Lecture 3 - Innovation

Gerhard Riener

Innovation and Market Structure

Innovation as a margin of competition

Innovation is the **dynamic** margin of competition: firms try to change the game by shifting **costs** and **demand**.

Why IO cares

- Innovation changes **prices, mark-ups, and welfare** today
- Innovation changes **market structure** tomorrow (entry/exit, dominance, concentration)
- Policy trade-off: **static efficiency** (low prices) vs **dynamic efficiency** (strong incentives)

Types of innovation (and what we model today)

Process innovation (this lecture's workhorse case)

- Lowers marginal (or average) cost, e.g. a better production method
- Think: a shift from c_0 to $c_1 < c_0$

Product innovation

- Raises willingness to pay, expands demand, or creates new varieties
- Often analysed with differentiated products and quality ladders (later in the course)

Stages (high level): Research $\rightarrow$ Development $\rightarrow$ Adoption

Learning objectives

- Compute the **private value** of a process innovation under different market structures
- Define **drastic vs non-drastic** innovations and explain the **replacement effect** (Arrow 1972)
- Understand how **free entry + endogenous R&D** link innovation to **concentration** (Dasgupta and Stiglitz 1980)

Today: roadmap

1. Benchmark model: value under **monopoly**, **perfect competition**, and **social planner**
2. **Drastic vs non-drastic** innovations and the **replacement effect**
3. Innovation with **oligopoly** and **entry threat**
4. **Concentration** and **R&D** (Dasgupta and Stiglitz 1980)

Discussion: Why does innovation matter for growth?

Before the Industrial Revolution ($\sim$1760–1840), global GDP per capita was roughly flat for centuries. Since then, it has grown exponentially.

Question for you

- What role did innovation (new production methods, machinery, transport) play in this transformation?
- Why might market structure affect the *rate* of innovation — and therefore long-run growth?
- Should we expect monopolies or competitive markets to innovate more? (We'll answer this formally in a moment.)

Market structure and innovation: a two-way relationship

Market structure → innovation

- Competition affects profits, appropriability, and the gain from becoming "better" than rivals

Innovation → market structure

- Cost/demand shifts affect entry, market shares, and concentration (and can create dominance)

Measuring incentives: willingness to pay (WTP)

- **Firm WTP**: the max lump-sum payment that leaves profits unchanged $\Rightarrow$ WTP $= \Delta\pi$
- **Planner WTP**: the max lump-sum payment that leaves welfare unchanged $\Rightarrow$ WTP $= \Delta W$

In what follows we compute WTP for: **Monopoly** (before/after), **perfect competition** (before; exclusive rights after), and the **social planner**.

Benchmarks: Value of a Process Innovation

Setup: linear demand + cost-reducing innovation

Inverse demand

$$P(Q) = A - Q$$

Technology

- Constant marginal cost $c \in \{c_0, c_1\}$
- Process innovation reduces marginal cost from c_0 to c_1 with $c_1 < c_0 < A$

Goal

Compute the value of moving from c_0 to c_1 under different market structures.

Monopoly benchmark: problem and solution

Problem

$$\max_{Q} \ (A - Q - c)Q$$

Solution

$$Q^m(c) = \frac{A-c}{2}, \qquad P^m(c) = \frac{A+c}{2}, \qquad \pi^m(c) = \frac{(A-c)^2}{4}$$

Monopoly WTP for innovation

WTP for the innovation

$$\Delta\pi^m = \pi^m(c_1) - \pi^m(c_0) = \frac{(A - c_1)^2 - (A - c_0)^2}{4}$$

Interpretation

$\Delta\pi^m$ is the monopolist's value of *exclusive* access to the lower cost c_1 (it is incremental because the firm already earns rents at c_0).

Perfect competition benchmark (innovation creates rents)

Before innovation (all firms at MC c_0):

- Competitive price: $P_0^{pc} = c_0$
- Firm profit: $\pi = 0$

After innovation (innovator has exclusive use / patent):

- **Drastic**: innovator behaves as a monopolist with cost c_1
- **Non-drastic**: innovator is constrained by the competitive fringe at cost c_0 (limit pricing)

