Economic Dynamics

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Abstract

The dynamics of R&D. Overlapping generations, including stochastic models.

The Theory of the "Second Best"

- There are a large number of circumstances where the *First Welfare Theorem*, *i.e.*, "market outcomes are Pareto efficient," does not hold.
- These are called *market failures.*
- The "Theorem of the Second Best" says that in cases of market failure, there is often no policy that achieves the first best. In these cases, the most effective policy often involves introducing *additional market failures.*

Intellectual Property as a Second Best Policy

- It is claimed that there is a market failure in the R&D industry, that there are *unpriced external benefits*: the "spillovers."
- In his famous article "The Problem of Social Cost" (*Journal of Law and Economics*, October 1960, pp. 1-44), Ronald Coase showed that many problems of externalities can be solved simply by allocating a *private property right*, either to conduct an activity or to prohibit it.
- "Intellectual property" are those rights created by law to conduct activities involving certain ideas.

Effects of Intellectual Property

- An *intellectual property right* is the exclusive right to conduct an activity involving an idea.
- *Copyright* is the exclusive right to copy the *expression* of an idea, as *fixed in a medium*.
  - Independent development of the idea *is not* restricted.
  - Copyright leads to *monopolistic competition*.
- A *patent* is the exclusive right to *practice* an idea, which is to construct a device based on the idea, to be used for a *specified purpose*.
  - Independent development and practice *is* restricted.
  - Patent leads to *(pure) monopoly* or "tight" *oligopoly*.
- In each case, an additional market failure is introduced: *creation of a monopoly*.

Motivation

- Monopoly has known effects of creating inefficiency; economists recommend reducing monopoly whenever possible.
- Monopolistic competition may result in "second best", where $P = ATC$.
- Boldrin and Levine argue that intellectual property protection is *unnecessary*, because the technology of the innovation process need not involve increasing returns to scale, merely indivisibilities.
- They argue that intellectual property protection is *harmful*, because where each innovation depends on previous innovations (an *innovation chain*), the monopoly will cause cumulative damage to the economy by inhibiting future innovations.

Historical Innovation

- There is no definitive history of innovation, but we can point out some interesting facts.
- Charles Dickens (author of *A Tale of Two Cities*, *Oliver Twist*, and other famous novels in English) complained that in the U.S. in the 1800s anyone was free to reprint foreign publications without payment to the author. Nevertheless, testimony to a commission on publishing showed that English authors would sometimes receive more from American publishers than from English ones.
- The mail-order business was invented by Montgomery Ward and Sears in the 1870s and 1880s, and despite a lack of price-fixing power were able to make very large profits from their innovation in business practice.

Spontaneous Innovation

- Innovation clearly occurs, and economic rewards to innovation can be great, without government-enforced monopoly.
- Boldrin and Levine conclude that "the issue of whether government grants of monopolies over ideas is second best is an empirical rather than theoretical issue."

Creative Destruction

- *Creative destruction* was proposed by Joseph Schumpeter as a way to view the dynamics of industry.
  - When a new technology is created, older ones are made obsolete, and often disappear (*i.e.*, are destroyed).
- Modern *endogenous growth theory* focuses on creative destruction as a mechanism for propagating new technology.
- Economists such as Paul Romer argue that a technology is a *fixed input*, so the R&D expense to create it is a *fixed cost*, and therefore there are automatically *increasing returns to scale* (decreasing average cost) related to technological progress.
  - These returns to scale are what makes per capita growth in the steady state possible, it is claimed.

Spillovers

- Technology also generates positive externalities called spillovers.
- A *spillover* occurs when a new technology is developed, and the innovation becomes known to others. They automatically become able to use the innovation (or some part of it).
- Spillovers result in *social benefit* that cannot be captured by the investors in new technology.
  - Inefficiently low incentive for R&D investment.
  - Free riding on the technology by rivals can lead to "dog eat dog competition" and a strong second-mover advantage, so nobody wants to developer new technology.
  - To address this *market failure*, *intellectual property* is created by law.

The Process of Innovation

- The innovation process is two-stage.
- First, a new idea is *invented*, and developed to some target level of quality.
  - Boldrin and Levine describe this as production of a *prototype*. The prototype must be complete, and thus involves an indivisibility.
- Once the invention is completed, it is replicated. *Replication* means
  - low (or zero) fixed cost
  - constant marginal cost
  - large scale

Taking It to the Market

- Another common terminology is where replication is called *innovation* in economics.
- Usually it's not important to determine whether "innovation" means "invention and replication" or just "replication".
- "Innovation" does imply "taking a product to market," which is the important part in economics.

