Research and Development

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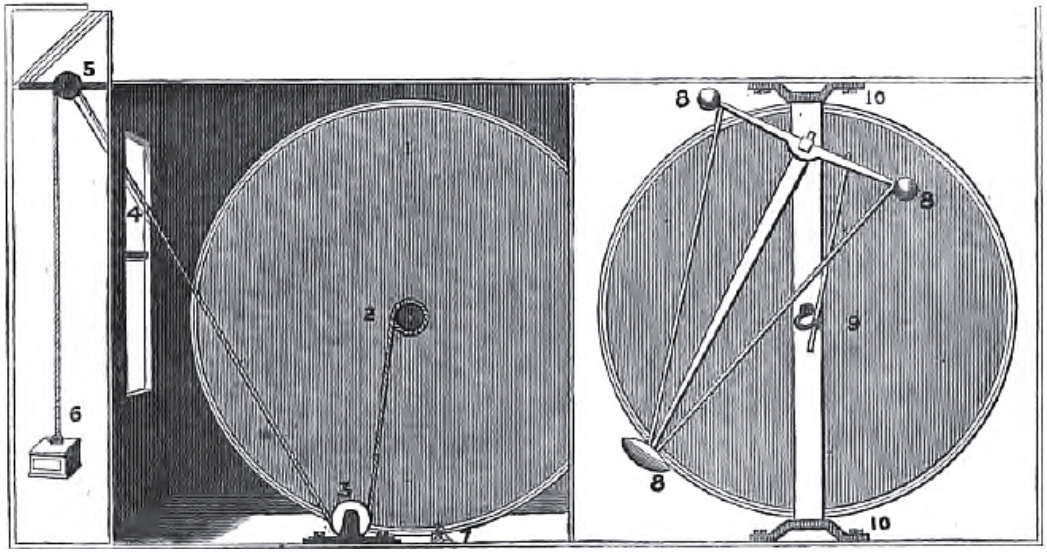
Introduction

- Most of our wealth comes from technological innovation
- Economic growth due to innovation is the real *perpetuum mobile* (and proof that economics beats physics)
  - Labor can only grow so much (bounded ecological capacity?)
  - Even capital does not grow indefinitely (depreciation!)
  - Technology is the engine of growth (R. Solow 1956)
  - Accounts for about half the growth in advanced economies



- Solow just assumed an exogenous rate of technological growth
- Alchian (1963) estimated a learning curve in airplane production
  - (gathered data during war but could only publish in 1963 because they were classified!)
  - found productivity in airplane production increased greatly without any obvious changes in machines or people
  - "learning by doing"
- But most often technological change is a result of conscious search for innovation
  - Research and Development!

- P. Romer (1986) - Technological change is *endogenous*
- **Economic growth occurs whenever people take resources and rearrange them in ways that are more valuable.** A useful metaphor for production in an economy comes from the kitchen. To create valuable final products, we mix inexpensive ingredients together according to a recipe. The cooking one can do is limited by the supply of ingredients, and most cooking in the economy produces undesirable side effects. If economic growth could be achieved only by doing more and more of the same kind of cooking, we would eventually run out of raw materials and suffer from unacceptable levels of pollution and nuisance. **History teaches us, however, that economic growth springs from better recipes, not just from more cooking.** New recipes generally produce fewer unpleasant side effects and generate more economic value per unit of raw material.
  Every generation has perceived the limits to growth that finite resources and undesirable side effects would pose if no new recipes or ideas were discovered. And every generation has underestimated the potential for finding new recipes and ideas. **We consistently fail to grasp how many ideas remain to be discovered. Possibilities do not add up. They multiply.**

KEY QUESTION

Are there sufficient incentives for R&D?

- Relatedly: Can policies be used to influence the incentives to innovate?
- Arrow (1962): How do different market structures influence the incentives to innovate?
- How do innovation opportunities affect market structure?