Innovation WTP under perfect competition

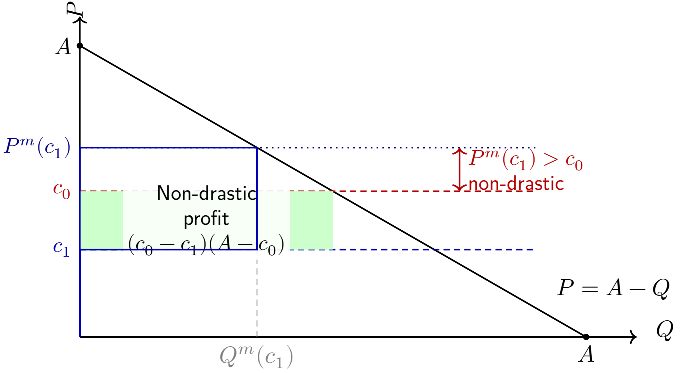
Innovator profit / WTP

$$\Delta\pi^{pc} = \begin{cases} \pi^m(c_1) & \text{(drastic)} \\ (c_0 - c_1)(A - c_0) & \text{(non-drastic, } p = c_0\text{)} \end{cases}$$

Why the non-drastic formula? If the innovator sets $p = c_0$, quantity is $Q = A - c_0$, so profits are $(p - c_1)Q = (c_0 - c_1)(A - c_0)$.

Drastic innovation condition

$$P^m(c_1) < c_0 \quad \Leftrightarrow \quad \frac{A + c_1}{2} < c_0 \quad \Leftrightarrow \quad A + c_1 < 2c_0$$



Numeric check: drastic or non-drastic?

Take $A = 20$, $c_0 = 10$, and $c_1 = 6$.

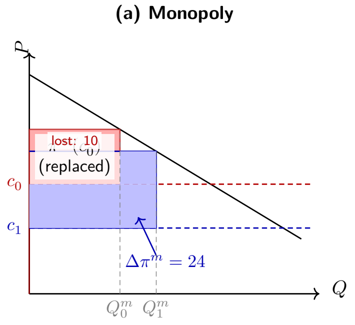
- **Drastic condition**: $A + c_1 = 26 > 2c_0 = 20 \rightarrow$ **non-drastic**
- Innovator limit-prices at $p = c_0 = 10$, sells $Q = A - c_0 = 10$
- Competitive innovator profit: $(c_0 - c_1)(A - c_0) = 4 \times 10 = 40$
- Recall monopoly WTP: $\Delta\pi^m = \frac{(14)^2 - (10)^2}{4} = \frac{196-100}{4} = 24$

Replacement effect preview

The competitive innovator earns $40 > 24$ (the monopolist's WTP). The monopolist gains less because it already earns $\pi^m(c_0) = 25$ before innovating — it is partly **replacing** existing rents.

Replacement effect: visual comparison

- Left panel: the incumbent monopolist already earns $\pi^m(c_0)$ before innovating.
- Innovation raises monopoly profit only by the increment $\pi^m(c_1) - \pi^m(c_0)$.
- Right panel: under competitive pre-innovation conditions, the innovation mostly **creates** rents.



Replacement effect (Arrow 1972)

- Under perfect competition, pre-innovation profits are approximately zero.
- Under monopoly, pre-innovation profits are positive.
- So the same innovation has a larger incremental private value in competitive settings.

Appropriability and imitation

- If the innovation cannot be protected (instant diffusion / perfect imitation), competition drives price to c_1 and the innovator's WTP is zero.
- Most IO policy questions start from the fact that appropriability is imperfect but positive (patents, secrecy, lead time).

Replacement effect: a one-line comparison (drastic case)

If the innovation is drastic and grants exclusive rights:

$$\Delta\pi^{pc} = \pi^m(c_1), \qquad \Delta\pi^m = \pi^m(c_1) - \pi^m(c_0)$$

$$\Delta\pi^{pc} - \Delta\pi^m = \pi^m(c_0) > 0$$

- The wedge equals pre-innovation monopoly rents, $\pi^m(c_0)$.
- The replacement effect is strongest when baseline monopoly rents are high.

Replacement effect: intuition

! Takeaway

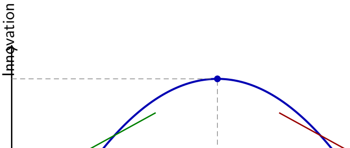
Holding everything else fixed, an incumbent monopolist has **weaker** incentives to innovate than a competitive industry because it is "replacing" its own pre-innovation rents.

Empirical example: competition and innovation

- Low competition: firms have little pressure to “escape.”
- Intermediate competition: innovation incentives are strongest for neck-and-neck firms.
- Very high competition: post-innovation rents are compressed, reducing innovation incentives.

