# Lecture 3 - Innovation

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# 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 (∼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**

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

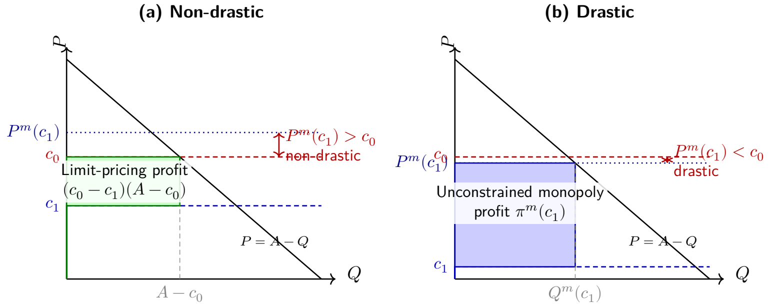
**Why the non-drastic formula?** If the innovator sets $p = c_0$, quantity is $Q = A - c_0$, so profits are $(p - c_1)Q = (c_0 - c_1)(A - c_0)$.

# Drastic vs non-drastic innovation condition

Drastic: $P^m(c_1) < c_0 \Leftrightarrow \dfrac{A + c_1}{2} < c_0 \Leftrightarrow A + c_1 < 2c_0$

Non-drastic: $P^m(c_1) \geq c_0 \Leftrightarrow \dfrac{A + c_1}{2} \geq c_0 \Leftrightarrow A + c_1 \geq 2c_0$

Boundary case: $P^m(c_1) = c_0$ (equivalently $A + c_1 = 2c_0$).



# Numeric check: drastic or non-drastic?

Use the same values as panel (a): $A = 18$, $c_0 = 10$, and $c_1 = 6$.

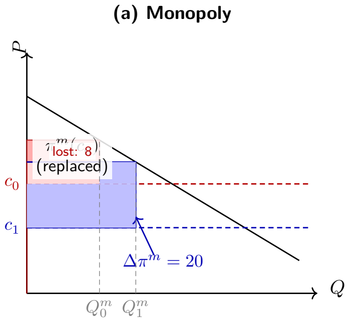
- **Drastic condition**: $A + c_1 = 24 > 2c_0 = 20 \rightarrow$ **non-drastic**
- Innovator limit-prices at $p = c_0 = 10$, sells $Q = A - c_0 = 8$
- Competitive innovator profit: $(c_0 - c_1)(A - c_0) = 4 \times 8 = 32$
- Recall monopoly WTP: $\Delta\pi^m = \frac{(12)^2-(8)^2}{4} = \frac{144-64}{4} = 20$

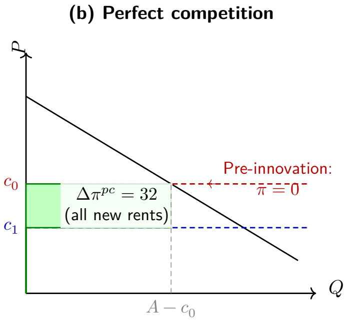
**Replacement effect preview**

The competitive innovator earns $32 > 20$ (the monopolist's WTP). The monopolist gains less because it already earns $\pi^m(c_0) = 16$ 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)

- The key object is the **incremental** value of innovation.
- Competitive benchmark: pre-innovation profits are approximately zero, so $\Delta\pi^{pc} \approx \pi^{pc}_{\text{after}}$.
- Monopoly benchmark: pre-innovation profits are positive, so $\Delta\pi^{m} = \pi^{m}_{\text{after}} - \pi^{m}(c_0)$.
- This gap in incremental value is the **replacement effect**.

# Drastic benchmark: one-line wedge

If 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.

# Appropriability and imitation

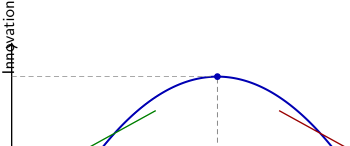
- If the innovation cannot be protected (instant diffusion / perfect imitation), competition drives price to $c_1$ and the innovator's WTP is zero.
- Most IO policy questions start from imperfect but positive appropriability (patents, secrecy, lead time).

# 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: $\Delta W$ **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 with rivals: intuition first

Innovation incentives are not monotone in "competition intensity."

- They depend on market structure ($n$, differentiation, price vs quantity competition).
- They depend on technology and institutions (protectability, spillovers).

**Rule of thumb**

More rivals reduce baseline profits (discouraging innovation), but can raise the value of becoming the low-cost firm (encouraging innovation).

# Number of rivals: Cournot intuition

In linear Cournot, R&D incentives can follow an **inverse-U** as $n$ rises:

- **Competition effect:** more firms compress profits for everyone.
- **Competitive advantage effect:** a cost lead is more valuable when many higher-cost rivals remain.

Which force dominates is an empirical question and can vary by industry.

# Entry threat framework: incumbent vs entrant

Consider an incumbent monopolist facing a potential entrant:

- Innovation lowers marginal cost from $c_0$ to $c_1 < c_0$.
- The entrant can profitably enter only if it obtains the innovation.
- Let $\pi^d(c_i, c_j)$ be firm $i$'s duopoly profit when own cost is $c_i$ and rival cost is $c_j$.

Timing:

1. Firms compete for innovation (patent auction / R&D race).
2. Innovation is allocated to the higher-valuation firm.
3. Entry decision and product-market competition occur after allocation.

# Who values innovation more?

Payoff logic by winner:

- If the **incumbent** wins: market stays monopoly, payoff $\pi^m(c_1)$.
- If the **entrant** wins: entry occurs, payoffs become $\pi^d(c_0, c_1)$ for the incumbent and $\pi^d(c_1, c_0)$ for the entrant.

So per-period valuations are:

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

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

The incumbent has stronger innovation incentives when:

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

This is more likely when products are close substitutes, so entry would sharply reduce incumbent profits.

**!** Interpretation

For incumbents, innovation has a **dual payoff**: efficiency gain (lower cost) plus market-structure protection (deterring entry). That is the pre-emption channel.

# 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)

# Planner benchmark: Social optimum

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

**First-order condition in $x$:**

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

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 $\varepsilon$ 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 ($\alpha$) 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 ($\alpha$, 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 $\alpha$) 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 $\sigma$) increase the return to cost reduction
- More effective R&D (higher $\alpha$) can support higher concentration in equilibrium

# Summary and next week

**Summary**

- Innovation value depends on the objective: $\Delta\pi$ **(private)** versus $\Delta W$ **(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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