Predicting the future of technological progress is hard

Professor Frink - (Simpsons Season 4 - Episode 20)

Compare this to Moore's law...

Fundamental uncertainties

1. Intrinsic uncertainty: results not guaranteed.
   - Ford spent 2 billion dollars building the car of the future...

   and all we got was this!?

2. Market uncertainty: effect on cost/output/revenue unknown.
   - Indeed nobody bought the Ford Edsel. Or the Apple Newton (early form of iPad), or Betamax recorders...
3. Rivalry uncertainty: Rivals may match R&D expenditures or imitate.
   - How many iPad clones are there in the world?

The patent dilemma

- Compensation comes in the form of a patent.

Definition

Patent: a monopoly awarded by the government to reward innovation.

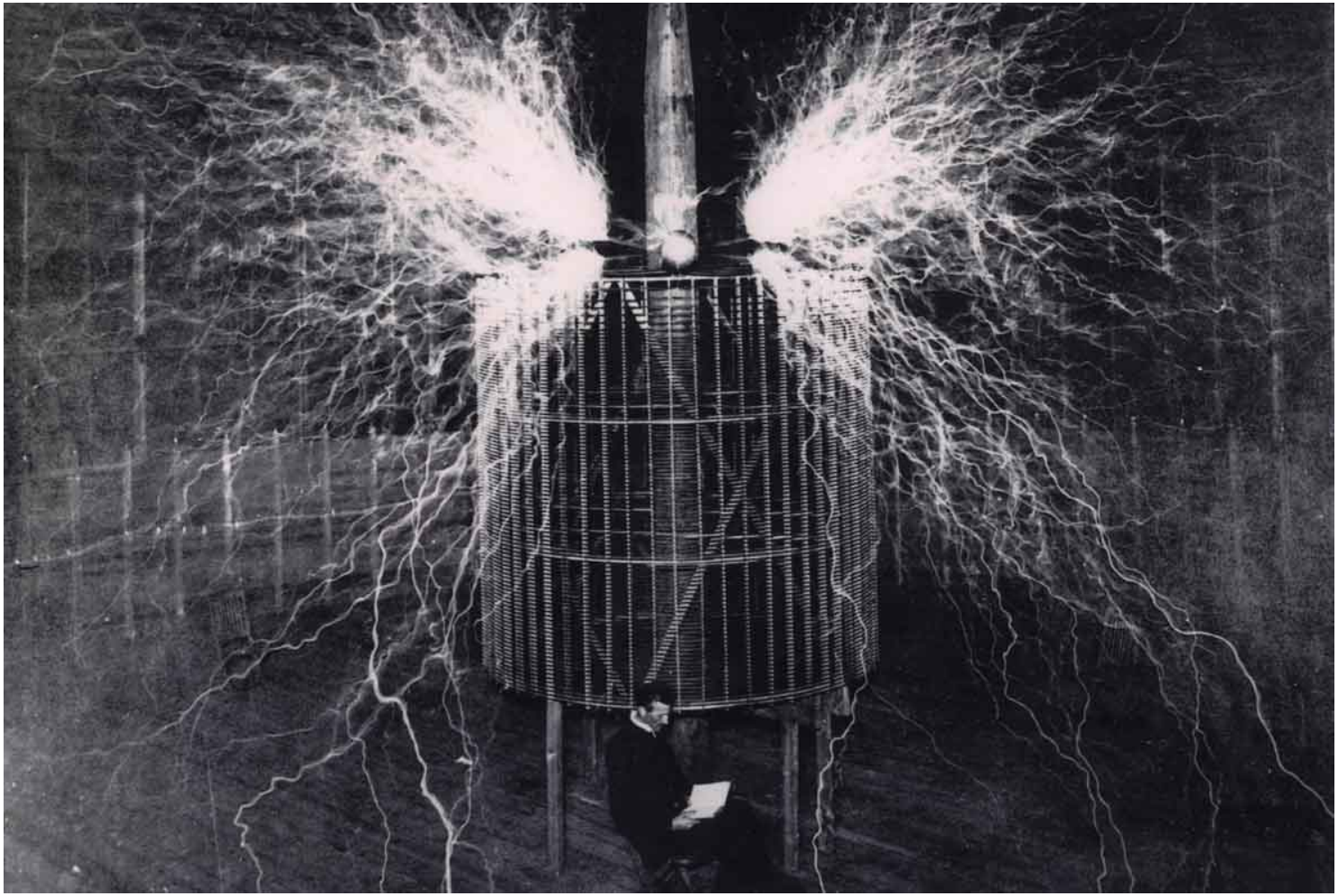
DILEMMA

The patent *encourages innovation*, but *prevents its diffusion*; it creates non-competitive situations.

- Big debate - Some people (e.g. economists M. Boldrin and D. Levine) believe there should be no intellectual property at all
  - To prove it, their book is actually freely available online here

- Example from B-L: Watt's steam engine.
- While there was a patent, 750 hp of steam engines were added per year to the UK stock.
- After patent expired: 4,000 hp per year!
- Other people say the whole industrial revolution comes from the protection of intellectual property rights
- Would Watt invent his engine if he couldn't get a patent?

The patent dilemma



- Tesla would probably have done it anyway (he actually died broke!)

The patent dilemma

- B-L claim a first mover advantage is just enough incentive to innovate.
  - Other firms can copy ipods and iphones, but Apple does it first and better.
- During the nineteenth century anyone was free in the United States to reprint a foreign publication
  - without copyright, authors still got paid, sometime more than with it
  - readers were impatient - American publishers who bought the manuscript had every incentive to saturate the market as soon as possible, to avoid cheap imitators to come in soon after.
  - British authors received more money upfront in the US than years of royalties in UK!
- But let's start with a simple model...

Incentives to innovate as a function of the market structure

- We will give a simple analysis of the incentives to innovate under competition and monopoly. Our main finding will be:

KEY POINT

It is the opportunity of *becoming* a monopoly that provides the incentives for innovation; a firm that is already in a monopoly situation does not have very strong incentives to innovate.
However, not even the opportunity of becoming a monopoly provides sufficiently strong incentives for innovation.

