

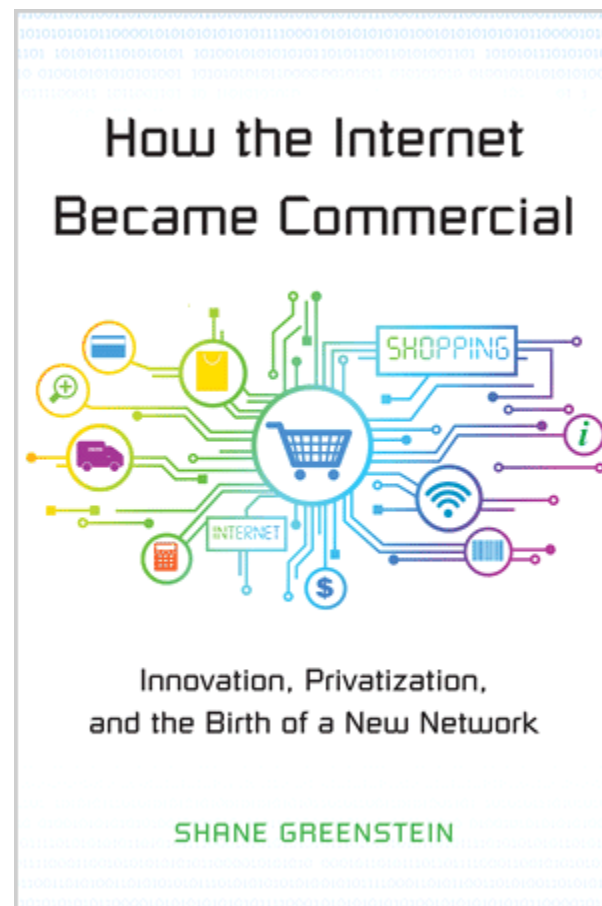
SOCIAL RETURNS TO PUBLIC INVESTMENT IN HUMAN CAPITAL & INFRASTRUCTURE

By Shane Greenstein
Harvard Business School
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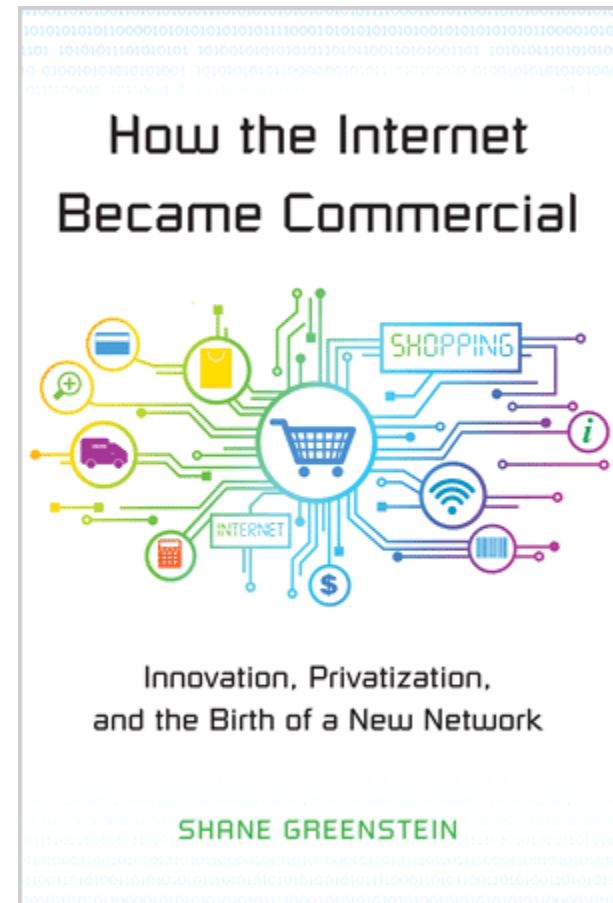
Introduction

- Thank you for providing opportunity.
- Question: What is/was the economic value of government investment in digital infrastructure?
- How should we think about the agenda?
- I wrote a book. Will review some themes from it.
 - Policy & institutions shape the rate and direction of innovation.
 - Digital dark matter: open issue.