Sources of Market Failure

- Benefits may not be *appropriable*. Because of *spillovers*, the total social benefit is not received by the innovator, who lacks incentive to produce the innovation.
- The product may involve *increasing returns to scale*. Typically this is due to the presence of a *fixed cost*.
  - The microeconomic problem is that $ATC > MC$, so the efficient Q^* where $P(Q^*) = MC(Q^*)$ cannot be produced at a profit.
- The product may be indivisible.
  - The microeconomic problem is that marginal analysis fails, because there is no "margin". Production must make big jumps, each of whose costs must be covered in total.

Embodiment of Ideas

- Ideas are *non-rival*: two people may use the same idea at the same time. *E.g.*, all students taking a test may know the correct answer.
- Boldrin and Levine claim that this is not interesting for economics. To each student, *mere existence* of the correct answer does not ensure high grades; the *student himself must know it*.
- Boldrin and Levine would say that the correct answer is *embodied* in students who know it. The process of embodiment is costly: the student must attend class or read a book to know the answer, and in many cases must practice or repeatedly study it.

Nonexistence of *Unpriced* Spillovers

- Note that in class the idea is “embodied” in the lecturer, while the book itself is an “embodiment” of the idea.
- Thus, *transmission of ideas* requires communication from one embodiment of the idea to another.
- If the source of the idea is priced, then even if the idea cannot be priced directly, its *value* will increase the value of the source embodiment, and thus the idea can be priced.
- Only the original invention is different; we can trace the source of all embodied ideas to their prototype, and the prototype can therefore accumulate the *total value*.
- There is no *failure of appropriability*.

Increasing Returns *vs.* Indivisibility

- Once the innovation is produced, the costs of R&D are *sunk* (they cannot be recovered by abandoning the product). Sunk costs are hard to distinguish from fixed costs in reality.
- Thus for the long run increasing returns (fixed cost giving decreasing average total cost) and indivisibility (presence of sunk cost) are hard to tell apart.
- Boldrin and Levine *assume* indivisibility, but not increasing returns, and remind us that in this case competition can fail to provide incentive for innovation, accounting for observed market failures in innovation.