Incentives to innovate

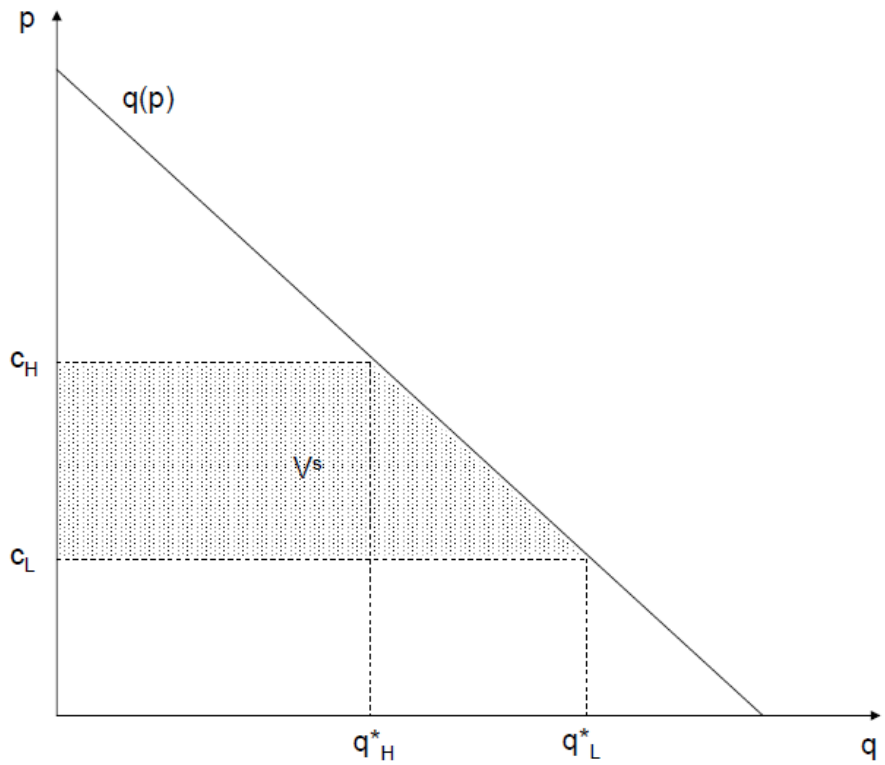
A simple model

- An innovation can reduce the constant marginal cost from c^H to c^L.
- The innovation is protected by a patent of unlimited duration.
- How much would a firm be willing to pay to obtain the superior technology?

Incentives to innovate

Social value of the innovation

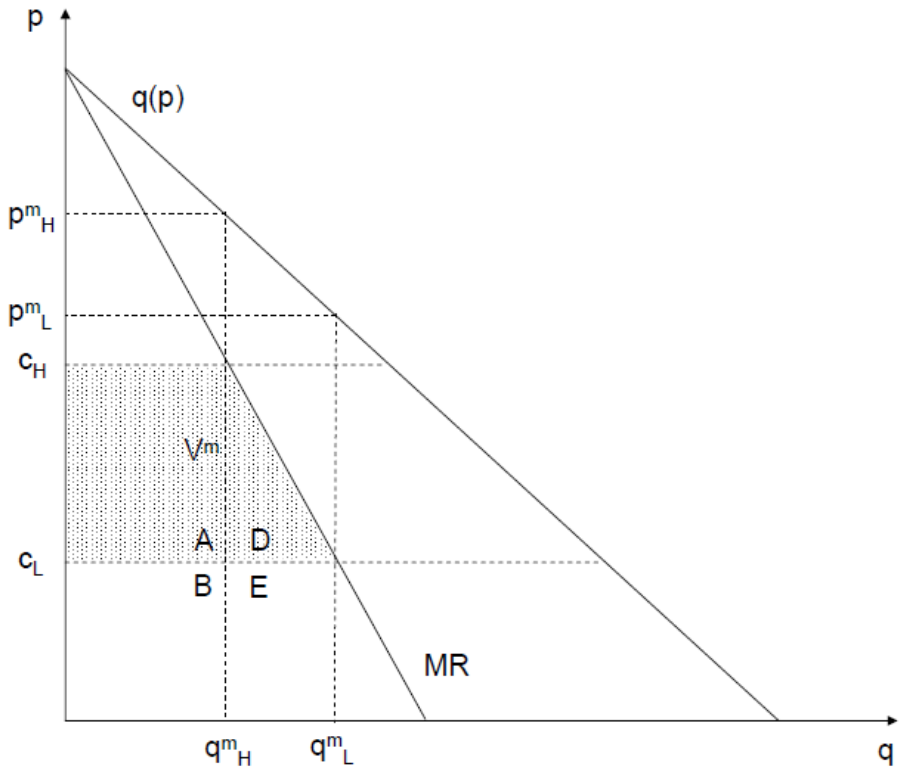
- Assume pricing is efficient
- What would be the social value of the innovation?
  - Before the innovation $p = c_h$ and after $p = c_l$.
  - The social value is then the increment in the consumer surplus $\Delta CS = V^s$.



Incentives to innovate

The monopolist's valuation of the innovation

- Now consider a monopolist.
- Willing to pay the amount by which the innovation increases profits.
- Before the innovation the monopolist produces q_H^m, and after the innovation, q_L^m.



