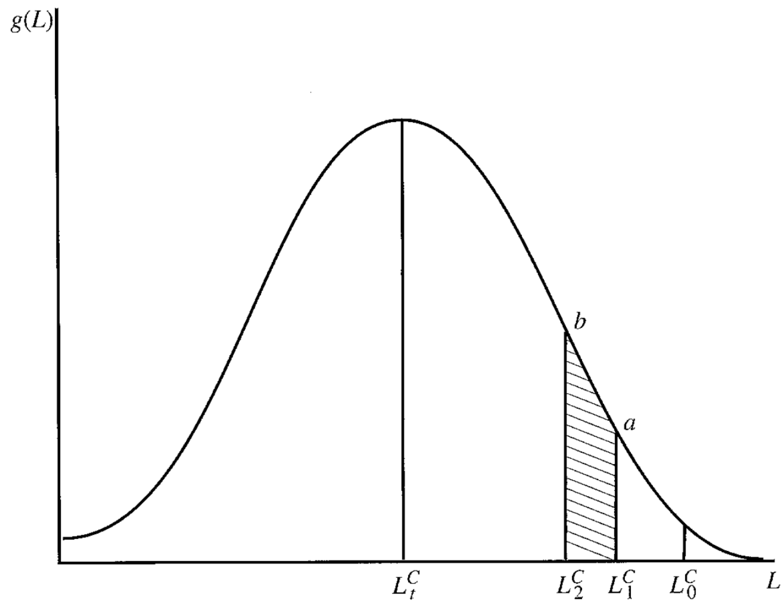


- Based on the idea that contracts lead to spread of the technology (at least within a given industry)
- Later expanded by (e.g.) Lehvall & Wahlbin (1973) with factors that mediate learning and separating firms into innovators and imitators
- Neither this nor earlier models incorporate decision-making process of an individual firm

Threshold Model

Paul David (1969)

- producers are heterogeneous and pursue profit maximizing behavior
- farms adopt new technology sequentially based on size. The critical threshold for adoption changes over time as the new technology becomes cheaper.



- The innovation increases the per-acre profits and assumes that adopting the technology is a fixed cost that varies over time (becomes cheaper over time), and thus farms with more acres will have marginal benefits to adopting that are higher than smaller farms.
- Note that this can lead to the S-shaped diffusion curve!
- Rhode (1993) found that smaller farms, in many cases, adopted new machinery first when the smaller farms cooperated and purchased jointly.

Risk

- It is commonly asserted that new technologies increase mean values, but also increase risk (variance) at least initially
- This will generally lead to more risk-averse agents adopting more slowly

Irreversibility and uncertainty

- There are also technologies designed to decrease risk (e.g. drought-resistant varieties), but initially these still pose some unknowns that are often modeled as risk. Particularly because farmers must pay for these new varieties, if we think of drought-resistant crops, they are generally though of as having the same yields under non-drought conditions and higher yields under drought conditions. Since farmers must pay for the seeds regardless they have . Risk exposure in these models typically depends on a combination of (1) the gains under bad (drought) conditions, (2) the probability of bad conditions, (3) the cost of the new technology, and (4) knowledge of the new technology.

Learning by Doing

Starts with Arrow (1962) Economic Welfare and the Allocation of Resources for Invention -16,288 cites!!!

Basic idea is that returns to input technology increase over time, which will affect the optimal time for adopting a new technology.

$$\underbrace{\overset{(+)}{\Delta \Pi(0)}}_{\text{Extra profit from adoption}} - \underbrace{\overset{(-)}{rK(t_0)}}_{\text{Investment cost}} + \underbrace{\overset{(-)}{\frac{\partial K(t_0)}{\partial t_0}}}_{\text{Learning by doing effect}} + \underbrace{\overset{(+)}{\int_0^\infty e^{-rt} \frac{\partial \pi(t)}{\partial t} \, dt}}_{\text{Learning by using effect}} = 0.$$

Learning by Watching

- pineapple farmers paper (next time)
- Note that their theoretical model is VERY simple and purposefully blanket. They do not assert how factors might affect the adoption decision, but instead indicate how you can tease out the different factors that are likely to affect it.

Cochrane Treadmill

Cochrane (1979) - first to incorporate partial equilibrium effects of technology adoption.

- divides the economy into early adopters, followers, and laggers.
- Early adopters profit from the innovation.
- The followers represent the bulk of farmers who adopt the innovation during the take-off stage. This adoption reduces prices. They may gain or lose from the innovation depending on the slope of the demand curve.
- Laggards adopt late or not at all and lose profits (or go out of business)
- This model demonstrates that technology may not result in farmers being better off.
- if we combine all of these literatures though, a few things stand out:
  - early adopters gain
  - larger farms tend to adopt sooner
  - political economy theory of innovation generation might suggest that these farms are more influential in technology generation
  - The innovation is likely to be generated if it is profitable for early adopters who have the means to finance the innovations.