

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 → Development → 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)

i 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.

i 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 $c_1 < c_0 < A$

i 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

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

Monopoly WTP for innovation

WTP for the innovation

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

i 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

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

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

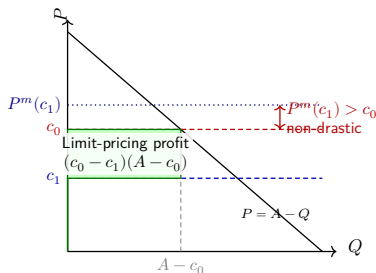
Drastic vs non-drastic innovation condition

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

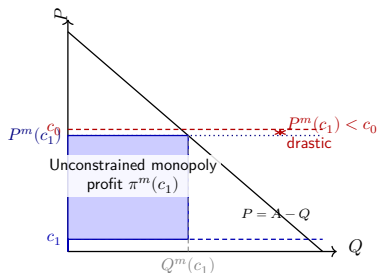
$$\text{Non-drastic: } P^m(c_1) \geq c_0 \Leftrightarrow \frac{A + c_1}{2} \geq c_0 \Leftrightarrow A + c_1 \geq 2c_0$$

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

(a) Non-drastic



(b) Drastic



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: $\Delta\pi^m = \frac{(12)^2 - (8)^2}{4} = \frac{144 - 64}{4} = 20$

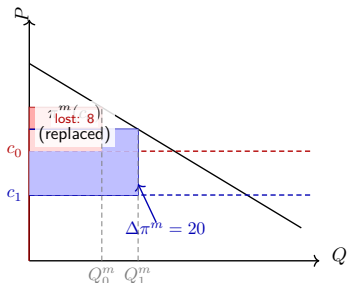
i Replacement effect preview

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.

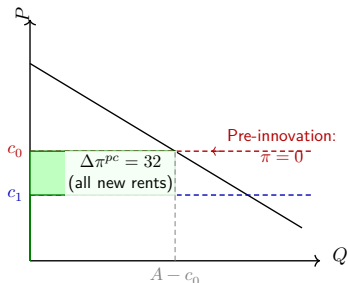
Replacement effect: visual comparison

- ▶ 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.

(a) Monopoly



(b) Perfect competition



Replacement effect (Arrow 1972)

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

Drastic benchmark: one-line wedge

If innovation is drastic and grants exclusive rights:

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

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

- ▶ 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

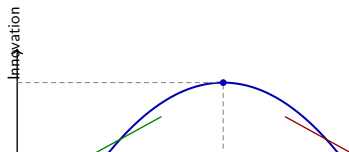
- ▶ If the innovation cannot be protected (instant diffusion / perfect imitation), competition drives price to c_1 and the innovator's WTP is zero.
- ▶ Most IO policy questions start from imperfect but positive appropriability (patents, secrecy, lead time).

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.

i 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

After the private-value benchmarks, we now switch to the **social objective**.

Efficient output (price equals marginal cost)

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

Total surplus (welfare):

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

i 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.

i 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)

Using the same calibration as earlier ($A = 18$, $c_0 = 10$, $c_1 = 6$):

- ▶ Monopoly: $\pi^m(c_0) = 16$, $\pi^m(c_1) = 36$, so $\Delta\pi^m = 20$
- ▶ Planner: $W(c_0) = 32$, $W(c_1) = 72$, so $\Delta W = 40$ (twice the monopoly gain)

i 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

We now move from benchmark environments to **strategic interaction** with rivals and entry threat.

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).

i 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:

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

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 (detering entry). That is the pre-emption channel.

Discussion: when does pre-emption fail?

i Discussion question

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

Answer: when entrant incentives dominate

Entrant incentives are stronger when:

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

- ▶ **Weak business-stealing effect:** products are more differentiated, so entry hurts the incumbent less.
- ▶ **Low market-structure protection value:** moving from duopoly to monopoly is not worth much to the incumbent.
- ▶ **High entrant upside from innovation:** entrant post-entry profits $\pi^d(c_1, c_0)$ are large (e.g., efficient entry, strong demand segment).
- ▶ **Large incumbent replacement effect:** the incumbent already has substantial rents without innovating, so incremental gains are limited.
- ▶ **Weaker appropriability for incumbents** (strong spillovers/imitation): innovation is less effective as an entry-deterrence tool.

Empirical example: strategic incentives and market share

i 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 pre-emptive innovation) in oligopolistic industries.

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

Big Question

In Dasgupta-Stiglitz, firms choose R&D and entry is endogenous. The central question is: **what jointly determines innovation intensity and concentration?**

This final model puts both objects, x and N , inside one equilibrium system.