- Total cost *before* the innovation is $A + B$;

Incentives to innovate

The monopolist's valuation of the innovation

- Total cost *after* the innovation is $B + E$.
- Thus the change in total costs are $\Delta C = (B + E) - (A + B) = E - A$.
- Since total revenue is the area under the marginal revenue curve, the increase in revenue due to the innovation is the area under the marginal revenue curve between q_H^m and q_L^m, i.e. $\Delta R = D + E$.
- Since the change in profits is the change in revenue less the increase in cost the change in profits are $\Delta\pi = \Delta R - \Delta C = (D + E) - (E - A) = D + A$.

- Thus the monopolist's valuation of the innovation is

$$V^m = \Delta\pi = D + A.$$

- By comparing the two figures, $V^m < V^s \Rightarrow$ the value to the monopolist is lower than the social value.
- The innovation is effectively replacing one profitable monopoly with another, which provides less incentives for innovation than the creation of a new monopoly would; hence the incentives to innovate are too weak (Arrow's "**replacement effect**").
- Another way to see: the monopolist is holding back the output (compared to the social optimum) the cost reduction is over a smaller number of units.

CONCLUSION

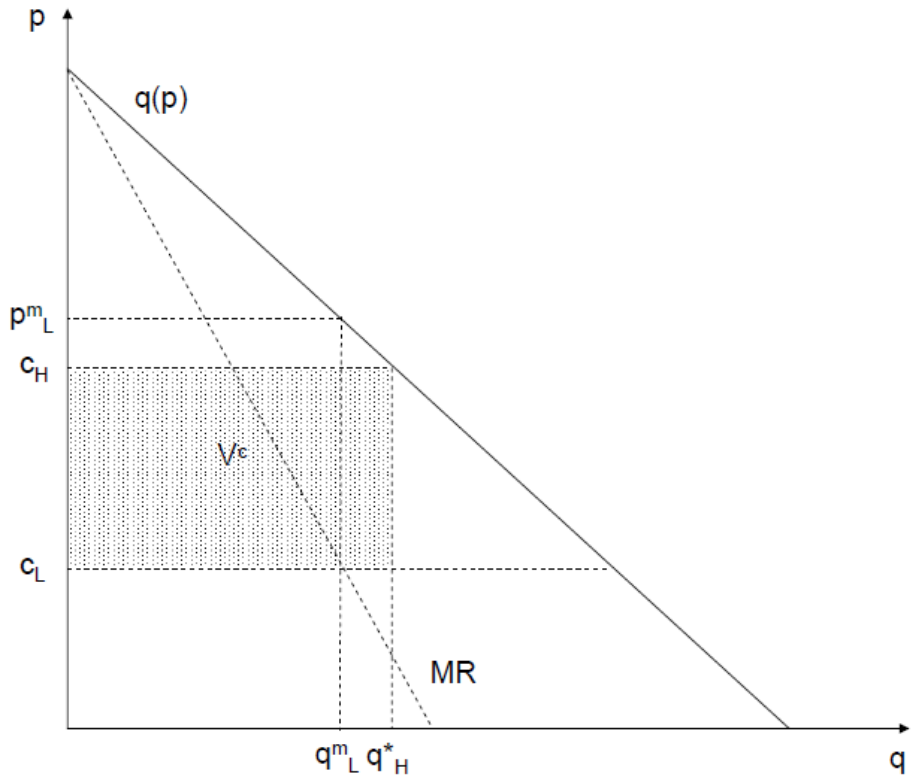
The monopolist's valuation of the innovation is less than its social value.

Incentives to innovate

The value of innovation under competition

- Assume that prior to innovation, the market is competitive: $p = c^H$.
- Think of two firms engaging in Bertrand price competition.
  - Initially zero profits.
- One firm obtains the cost-reducing technology (unlimited patent).
- Taxonomy:
  - The innovation is said to be *drastic* if the innovating firm can act as an unthreatened monopolist after the innovation ($p_I^* = p_I^m \leq c^H$).
  - The innovation is said to be *non-drastic* if the postinnovation monopoly price exceeds the original level of marginal costs ($p_L^m > c^H$)
    - so $p_I^* = c^H - \varepsilon$ to gain the whole market

- Assume that the innovation is non-drastic. Then the market price will not change.