Production with Increasing Returns

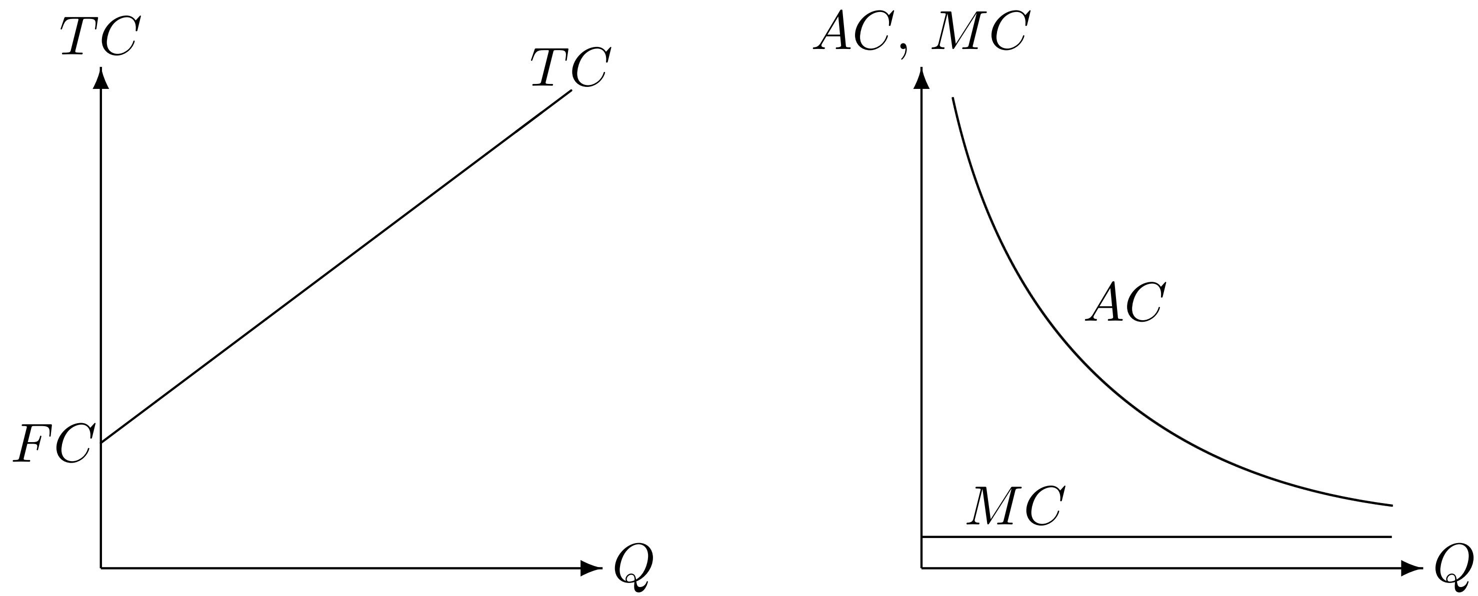

Figure 1: Cost with increasing returns

Market with Constant Returns

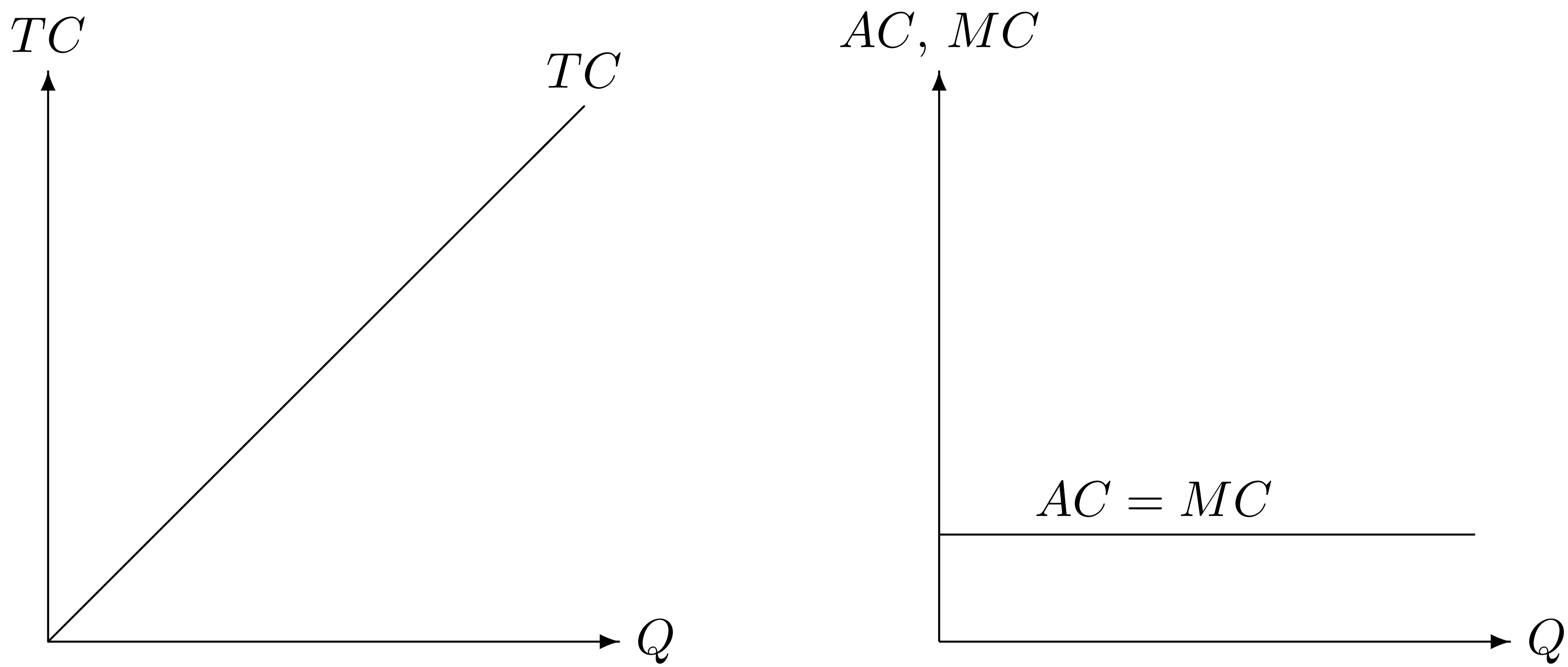

Figure 2: Cost with constant returns

Market with Indivisibility

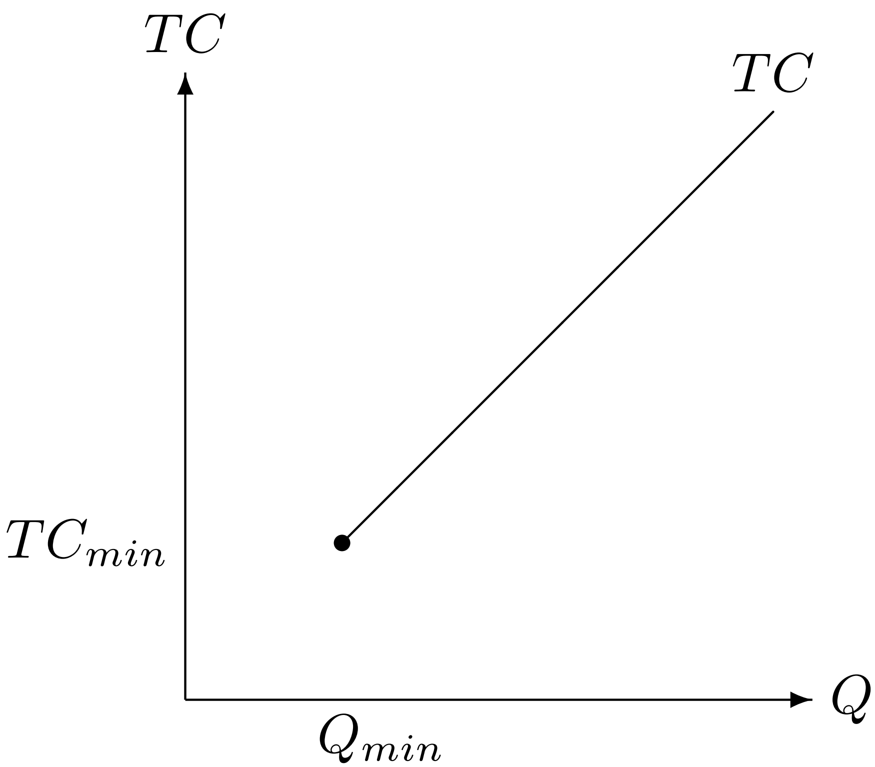

Figure 3: Cost with nonconvexity

A Simple Dynamic Model of Innovation

- Focus on pricing of copies of the prototype or template good.
- Assume copies are perfect substitutes (in use and in copying) to the prototype.
- Producing copies takes time, but consumes no other resources.
  - This unrealistic assumption is made to minimize the difference from the past literature which assumed the possibility of spillovers.
  - Spillovers are externalities, so they consume no extra resources at all, not even copying time.

Copying Technology

- Denote the stock available by k.
- Consumption is given by c, $0 < c \leq k$. Copies used exclusively for new production are $k - c$.
- Pure copying occurs at the rate β, while copying in conjunction with consumption occurs at rate ζ. The dynamics of k are given by $k_{t+1} = \beta(k_t - c_t) + \zeta c_t$.
- The dynamic resource constraint can be solved for c_t, giving

$$c_t = \frac{\beta k_t - k_{t+1}}{\beta - \zeta}.$$

  - Note $\zeta = \beta$ is a special case; obviously $c_t \equiv k_t$.

Copying Parameters

- Clearly $\beta > 1$, or simply storing the good is better than copying. ($\beta < 1$ means the original is damaged!)
- Since consumption should interfere with copying, $\zeta \leq \beta$.
  - It could be that copying and consumption can take place at the same time (*e.g.*, the iTunes player on the Mac can copy a CD to the MP3 library, and play the MP3s at the same time, after a short delay to start copying the first song). Then $\zeta \cong \beta$.
  - It could be that only one activity can occur, and that consumption causes depreciation. Then $\zeta < 1$.