Key forces:

- ▶ **Demand conditions** (elasticity, market size)
- ▶ **R&D technology** (how effectively spending lowers cost)
- ▶ **Free entry** (how many firms can cover R&D outlays)

Notation for this section

Symbol	Type	Meaning
x	Choice	R&D expenditure per firm
$c(x)$	Function	Marginal cost, with $c'(x) < 0$
N	Outcome	Number of active firms (endogenous)
ε	Parameter	Market demand elasticity
α	Parameter	R&D cost elasticity, $\alpha = -\frac{dc(x)}{dx} \frac{x}{c}$

Planner benchmark: why scale matters

Planner problem:

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

FOC for R&D:

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

Interpretation: the marginal benefit of R&D is proportional to output scale Q , so larger markets justify more cost-reducing innovation.

Empirical anchor: market size and innovation

i Pharmaceutical innovation responds to demand

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

- ▶ more pharmaceutical innovation (new drugs / new molecular entities)
- ▶ consistent evidence that innovation incentives rise with market scale

Industry side: firms choose output and R&D

Assume symmetric Cournot competition. Firm i solves:

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

In symmetric equilibrium, $q_i^* = Q^*/N^*$ and $x_i^* = x^*$.

Two equilibrium conditions

From Cournot pricing (perceived elasticity $N\varepsilon$):

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

From free entry (zero profit):

$$(P - c) \frac{Q}{N} - x = 0 \quad \Leftrightarrow \quad P - c = \frac{Nx}{Q}$$

Entry continues until operating margins exactly cover per-firm R&D spending.

Deriving concentration in one step

Equate the two expressions for the margin:

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

Use the R&D elasticity definition with the R&D FOC ($-c'(x)q = 1$), which implies:

$$\frac{x}{q} = \alpha c \quad \Rightarrow \quad \frac{Nx}{Q} = \alpha c$$

where symmetry implies $q = Q/N$.

So:

$$\frac{P}{N\varepsilon} = \alpha c$$

Divide by P and substitute $c/P = 1 - \frac{1}{N\varepsilon}$:

Core result: equilibrium concentration

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

i Interpretation

Concentration and innovation are jointly determined.

Higher R&D effectiveness (α) supports higher concentration, while more elastic demand (ε) supports lower concentration.

Numerical check

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

- ▶ If $\varepsilon = 2$ and $\alpha = 1$, then $\frac{1}{N^*} = \frac{1}{4}$ so $N^* = 4$.
- ▶ If $\varepsilon = 2$ and $\alpha = 3$, then $\frac{1}{N^*} = \frac{3}{8}$ so $N^* \approx 2.7$.

i Discussion question

If policy raises R&D effectiveness (α), the model predicts **more concentration** (lower N^*).

When is that welfare-improving once we account for both dynamic gains and static mark-up losses?

Comparative statics and trade-offs

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

- ▶ Here, $\sigma > 0$ is a demand-level (market-size) shifter.
- ▶ $\frac{\partial(1/N^*)}{\partial \alpha} > 0$: more effective R&D tends to increase concentration.
- ▶ $\frac{\partial(1/N^*)}{\partial \varepsilon} < 0$: more elastic demand tends to reduce concentration.
- ▶ $\frac{\partial x^*}{\partial \sigma} > 0$: larger markets raise R&D effort.
- ▶ Typically, $x^*(N+1) < x^*(N)$ but $Q^*(N+1) > Q^*(N)$: more firms improve static efficiency yet can weaken per-firm innovation incentives.

This is the core dynamic-static tension in endogenous market-structure models.

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

Acemoglu, Daron, and Joshua Linn. 2004. 'Market Size in Innovation: Theory and Evidence from the Pharmaceutical Industry'. *Quarterly Journal of Economics* 119 (3): 1049–90. <https://doi.org/10.1162/0033553041502144>.

Aghion, Philippe, Nick Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt. 2005. 'Competition and Innovation: An Inverted-u Relationship'. *Quarterly Journal of Economics* 120 (2): 701–28. <https://doi.org/10.1093/qje/120.2.701>.

Arrow, K. J. 1972. 'Economic Welfare and the Allocation of Resources for Invention'. In *Readings in Industrial Economics: Volume Two: Private Enterprise and State Intervention*, edited by Charles K. Rowley. Macmillan Education UK. https://doi.org/10.1007/978-1-349-15486-9_13.

Blundell, Richard, Rachel Griffith, and John Van Reenen. 1999.