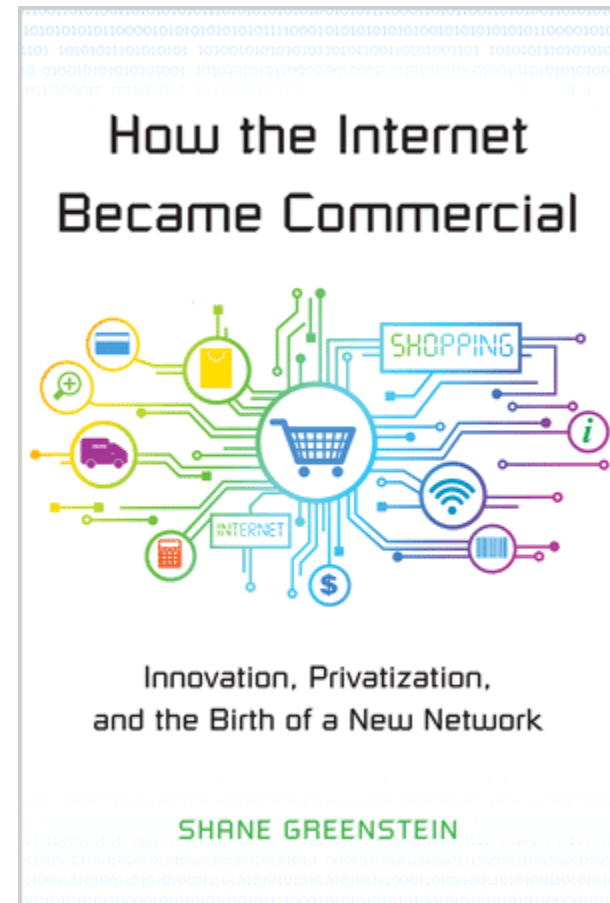
The twitter message of this talk (preferred language of the incoming administration).

- Reduction in federal R&D raises danger. Could delay arrival of the next Internet. Hhhhhhuge society losses for the future. Sad.
- The details matter. Hire somebody who reads books. Please.



Outline

- History & institutions shape the rate and direction of innovation.



Starting point: The standard economic model of public investment in innovation.

- Standard model: Government can address issues in innovation when risky, has long term returns, fragmented benefits difficult to capture.
 - So...Government funds R&D... using a variety of mechanisms... ***then something wonderful happens***.... inventions eventually works their way into commercial use.
- Yes, this fits parts of the experience in the Internet.
 - DARPA paid for initial experiments when nobody else did, & NSF paid for a wide variety of CS experiments among academics.
 - First cost approximately \$200m, second also approx.\$200m.
 - Yes, ***ex post*** payoff more than justified the expenditure on this & on many failed experiments. Though let's be careful with those numbers. (Hold that thought. More in a moment).

Standard model is too simple & it directs attention away from crucial phenomena.

- Important feedbacks from users into invention.
 - Gov't a lead user of IT internetworking.
 - Large private community too.
- Historically inaccurate to interpret gov't as (solely) motivated by economic concerns.
 - DOD and the NSF (primarily) invested in the Internet to solve their own problems, and for their own parochial reasons. DOD & NSF had big incentives to solve a big problems, and they did because there was a big payoff for realizing their own mission.
- Dual-use technologies: Needs at DOD and among NSF's users overlapped with needs faced by private actors.
 - As it turned out, the government solution also had relevance to the similar private problem.

Transfers from academic invention into private hands was not magic.