- The best the innovating firm can do is to set the price (just below) $p = c^H$.

- Thus total price, total output, and consumer surplus do not change.
- However, the innovating firm will earn profits V^c, but $V^c < V^s$.

CONCLUSION

The value of an innovation to a firm under competition is also lower than its social value.

- We considered the incentives to innovate as a function of the market structure.
  - A firm in a competitive market has an incentive to innovate in order to gain a monopoly position.
  - A monopolist has weak incentives to innovate: he is simply improving his technology, and since he is producing a "low" output, the value of the cost reduction is small.
  - In both cases, are the incentives to innovate to small: the private gains are smaller than the social value.

$$V^s > V^c > V^m.$$

Incentives to innovate

Problems with the above analysis

- Ignores (i) competition in obtaining the innovation, and (ii) uncertainty in the innovation process.

Patent races

Definition

A patent race is a situation where several firms compete to be the first to make a discovery.

- Patent race analysis tackles the above problems.
- Intuition: Winner-takes-it-all situation
  - each firm may want to accelerate its research program to beat the opponents.
- A "common-pool" problem – each firm generates a negative externality on other participating firms since a firm participating in the race reduces the chance for another competing firm to win the race.

- Implication: There may then be *excessive* expenditure on R&D!
- However, there may be *spillover effects*.
  - Knowledge leakage to other firms, patent circumvention.
  - Benefits to consumers (from lack of perfect price discrimination).
- There may be learning effects (accumulated experience)

CONCLUSION

Patent races may generate excessive undertaking of R&D, but the presence of spillover effects and learning effects can reverse that conclusion.

Patent Races

Competition in a "memoryless" patent race

Definition

The R&D process is said to be memoryless if the probability of making a discovery only depends on current R&D expenditures (no accumulated experience).

- In this case, no advantage from having tried longer...
- The race to be first leads to intensive R&D efforts (Dixit, 1988)

Patent Races

A mini-example

The race

- Two firms $i = 1, 2$.
- Each firm can invest $I = \$1$ in R&D which gives a probability $\alpha = 1/2$ of making a specific discovery.
- There is a value/profits of $V = 3$ of making a discovery (no spillover effects).
- If both firms make the discovery they split the profits.

- If *only one* firm enters the race, its expected profits are:

$$\pi_i(1) = \alpha V - I = \frac{3}{2} - 1 = \frac{1}{2}. \tag{1}$$

- If *both* firms invest in R&D, each firm's expected profits are

$$\pi(2) = \alpha^2 \frac{V}{2} + \alpha(1-\alpha) V - 1 = \frac{1}{4}\left(\frac{3}{2} + 3\right) - 1 = \frac{1}{8}. \tag{2}$$

- Write down the pay-off matrix: choice is whether to invest (enter) or not (stay out).

		Firm 2	
		ENTER	STAY OUT
Firm 1	ENTER	1/8 , 1/8	1/2 , 0
	STAY OUT	0 , 1/2	0 , 0

- Each firm would like to be the only one to engage in R&D, but *both decide to enter the race* in a Nash equilibrium.

The social optimum

- What number of firms should engage in R&D?
- The social value V is realized *if at least one firm* makes the discovery.
- More firms entering increases the probability of a discovery, but at a decreasing rate (due to duplication). The costs however increase proportionately.
- The social value of one firm investing is

$$W(1) = \alpha V - I = \pi(1) = \frac{1}{2}. \tag{3}$$

- The social value of having 2 firms investing is

$$W(2) = \left[1 - (1-\alpha)^2\right] V - 2I = 3\left(\frac{1}{4} + \frac{2}{4}\right) - 2 = \frac{1}{4}. \quad (4)$$

  (note that $(1-\alpha)^2$ is the probability that two firms fail.)
- Thus the social optimum is for only one firm to invest in R&D. Having two firms engaging in R&D is too expensive.