The Utility and Value Functions

- There is a representative consumer with a utility function $u(c)$ for consumption in each period. Utility is discounted, so that the consumer wishes to maximize $\sum_{t=0}^{\infty} \delta^t u(c_t)$.
- The consumer is a price-taker.
- For a utility-maximizing consumer, there will be a *value function* giving the maximum utility that can be gained from optimal use of the current stock k:

$$v(k) = \max_{0 \le c \le k} \{u(c) + \delta v(\beta k - (\beta - \zeta)c)\}.$$

Competitive Prices for Rental Consumption and Production Stock

- If the good were *rented* for one period, the marginal value of consumption would be equated to price: $p_t = u'(c_t)$. (This justified by the assumption that the consumer is a price taker.)
- The price for *purchasing* the good can be determined by the value function: $q_t = v'(k_t) = p_t \frac{\beta}{\beta - \zeta}$.
- At innovation we have $k_0 = 1$, with R&D cost C. Then
  - $c_0 \leq 1$ (cannot consume more than exists)
  - $p_0 = u'(c_0) \geq u'(1) > 0$ (diminishing marginal utility)
  - $q_0 = p_0 \frac{\beta}{\beta - \zeta} \geq p_0$
- Thus for $0 \leq C < q_0$, the innovation is economically justified for the profit-maximizing inventor.
  - Since C and $q_0 = v'(1)$ are determined by the technological parameters, we see what Boldrin and Levine mean by "empirically determined."

Overlapping generations models

- Up to the present, we've considered dynamic constraints on single homogeneous entities. Examples:
  - In Solow's model, the single "interesting" entity is the *representative worker/consumer*, which we derive using the special properties of CRTS production.
  - In the fishery, the "interesting" entity is the *population* of fish (or whales). Although the fisherman do interact in equilibrium, the dynamic constraint is on the population.
- By contrast, in an *overlapping generations* (OLG) *model*, there are constraints between agents existing at the same time and a given agent across time periods.

A simple OLG model

Follows Ch. 17 of Lucas and Stokey.

- The economy has a constant population of agents (worker/consumers).
- The agent lives for two periods, working when young and consuming when old. (This is a *technical* assumption, convenient in notation, computation, and interpretation because the number of workers equals the number of consumers equals half the population.)
- The utility function is $U(c, l) = -H(l) + V(c)$.
- There is a single, non-storable good, produced with a linear technology $y = xl$, where X is generated by a *Markov process.* (This means that x_{t+1} is generated by a random variable which may depend on x_t but nothing else.)
- There is a constant supply of *fiat money* (government-issued, as with yen and dollars) M.

How the OLG model works

- We make the *technical* assumption that there's one person in each generation. (Like Solow's model, this one is CRTS.)
- Based on an assumption of equilibrium, markets will clear:
  - The young worker will supply labor l, produce $y = xl$, and receive all the money M from the old consumer.
  - The old consumer will consume $c = y$, and pay all the money M to the young worker.
- The old consumer's behavior is forced: they have money, they buy the good in a competitive market, so they'll spend all the money and buy all the good.

The worker's model

- When young, the worker dislikes working, with the usual "decreasing returns to scale" conditions: $H : [0, L) \to R_+$ satisfies
  - $H'(l) > 0$ and $H''(l) > 0$ for all l, and
  - $H'(0) = 0$ and $\lim_{l \to L} H'(l) = \infty$ (Inada!).
- When old, the consumer likes consuming, with decreasing marginal utility. $V : R_+ \to R_+$ satisfies
  - $V'(c) > 0$ and $V''(c) < 0$ for all c.
- The equilibrium is characterized by
  - the "price" (of money in goods, not the reverse!) $p(x)$, which depends on the state of the world (random worker productivity),
  - the "labor supply" function $n(x)$ (n depends on x, not the wage), and
  - market-clearing $xn(x) = M/p(x)$.
- When old, the worker born at t consumes $x_t n(x_t)(p(x_t)/p(x_{t+1}))$.

The worker's optimization

- The worker chooses $n(x)$ to maximize

$$-H(l) + \mathcal{E}_\xi \left[V(xl\frac{p(x)}{p(\xi)}) \mid x \right]$$

where the worker knows her own productivity x but the productivity of the next generations is random ξ.

- Given a price function p, the first-order condition for n is given by solving

$$H'(n(x)) = \mathcal{E}_\xi \left[V'(xn(x)\frac{p(x)}{p(\xi)}) \mid x \right]$$

(there are no n' because x is a parameter known to the worker, not a choice variable).

- Substituting from the market-clearing conditions for this period and next gives

$$n(x)H'(n(x)) = \mathcal{E}_\xi \left[\xi n(\xi) V'(\xi n(\xi)) \mid x \right]$$

- Suppose x has a distribution independent of time and across time. Then $n(x) = \bar{n} > 0$ for all x.