Dfn "tech"

» something that enhances value and/or productivity

- but what is it?
- knowledge of some form!
  - • so why isn't the whole world well off? → diffusion, appropriateness
  - • public good ←→ what incentives to provide?
    - = patents, copyrights & trademarks
    - = trade secrets as "property" ←→ theft illegal
    - = (free) provision by governments and non-profits

» purest test: PPF shift

- but data challenges:
  - • like vs like ⇒ agriculture good, most other areas not
    - = Hayami and Ruttan: induced innovation
    - = Griliches: diffusion
  - • TFP: change in output after accounting for inputs
    - = empirically weak: unobserved variables, mis-measured inputs, price vs quantity effects
    - = provides a crude upper bound

» metrics

- outputs
  - • patent analysis
    - = much industry level variation in "propensity to patent"
    - = most patents have no direct value / are never used
    - =non-patented technologies
- inputs
  - • engineer headcounts, R&D budgets
    - = not all innovation from formal processes
    - = not all formal processes focus on innovation
- case studies: history of science / history of innovation

Chester Carlson / Xerox story

» typologies: Nelson, Rosenberg, Schmookler, others

	Cost	Risk	Appropriable?	Who
- science: pure knowledge	very low	very high	none	governments, universities
- development (applied research)	low	high	some	universities, corp advanced R&D
- commercialization	modest	modest	modest	corporate
- innovation (refinement)	high but predictable	low	high	corporate

much science is a by-product of other activities, and on average is fairly low in cost. most projects fail – and it's really awkward if your PhD advisor sets you to working on a pet theory that proves wrong. there's almost no ability to bottle things up, again with variation across fields. the grants used to fund research in university labs frequently require open publication of results and free access to data. careers depend on reputation, so there's a strong incentive to actively advertise/communicate results.

development is more costly, and much doesn't work out. but unlike basic science, there's less obligation and fewer career benefits from making results public. moot of course when projects fail, unless you can find a systematic cause of failure to help you choose your next project more carefully. in practice there's a lot of effort spent evaluating early results to decide whether to continue allocating researcher hours, funds for equipment & materials, and lab time/space.

commercialization is much more costly, but is done almost exclusively by firms. for the global Tier I suppliers in the auto industry, they've lots of experience in project management to help choose what they do and when they stop a project. for every 80 projects, perhaps 4 or 5% will keep going.

innovation can be extremely expensive, teams of engineers working with customers. but with a product in the market, firms can gauge how much benefit they get from taking out cost and improving performance, and how much it will run then in R&D to get there. this part of the technology sequence may be part of the regular corporate budget cycle, replete with a target date for intermediate reports and for the first delivery of the final product to customers.

the pharmaceutical industry fits this pattern, but with an extra zero or two on the cost side.

- Millions will be spent on the initial development and screening of candidate compounds, with 10,000 compounds resulting in a handful of candidates that pass the assay for (say) killing a particular type of cancer cell in a petri dish.
- Ten million will be spent on the initial animal trials for toxicity and *in vivo* efficacy. Most fail at that stage – a compound that kills cancer cells tends to kill non-cancer cells in a living organization, or may be neutralized by other things in the body.
- A hundred million will be spent on early-stage clinical trials, but most don't make it beyond Stage I – side effects (a muted version of that toxicity issue), or minimal efficacy (killing 50% of a particular type of cancer cell may not do much for the patient), or only works for certain types of patients/cancers.
- A few hundred million will be spent on late-stage clinical trials, licensing, production and advertising.
    - Since a company has to cover all the failures along the way, the cost per successful new pharmaceutical can easily hit $1 billion.
    - Innovation doesn't stop – multi-drug cocktails, variations on the original compound, refinements of prescription guidelines to lessen side effects and adjust dosages/ schedules. (However, I don't know how important or costly this is.)