Inverted-U evidence (QJE)

Aghion et al. (2005) document an **inverted-U** relationship between product-market competition and innovation (patents/citations) in UK firms, consistent with “escape competition” incentives for neck-and-neck firms and a **replacement effect** for laggards.



Social Value of Innovation

Social planner: value of a cost reduction

Efficient output (price equals marginal cost)

$$Q^{sp}(c) = A - c$$

Total surplus (welfare):

$$W(c) = \int_0^{A-c} (A - Q - c)\, dQ = \frac{(A-c)^2}{2}$$

Interpretation

In this linear example, $\Delta W = 2\,\Delta\pi^m$: the planner values the output expansion that the monopolist does not internalise.

Social planner WTP for innovation

Max WTP for innovation (social planner):

$$\Delta W = W(c_1) - W(c_0) = \frac{(A - c_1)^2 - (A - c_0)^2}{2}$$

- This is the full increase in total surplus from lowering marginal cost.
- In the linear benchmark, it is exactly twice the monopoly incremental profit.

Putting the benchmarks side-by-side

Environment	What the innovator captures	WTP / value
Monopoly (incumbent)	Incremental rents	$\Delta\pi^m = \pi^m(c_1) - \pi^m(c_0)$
Perfect competition (pre) + exclusive rights (post)	Mostly created rents	$\Delta\pi^{pc} = \pi^m(c_1)$ if drastic; otherwise limit pricing profit
Social planner	Full surplus gain	$\Delta W = W(c_1) - W(c_0)$

! Policy interpretation

Private incentives and social value need not align: ΔW **can exceed** $\Delta\pi$, but market power created by IPRs also generates static distortions. This is the basic patents trade-off.

Empirical example: private vs social returns

- Measured producer gains capture only part of innovation's value.
- Consumer surplus from quality improvements can be very large.
- This gap motivates policy tools that raise private appropriability.

Welfare gains from product innovation (JPE)

Trajtenberg (1989) estimates consumer and producer surplus gains from quality improvements in computed tomography (CT) scanners, illustrating that the **social value** of innovation can greatly exceed the innovator's private returns.

Quick numeric check (optional)

Take $A = 20$, $c_0 = 10$, and $c_1 = 6$.

- Monopoly: $\pi^m(c_0) = 25$, $\pi^m(c_1) = 49$, so $\Delta\pi^m = 24$
- Planner: $W(c_0) = 50$, $W(c_1) = 98$, so $\Delta W = 48$ (twice the monopoly gain)

Discussion question

In what sense is this "too little" innovation from a welfare perspective? What policy instruments could close the gap?

Innovation with Rivals and Entry

Incentives to innovate in oligopoly

Takeaway

- Innovation incentives need not be monotone in "competition intensity"
- They depend on:
  - Number of firms (n)
  - Product differentiation
  - Mode of competition (price vs quantity)
  - Whether innovation is **protectable** (patents/lead time) and whether there are **spillovers**

Rule of thumb

More rivals reduces baseline profits (hurting incentives), but can increase the value of being the low-cost firm (helping incentives).

Impact of number of firms (Cournot intuition)

Linear Cournot with n firms: incentives can follow an **inverse-U** as n increases.

Two opposing effects as $n \uparrow$:

- **Competition effect**: profits for all firms fall (discourages innovation)
- **Competitive advantage effect**: cost advantage becomes more valuable when there are more inefficient rivals (encourages innovation)

Monopoly threatened by entry: setup

Incumbent monopoly faces potential entrant:

- Both can acquire innovation reducing MC from c_0 to $c_1 < c_0$
- Entrant can enter profitably **only if** it gets innovation
- Let $\pi^d(c_i, c_j)$ denote firm i's profit in the post-entry **duopoly** when own cost is c_i and the rival's cost is c_j

Timing/game structure:

We compare the **willingness to pay** for innovation (e.g., in a patent auction or R&D race). The innovation is awarded to whichever firm values it more highly. Entry happens *after* the innovation is allocated.

Entry threat: payoff structure

Payoffs:

- **If incumbent gets innovation**: entrant stays out
  - Incumbent: $\pi^m(c_1)$; Entrant: 0
- **If entrant gets innovation**: entrant enters
  - Incumbent: $\pi^d(c_0, c_1)$; Entrant: $\pi^d(c_1, c_0)$

Strategic value

Innovation can change market structure (monopoly vs duopoly), so incentives are not only about production efficiency.