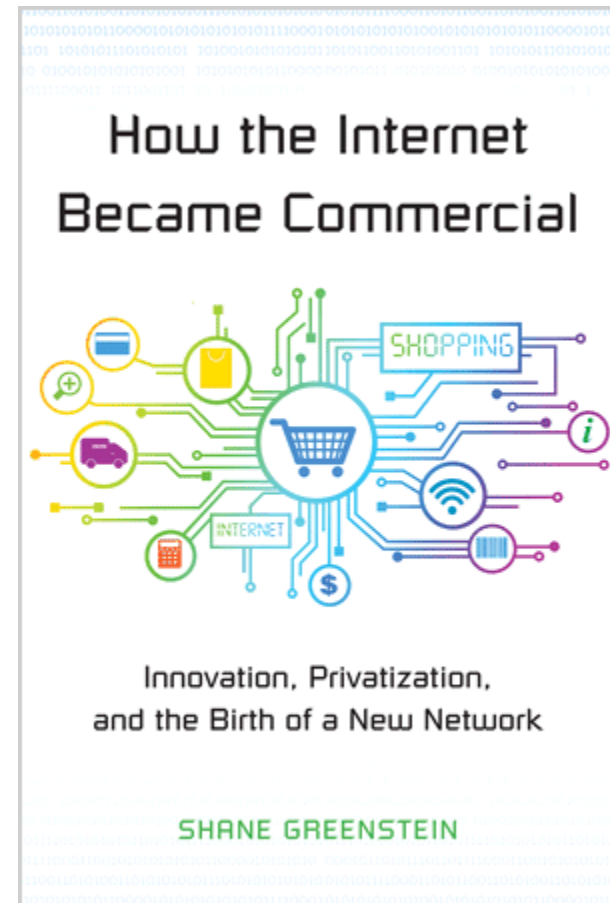
- Why did the government solution have relevance to private users too? (Chapter 3, 4, 5).
 - The mechanisms for the transfer – in licensing, in shareware, in students mobility – have an economic logic. **It's complicated.**
 - Ideas flow in ***both*** directions: b/w academics, private, & amateurs.
- Putting it into practice required investment. (Ch 6-15)
 - Relevant apps (e.g. email, file transfers, electronic commerce) were awaiting a public & open solution to interconnection.
 - No private firm had invested in public open protocols.
 - The privatization of the NSFNET provided enabling capital & software protocols. Private firms had taken risks w/potential long term gains, but tried proprietary approaches. **It's very complicated.**
- **If you are curious, read the book.**

Government action at early moments set in motion large scale investment.

- Government action matters because the scale of private investment swamped the government investment...
 - NSFNET's privatization helped **enable** investment.
 - Many potential private participants were fence-sitting, waiting for the arrival of widely-used protocols. NSFNET privatization did that.
 - Government backbone helped by hooking together so many networks.
- **US gov't got help: a catalyst to commercial growth.**
 - European science paid for invention of Web by Berners-Lee.
 - Then Berners-Lee moved to Cambridge, MA. Why? Myopic European technology policy + help from MIT (who was getting help from ...???)
 - **Catalyst for investment came from Web, Netscape + Apache & thousands of ISPs and VCs with many startups.**
- The point: ***Putting invention into practice should not be a footnote in our thinking.* Shapes the direction of returns, and, therefore, potentially also its rate.**

The point? Rate & direction of technical change determined by history/institutions.

- Sure, the government helped unleash economic growth by funding the Internet, but that is a ex post rationalization, and at best, an explanation for only part of the experience.
- Agenda: what factors shape the direction of R&D?



Outline

- Digital Dark Matter: an open issue



The (peculiar) role of measurement in figuring out returns....

- Digital dark matter: Asset w/o apparent monetary value, that can be replicated without limit, & act as IT input into production.
 - Mixes aspects of public and private goods.
 - Know it is there & plays a role in economy, but hard to observe. Digital goods seem particularly susceptible to mismeasurement, which makes it challenging to calculate returns from federal R&D.
- Why care? Many of the investments from the Internet found their way into private hands without a license or any economic transaction.
 - Is the ICT productive? Hard to know if there is a large addition stock of software that we largely don't measure.
 - In 2015 U.S. firms invested \$326 billion in software.

