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 (∼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

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

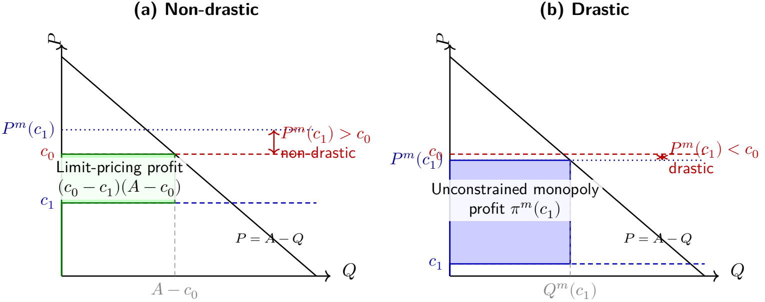
Why the non-drastic formula? If the innovator sets $p = c_0$, quantity is $Q = A - c_0$, so profits are $(p - c_1)Q = (c_0 - c_1)(A - c_0)$.

Drastic vs non-drastic innovation condition

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

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

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



Numeric check: drastic or non-drastic?

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

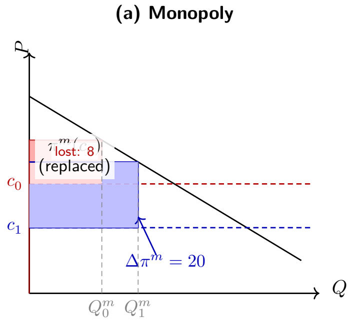
- **Drastic condition**: $A + c_1 = 24 > 2c_0 = 20 \rightarrow$ **non-drastic**
- Innovator limit-prices at $p = c_0 = 10$, sells $Q = A - c_0 = 8$
- Competitive innovator profit: $(c_0 - c_1)(A - c_0) = 4 \times 8 = 32$
- Recall monopoly WTP: $\Delta\pi^m = \frac{(12)^2-(8)^2}{4} = \frac{144-64}{4}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

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

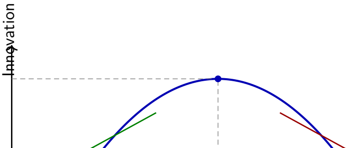
- If the innovation cannot be protected (instant diffusion / perfect imitation), competition drives price to c_1 and the innovator's WTP is zero.
- Most IO policy questions start from imperfect but positive appropriability (patents, secrecy, lead time).

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: 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 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?

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

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)

Big Question

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

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

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:

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

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:

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

So:

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

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

Core result: equilibrium concentration

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

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 $N^* \approx 2.7$.

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 $c(x) = \beta x^{-\alpha}$:

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