Entry threat: pre-emption incentives (Gilbert and Newbery 1982)

Per-period value of innovation

$$V_I = \pi^m(c_1) - \pi^d(c_0, c_1)$$

$$V_E = \pi^d(c_1, c_0)$$

Incumbent has stronger incentives if:

$$V_I > V_E \quad \Leftrightarrow \quad \pi^m(c_1) > \pi^d(c_1, c_0) + \pi^d(c_0, c_1)$$

This typically holds when products are close substitutes (entry is very harmful).

! Interpretation

The incumbent may innovate **more** than an entrant because

Discussion: when does pre-emption fail?

Discussion question

Under what market conditions might an entrant have stronger innovation incentives than the incumbent? What features would reverse the pre-emption result?

Empirical example: strategic incentives and market share

Pre-emptive innovation patterns (ReStud)

Blundell et al. (1999) find that higher market share and market value predict more patenting/innovations in UK manufacturing firms, consistent with **strategic** incentives (including preemptive innovation) in oligopolistic industries.

Endogenous R&D and Market Structure: Dasgupta and Stiglitz (1980)

Setup and key result

The Dasgupta and Stiglitz (1980) model treats R&D as an **endogenous sunk cost**: firms spend on R&D to reduce marginal cost, and entry adjusts endogenously.

The key result is a clean link between:

- **Demand conditions** (elasticity, market size)
- **Innovative opportunities** (how effective R&D is at lowering costs)
- **Equilibrium concentration** (how many firms survive under free entry)

The linear model gave us clean closed-form comparisons. The D-S framework sacrifices tractability for generality — but delivers a structural result linking innovation to concentration.

Notation for this section

Symbol	Type	Meaning
x	Choice	R&D expenditure per

Planner benchmark

Question: Do more firms imply more innovation?

Primitives:

- $U(Q)$ = gross social benefit
- $c = c(x)$ = constant marginal cost depending on R&D expenditure x
- Assumption: $c'(x) < 0$ (R&D reduces cost)

Social optimum:

$$\max_{x,Q} \; V(x,Q) = U(Q) - c(x)Q - x$$

First-order condition in x:

$$-c'(x)Q = 1$$

Planner benchmark: interpretation

- Optimal R&D increases with scale Q: a larger market makes cost reduction more valuable

Empirical example: market size and innovation

Pharmaceutical innovation responds to demand

Acemoglu and Linn (2004) show that larger potential markets lead to

- more pharmaceutical innovation (new drugs/new molecular entities)
- $\rightarrow$ consistent with models where the return to innovation rises with **scale**.

Firm's problem

Assumptions: Firms engage in **Cournot (quantity) competition** with symmetric costs. Each firm chooses R&D expenditure x_i and output q_i simultaneously.

Firm i's problem:

$$\max_{x_i, q_i} \pi(x_i, q_i) = [P(q_i + q_{-i}) - c(x_i)]q_i - x_i$$

Symmetric equilibrium:

- $q_1^* = \cdots = q_N^* = Q^*/N$ and $x_1^* = \cdots = x_N^* = x^*$

Intuition check: What determines N^*?

What forces at work here?

- **Entry incentive:** If industry profits are positive, more firms want to enter
- **R&D cost:** Each firm must spend x^* to achieve low cost $c(x^*)$
- **Market power:** More firms $\rightarrow$ lower mark-ups $\rightarrow$ lower operating profits
- **Zero-profit equilibrium:** Entry stops when operating profits just cover R&D outlays

Key insight: Equilibrium concentration (N^*) balances these forces. We'll derive the precise formula by combining the pricing and free-entry conditions.

Reminder: Cournot perceived elasticity

From Lecture 1: Under Cournot competition, firm i perceives the demand elasticity facing its own output as $N\varepsilon$, where ε is the market demand elasticity.

This gives the markup formula:

$$\frac{P-c}{P} = \frac{1}{N\varepsilon}$$

Rearranging:

$$P\left(1 - \frac{1}{N\varepsilon}\right) = c$$

We'll use this to link pricing to R&D in the Dasgupta–Stiglitz model.

Equilibrium pricing

First-order condition in q_i:

$$P(Q^*)\left(1 - \frac{1}{N\varepsilon}\right) = c(x^*)$$

where $\varepsilon = -\frac{\partial Q}{\partial P}\frac{P}{Q}$ is the demand elasticity.