Illustration: Apache



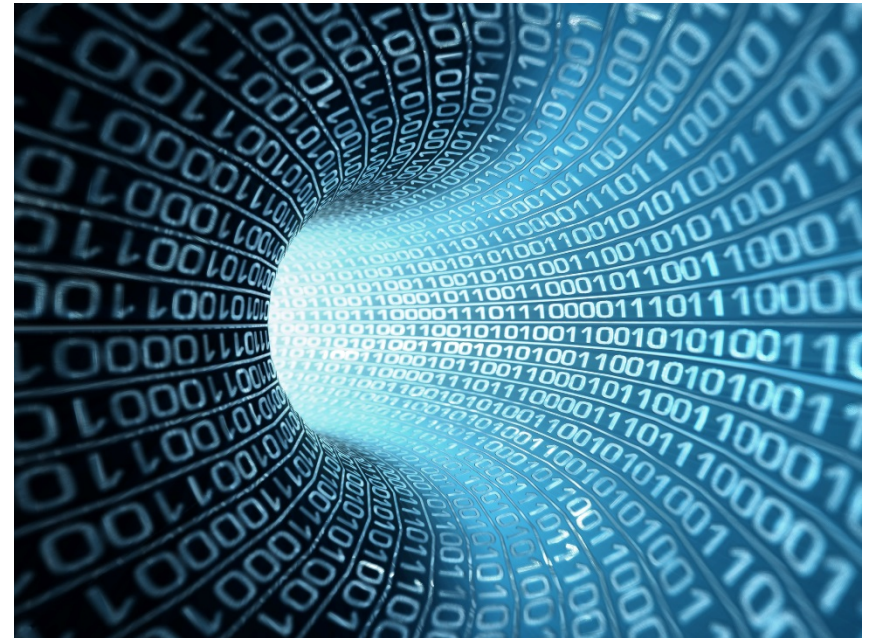
- Greenstein & Nagle (2014) took deep dive.
 - Takes a one percent sample of all IP addresses and estimates the total number of Apache servers in the US → 4 million....
 - Use standard procedures for “near market goods,” as defined by Nordhaus (2006). Sense for whether value is big or small.
- Findings: Apache accounts for a mismeasurement of somewhere b/w \$2 billion and \$12 billion in software.
 - Equates to b/w 1.3 % & 8.7 % of stock of prepackaged software in private fixed investment in the US
 - That is just one piece of software.
- Return on Apache ***alone*** would have generated sufficient rate of return to justify investment in Internet R&D
 - Potential for omission biases in productivity calculations? Yes.

Digital dark matter is a bigger issue than just one example

- Mechanisms that produce issue arise often.
 - Similar for Linux, TCP/IP software, Wikipedia, many new online languages, wifi software, and on and on.
- No prices for output and no prices for inputs. Many free goods on the Internet raises Internet value to users. It is not counted. Priced at zero.
 - BLS policy. Only ad \$\$\$ count in GDP. Improvement in the search services from Google, YouTube, Facebook don't count anywhere.
- **Why else? Challenging computation for price indices.**
 - Internet access a \$50B (and growing) today. CPI for Internet (broadband) access, 8/2007-8/16: 5.3% rise (73.1 → 77.0).
 - What is the price-equivalent decline in access prices for the entry of Facebook and YouTube and the improvement of Google? **Perhaps it needs an adjustment.**

The point? Rate & direction of technical change extremely difficult to measure

- The returns from government investment are hard to measure b/c some of the investment leave little economic trace in traditional GDP measures.
- Digital dark matter is an issue in need of more attention.



Thank you!

- Thank you for your attention.

Extra slides

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Some facts

- On Oct 15, 2011, there were 1.5B IPv4 addresses in US.
 - We took a 1% sample, approx 15.8m addresses.
 - Ask the IP address if it is running a web server. If so, which one?
- We found 195.9K (1.2%) servers in the IP sample.
 - We found 22% running Apache, and 12.3% running MS IIS.
 - Extrapolates to 4.2 million Apache servers in US.
- A few smell tests.
 - We looked at the distribution of tld and did not see anything implausible. Com is largest, Net is next (ISPs), etc...
 - Looked at the geographic distribution of servers and did not see anything implausible. (Major areas)
 - Looked at sld, symptom of firms: did not see anything implausible...
 - Average approx 33 web pages per Apache server....