CONCLUSION

Too many firms enter the patent race: there is excessive undertaking of R&D.

Patent Races

Patent race with learning effects

- The probability of making a discovery may not only depend on current expenditures, but also on accumulated experience, i.e. there may be *learning effects*.
- A firm can then be "ahead in the race", i.e. having a first mover advantage.
  - If one firm has a sufficient lead, then the other firms may drop out.
    - "Michael Jordan effect": Playing in a basketball contest against MJ $=>$ optimal effort is zero

- Competition in R&D may be strongly restricted if there are learning effects and first-mover advantage.
  - The company that started innovating first might have such a distance from the followers that they give up. The leader can then afford to be lazy...

CONCLUSION

If there are learning effects there may be too little incentives for R&D.

- **READ**: Case Study 18.1 in CW on investment in pharmaceutical R&D.

The effect of innovation opportunities on market structure

- Dasgupta and Stiglitz (1980) argue that industries in which R&D is effective in reducing production costs are likely to be concentrated.
- Thus causality is not from concentration to innovation, but rather from innovation opportunities to concentration.
- Dasgupta and Stiglitz argue that if R&D is effective in reducing marginal cost, there will be
  - substantial innovation
  - a high price-markup (to recover the R&D costs)
  - few firms (high market concentration)
- think of big pharmaceutical companies

CONCLUSION

Hence innovation opportunities cause concentration (not the reverse).

Incentives and policy

- What are the incentives for innovation? What are the mechanisms for appropriating the returns to innovation?

1. Lead time/secrecy
2. Moving down the learning curve
3. Patents

Incentives and policy

Alternative policies directed at R&D

- Patents
  - Additional benefit of encouraging disclosure of new discoveries (other firms are allowed to see, but not directly use the discovery!)
  - Disclosure can increase the pace of inventions as one inventor builds on the work of another
    - Without patents, firms going for a first mover advantage would try to obscure the details of their invention as much as possible (e.g. Intel would try to hide the real capabilities of their CPUs)
    - Other firms would not even know what is exactly possible given existing technology of other firms, and creating everything from scratch could be prohibitively slow/expensive
- Research contracts and prizes
  - Useful in specific context (well-defined race) where there is a perceived underinvestment (due to spillover effects). e.g. Human Genome Project

- Even private foundations can offer research prizes: e.g. X-Prize foundation (spaceflight, genomics, clean cars, robots on the moon)

- General subsidies to R&D
  - More useful when there is no well-defined race.
    - This means funding universities/"basic" research (e.g. this is where the salary of yours truly partly comes from)

A special case of intellectual property protection: Copyright

- Applies to works of authorship (e.g. books, music, software)
- The Mickey Mouse laws (Copyright Term Extension Act): copyright lasts for the author's life plus 50, 70, ... X years (where $X = T - D$, where T current date and D year of Disney's death)
  - Does it make sense from an incentive point of view? The author is dead but someone still gets paid. Why?
  - Simple calculation $U(\text{extra year}) = r^{(X+1)}(U(\pi_X) - U(\pi_{X+1}))$
  - What about extending the copyright duration *although the author has died already*?
- Hot debate: ideas are explicitly excluded from protection, but economic value sometimes can be protected
  - Example 1: *Lotus vs Borland* regarding menu command structure
  - Example 2: Amazon's one click buying

What to remember from this lecture

- The public good property of knowledge - the patent dilemma.
- The relation between market structure and innovation - direction of causality.
- The notion of patent races and why there may be excessive R&D
- The role of accumulated experience in reducing competition in R&D - spillovers
- That patents is not the only possible mechanism for securing a return to R&D.