Public Investment in Private R&D

NAS Innovation Policy Workshop

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Why subsidize private R&D?

- **Innovation spillovers**
  Arrow (1962), Akcigit and Kerr (2011), Haltiwanger et al. (2013), Griliches (1998)
  - R&D creates benefits that firm can't capture as profits
  - To rivals, complementary products
  - Social benefits (e.g. fossil fuel externalities)
- Well-established: Basic R&D has such large spillovers ⇒ Must happen in academia/gov't labs
  Griliches (1998), Aghion, Dewatripont and Stein (2008)
- Less obvious: Public funds should be used to support applied R&D within private firms

Challenges

- Might **crowd out** private investment
  - Worry projects would have gone forward with private finance in the absence of the grant
- Role of government in economy
  - Should gov't officials be choosing "worthy projects" for private firms to pursue?
  - Political capture/special interests

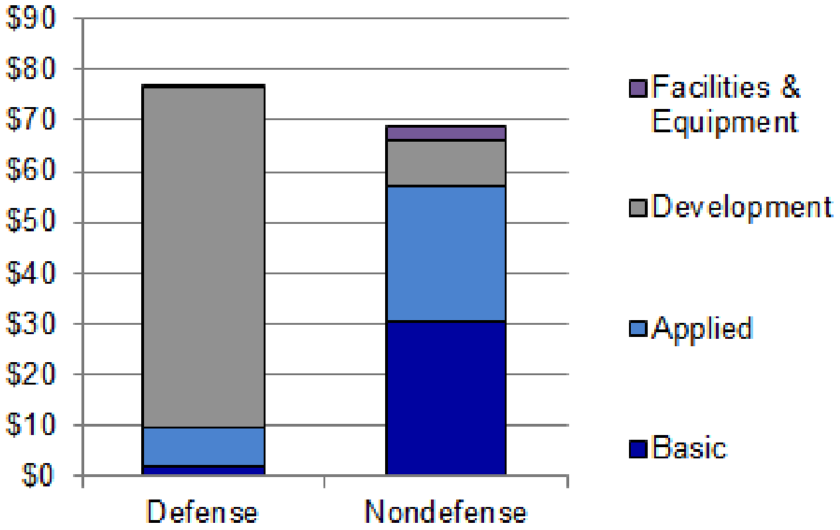
Why subsidize R&D in startups?

- **Costly external finance**
  Holmstrom (1989), Hall & Lerner (2009)
  - Capital market frictions: information asymmetry, incomplete contracting
- Entrepreneurial firms entering R&D-intensive sectors disproportionately innovative, play key role in economic growth
  Decker et al. (2015), Akcigit and Kerr (2011), Cohen and Klepper (1996)

Reality

- Governments and innovation intimately linked (war-technology interplay)
  Perez (2002), Chambers (1999)
  - Most important technologies developed post-1940 have a root or connection to gov't-funded research
  - Little formal evaluation
- Two models for gov't to advance technology
  - Connected (challenge) ⇒ DARPA
    - Basic science ⇒ prototype ⇒ application
  - Pipeline (basic) ⇒ NSF
    - Perceived "valley of death"

Federal FY2016 R&D by type; Total=$146 billion



Defense Advanced Research Projects Agency (DARPA)

UNCLASSIFIED

Department of Defense
FY 2017 President's Budget
Exhibit R-1 FY 2017 President's Budget
Total Obligational Authority
(Dollars in Thousands)

08 Jan 2016

Summary Recap of Budget Activities	FY 2015 (Base & OCO)	FY 2016 Base Enacted	FY 2016 OCO Enacted	FY 2016 Total Enacted	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Basic Research	381,371	389,663		389,663	420,088		420,088
Applied Research	1,136,845	1,163,380		1,163,380	1,246,308		1,246,308
Advanced Technology Development	1,241,088	1,243,667		1,243,667	1,232,637		1,232,637
Management Support	156,628	71,571		71,571	74,003		74,003
Total Research, Development, Test & Evaluation	2,915,932	2,868,281		2,868,281	2,973,036		2,973,036

- \$0.4 bill for basic research
- \$1.2 bill for applied research
- \$1.2 bill for development (later stage) research

DARPA

- Connected model ("challenges" target specific/abstract capabilities)
  - **Tolerance of failure**
  - Built teams from universities & industry
  - Reliance on small, young firms (not established defense contractors, Lockheed "Skunk Works" excepted)
- IT Revolution
  - Licklider catalyzes internet
  - Admirals Owens & Cebrowski translate to "network centric warfare"
  - 1990s productivity gains
  - E.g. Akamai Technologies