Interpretation:

- The term $\left(1 - \frac{1}{N\varepsilon}\right)$ captures market power via the perceived demand elasticity under Cournot
  - More firms ($N \uparrow$) $\rightarrow$ perceived demand becomes more elastic $\rightarrow$ mark-ups fall

Free entry condition

Zero profit condition (free entry):

$$\pi = 0 \quad \Rightarrow \quad (P - c)\frac{Q^*}{N^*} - x^* = 0$$

Rearrange:

$$P - c = N^* \frac{x^*}{Q^*}$$

Deriving the concentration formula (I): Setup

Combine the two conditions:

- From pricing FOC: $P - c = \frac{P}{N\varepsilon}$
- From free entry: $P - c = \frac{Nx}{Q}$

Equating the two expressions:

$$\frac{P}{N\varepsilon} = \frac{Nx}{Q}$$

(We solve for N on the next slide.)

Deriving the concentration formula (II): Solution

Introduce the R&D cost elasticity $\alpha = -\frac{dc(x)}{dx}\frac{x}{c}$ (from firm's R&D FOC).

This implies: $\frac{x}{cq} = \alpha$, so $\frac{Nx}{Q} = \frac{Nx}{Nq} = \frac{x}{q} = \alpha c$

Substitute into our equation:

$$\underbrace{\frac{P}{N\varepsilon}}_{\text{markup}} = \underbrace{\alpha c}_{\text{R\&D cost per unit}}$$

Divide by P and use $c/P = 1 - 1/(N\varepsilon)$ from the pricing FOC:

$$\frac{1}{N\varepsilon} = \alpha\left(1 - \frac{1}{N\varepsilon}\right) \quad \Rightarrow \quad \frac{1}{N^*} = \frac{1}{\varepsilon} \cdot \frac{\alpha}{1+\alpha}$$

Equilibrium concentration

Equilibrium concentration satisfies:

$$\frac{1}{N^*} = \frac{1}{\varepsilon} \cdot \frac{\alpha}{1+\alpha}$$

Interpretation

Concentration and research intensity are jointly determined: entry expands N until operating surplus covers R&D outlays x^*. Higher R&D cost elasticity (α) supports higher concentration; more elastic demand lowers concentration.

Numerical illustration

Using the concentration formula with specific values:

$$\frac{1}{N^*} = \frac{1}{\varepsilon} \cdot \frac{\alpha}{1+\alpha}$$

- If $\varepsilon = 2$ and $\alpha = 1$: $\frac{1}{N^*} = \frac{1}{2} \cdot \frac{1}{2} = \frac{1}{4}$, so $N^* = 4$ firms
- If $\varepsilon = 2$ and $\alpha = 3$: $\frac{1}{N^*} = \frac{1}{2} \cdot \frac{3}{4} = \frac{3}{8}$, so $N^* \approx 2.7$ firms

> **Discussion question**
>
> If a government subsidy increases the R&D cost elasticity (α, making R&D more effective), what does the model predict for market structure? Is this welfare-improving?

Key comparative statics (I)

With $P(Q) = \sigma Q^{-\varepsilon}$ and $c(x) = \beta x^{-\alpha}$:

Dynamic vs static efficiency trade-off:

- $x^*(N+1) < x^*(N)$ (more firms $\rightarrow$ less R&D per firm)
- $Q^*(N+1) > Q^*(N)$ (more firms $\rightarrow$ higher output)

Research intensity:

- Often maximized at moderate concentration (Scherer-style inverse-U)

Interpretation:

- Market structure affects both static outcomes (Q) and dynamic investment incentives (x)

Key comparative statics (II)

Greater R&D effectiveness (higher α) associated with higher concentration:

$$\frac{\partial(1/N^*)}{\partial\alpha} > 0$$

Demand growth stimulates R&D:

$$\frac{\partial x^*}{\partial\sigma} > 0$$

Interpretation:

- Larger markets (higher σ) increase the return to cost reduction
- More effective R&D (higher α) can support higher concentration in equilibrium

Summary and next week

Summary

- Innovation value depends on the objective: $\Delta\pi$ **(private)** versus ΔW **(social)**
- Replacement effect: pre-innovation rents reduce the incumbent's incremental gain from innovation
- With entry threat, innovation can be worth more because it changes **market structure** (monopoly vs duopoly)
- In oligopoly, incentives reflect competing forces (competition effect vs competitive advantage effect)

Next week: patents and IPRs

- Patents as incentives: monopoly rights vs. dynamic efficiency
- Patent races and timing
- Disclosure, licensing, and welfare
- Horizontal and vertical innovation (brief)

References

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