DARPA Today

- Ingredients for DARPA innovation system
  - Academics must have leeway to pursue their interests
  - DoD (client) must be open to new ideas
  - Entrepreneurs can access ideas to commercialize them
  - $\Rightarrow$ Breaks down if everything is classified
- Concerns post 2001:
  - Falloff in computer science
  - "Contract"-like projects, less open-ended
  - Shift to "black" research cuts out universities, non-defense firms
- **No formal evaluation** (to my knowledge)

DARPA Project Example 1

Quantitative Model of the Brain

$\implies$ Basic research, obvious civilian potential

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**
Title: Quantitative Models of the Brain ***Description:*** The Quantitative Models of the Brain program will establish a functional mathematical basis on which to build future advances in cognitive neuroscience, computing capability, and signal processing across the DoD. An important focus of this program will be determining how information is stored and recalled in the brain and other DoD-relevant signals, developing predictive, quantitative models of learning, memory, and measurement. Using this understanding, the program will develop powerful new symbolic computational capabilities for the DoD in a mathematical system that will provide the ability to understand complex and evolving signals and tasks while decreasing software and hardware requirements and other measurement resources. This includes a comprehensive mathematical theory to extract and leverage information in signals at multiple acquisition levels that would fundamentally generalize compressive sensing for multi-dimensional sources beyond domains typically used. New insights related to signal priors, task priors, and adaptation will enable these advances. This program will further exploit advances in the understanding and modeling of brain activity and organization to improve training of individuals and teams as well as identify new therapies for cognitive rehabilitation (e.g., Traumatic Brain Injury (TBI), Post Traumatic Stress Disorder (PTSD)). Critical to success will be the ability to detect cellular and network-level changes produced in the brain during the formation of new, hierarchically organized memories and memory classes, and to correlate those changes with memory function of animals during performance of behavioral tasks.	9.600	6.127

DARPA Project Example 2

Extended range modular rocket launcher

$\Longrightarrow$ Applied research, DOD application focus

C. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Complete test and evaluation of all elements and sub-systems of the aircraft. - Fabricate and assemble the full, complete aircraft with integrated systems and subsystems.			
Title: Distributed Fires (DFires) ***Description:*** The goal of the Distributed Fires (DFires) program is to create a capability which would allow for precision fires from extended ranges to be rapidly accessed for use. The DFires system would be a stand-alone system that would be transported by trucks, rotorcraft, or boats and delivered to supporting locations on the battlefield. The modular launcher unit would provide the communications link and pass along targeting commands to the onboard stores. The onboard stores would consist of multiple tube launched munitions. Technology areas to be developed include the overall system architecture, the communications requirements and protocols, and specific stores. The anticipated transition partners for this effort are the Army, Marine Corps, and Special Operations Forces.	-	6.000	5.000

Advanced Research Projects Agency-Energy (ARPA-E)

- Authorized 2007; total budget 2009-2015 $1.66 billion
  - "ARPA-E catalyzes transformational energy technologies to enhance the economic, environmental, and energy security of the United States by advancing high-potential, high-impact energy projects that are too early for private sector investment."
- Explicitly modeled on DARPA
  - But no gov't client
  - Much political scrutiny; little scope for failure
- NAS evaluation ongoing; no experimental/quasi-exp. evaluation

ARPA-E Grant to Ford

LOW PRESSURE MATERIAL-BASED NATURAL GAS FUEL SYSTEM

Ford Motor Company

Covalent and Metal-Organic Framework High-Capacity

Program: MOVE
ARPA-E Award: $5,050,082
Location: Dearborn, MI
Project Term: 09/17/2012 to 03/31/2015
Project Status: CANCELLED
Website: www.ford.com
Technical Categories: Transportation Fuels

ARPA-E Grants to GE

Grantee	*Project*	*Term*	*Funding*
GE Global Research	Cost-Effective Cable	02/24/2012 to 05/31/2014	$821,880
GE Global Research	Connecting Renewa	01/23/2012 to 01/22/2015	$4,487,156
GE Global Research	Nanocomposite Ma	10/01/2010 to 09/30/2013	$2,249,980
GE Global Research	Thin-Film Temperat	01/01/2013 to 12/31/2016	$3,128,285
GE Global Research	Chilled Natural Gas	01/01/2013 to 04/20/2014	$1,799,885
GE Global Research	Scalable Thick-Film	01/01/2011 to 07/17/2012	$811,520
GE Global Research	CO2 Capture with Li	10/01/2010 to 09/30/2013	$3,717,511
GE Global Research	Water-Based Flow B	03/28/2014 to 04/02/2015	$891,576
GE Global Research	High-Power Gas Tub	04/30/2013 to 04/30/2017	$5,395,993
GE Global Research	Electrochemical Ene	08/01/2014 to 07/31/2017	$2,275,671
GE Power & Water	Fabric-Based Wind T	05/01/2013 to 12/31/2014	$3,703,184
General Electric (GE)	Absorption Heat Pu	09/01/2015 to 03/02/2017	$1,099,941
General Electric (GE)	Optical Fibers for M	05/15/2015 to 05/15/2017	$1,438,627
General Electric (GE)	Silicon Carbide Supe	05/10/2016 to 05/09/2019	$2,561,429
General Electric (GE)	Synthetic Reserves f	06/10/2016 to 06/09/2019	$4,050,000
		Total	**$38,432,638**

Small Business Innovation Research (SBIR) Program

- Established 1983, 11 federal agencies participate
- Allocate 2.9% of R&D budget to SBIR grants (3.2% from 2017)
- Lump sum grants fund R&D in small, privately held, for-profit firms
- Two phases
  - 1: $150,000; Early-stage testing
  - 2: $1 million, Phase 1 winners eligible; Later-stage demonstration

SBIR best-studied R&D program

- Lerner (1999): SBIR awardees 1983-1985
  - Grew more than a matched sample
  - But only those with no prior awards, and in regions with high VC activity
- Wallsten (2000): 367 SBIR awardees, 90 rejects 1990-1992
  - No measurable effect on employment
  - Crowded out private R&D investment

"Financing Innovation: Evidence from R&D Grants" Howell (Forthcoming)

- Ranked applications to DOE SBIR grant program 1995-2013
    - Quasi-experiment compared firms firms just above and below cutoff for award
- Large average impact on subsequent cite-weighted patents and VC investment
    - Stronger for young firms, and those with no prev SBIR awards
- Mechanism seems to be technical derisking through prototyping
    - $\rightarrow$ reduces cost of external finance

SBIR-like programs abroad

- Israel: OCS grants
  - Lach (2002) finds strong positive effect, but only for smaller firms; they increased private R&D spending by 14 times the amount of the subsidy
- UK's Innovation Investment Fund
- China's Innofund
- Finland's National Technology Agency
- Chile's InnovaChile.
- Etc.

Role of VC in Innovation

- Venture capital played important role in post-1960 U.S. innovation
  - Kortum and Lerner (2000): VC 3-4x more powerful source of innovation than corporate R&D
  - Gornall and Strebulaev (2015): VC-backed companies account for 44% of all R&D spending of U.S. public companies, employ 4 million people
  - Gans and Stern (2003), Hellmann and Puri (2000)
- Should gov't be in the VC business?

Small Business Investment Company (SBIC) program

- SBIC program (est. 1958) jump-started U.S. VC industry
- SBICs are PE firms that lever up using cheap SBA loans (max $250 mill), which are then securitized and sold to public
- Tightly regulated
- 313 licensees w/ $28 billion AUM, of which >1/3 is gov't loans (9/2016)
- **No evaluation**

A few examples of many local gov't venture funds

- Venture Michigan Fund
  ($670 million of gov't investment in fund-of-funds/ VC tax vouchers)
  - **No evaluation**
- Florida Opportunity Fund
  (est. 2007, $1.5 bill to make FL a biotech hub)
  - 2010: "has not yet resulted in the growth of technology clusters in the counties where program grantees have established facilities."
  - **No evaluation**
- Ohio Third Frontier
  (est. 2002, $2.2 bill to support "innovation ecosystems" w/ early stage equity investment)
  - "They are inventing the cure for the Rust Belt."
    - then-Gov. Ted Strickland
  - **No evaluation**

Foreign government venturing

- Some evaluation of Canada gov't-backed VC (national and province-level)
  E.g. Labour Sponsored Venture Capital Corporation
  - Cumming and MacIntosh (2006): Gov't VCs earn lower returns, and crowd out (displace) private capital
  - Brander, Hellman and Egan (2008): Gov't backed VCs underperform (+ exits, patenting)
- Many such programs exist globally
  - In 2015 China committed > $231 bill to gov't-backed venture funds

Research agenda

- Evaluation methodologies
  - Can evaluation be built in on front end?
  - Randomize within high-quality applicants
- What are social returns to these programs?
  - Can programs be improved, e.g. by eliminating "SBIR mills"?
  - Are there really capital constraints to high-tech entrepreneurship in 21st century?

How does government venturing compare to less distortionary policies?

- Tax policy
- Reducing cost of financial intermediation (“fintech”)
- Pipeline model of science

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