Government-directed R&D and Innovation: Evidence from NASA Budget Requests

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Government's role in innovation

Innovation: main driver of modern economic growth

Market failures, externalities $\Longrightarrow$ **role for government**?
(Nelson 1959, Arrow 1962)

This paper:

Trace the full role of government R&D **investment** and **coordination**

NASA R&D a canonical case study

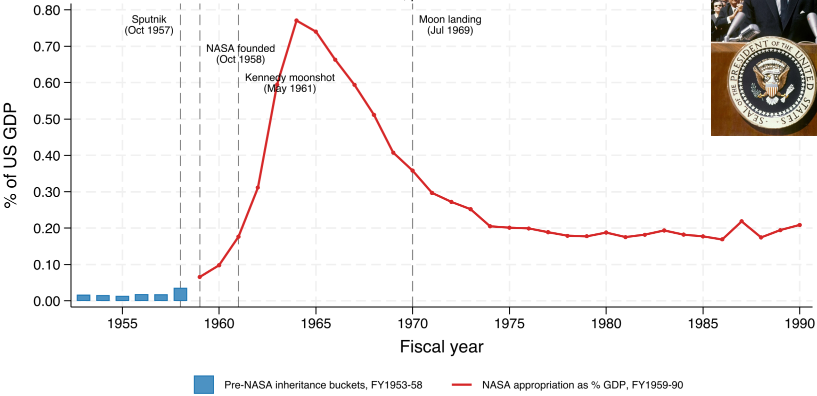
Apollo Mission & Gov. Directed Innovation

Project objectives

1. **Narrow:** What was the effect of the NASA mission on innovation?
   - Many anecdotes + Mazzucatto (2021): Canonical example of mission-oriented R&D
   - Billstein (1980), Launius (1994): NASA heavily indebted to 1950s missile defense R&D

2. **Broad:** Is government-directed innovation a unique input to knowledge production?
   - Potential market failures: technologies farther from commercialization; bigger technological problems?

NASA's Moonshot & Innovation



Pre-NASA fraction = sum of identifiable inheritance buckets / nominal US GDP (OMB Hist Table 10.1). NASA fraction = NASA appropriation / GDP.
Apollo-era peak: NASA = ~0.7% of GDP in mid-1960s. Pre-NASA fraction stays below 0.1% throughout FY1953-FY1958.
Sources: see Figure 09 caption. Pre-NASA buckets understate the true pre-NASA fraction (data gaps in ABMA/JPL/Vanguard pre-1957).
This was produced by Claude Code. All findings should be human verified.

NASA BUDGET REQUESTS ⇒ TECHNOLOGY OUTCOMES

Data: Detailed NASA congressional budget requests

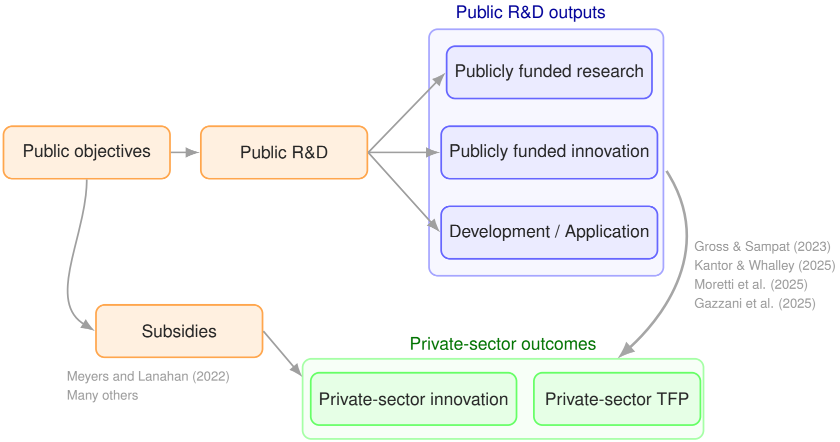
- Technological needs and public R&D justifications
- With $s allocated to each technological need

Measurement: LLM textual analysis identifies technological problems ⇒ technology classes

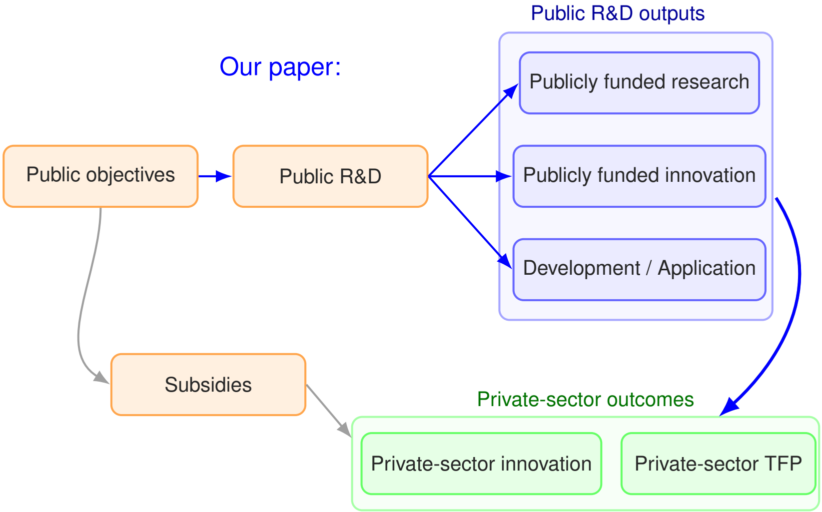
- More granular treatment than existing methods

Event study analysis: How did technologies NASA prioritized fare relative to comparable control group technologies?

Public R&D Policy

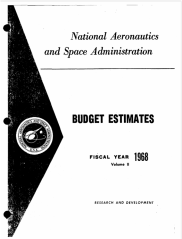


PUBLIC R&D POLICY



Textual Data

TEXTUAL SOURCE: NASA R&D BUDGET REQUESTS



Title Page of NASA's 1968 R&D Budget Request

NASA submitted **annual budget requests** to Congress:
R&D budget by program (Apollo, Mercury)

Annual hierarchy:
program → sub-program → ....

We extract budget **$s and full text description** at all program levels

NASA R&D Budget Requests

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1963 ESTIMATES

LAUNCH VEHICLE TECHNOLOGY

SUMMARY OF REQUIREMENTS:

	1961	1962	1963	Page No.
Advanced System Studies	$ 5,029,000	$ 6,116,000	$ 7,452,000	RDO 15-2
Vehicle Technology	8,822,000	16,964,000	24,238,000	RDO 15-3
TOTAL	$13,851,000	$23,080,000	$31,690,000	

OBJECTIVES:

The purpose of the Launch Vehicle Technology program is to advance the technology which will be required to support design and development of future launch vehicles; to solve technical problems faced by launch vehicles that are now being designed; and to examine alternate design concepts and systems for general application to space missions.

JUSTIFICATION:

In order to meet the long range goals of manned flight, lunar orbits and landings, and eventually planetary missions, the basic technology must keep pace with advancing vehicle concepts. Effort in this area is an integral part of the planning and development required for both current and future vehicles.

The need for high system reliability for manned space flight and the fact that the required large vehicle systems are now in their infancy dictate the need for a Vehicle Technology effort that is aimed well beyond the requirements of current developmental vehicles. Similarly, the long lead times associated with the development of these advanced vehicles requires that experimental and prototype hardware be developed in sufficient time to permit integration into the detailed design requirements of a particular vehicle. For example, improved electronic systems will be required that are capable of surviving the very long operating periods associated with lunar and planetary missions. The problems associated with the use of the high energy propellant liquid hydrogen for space missions must also be resolved.

Technical problems characteristically arise during the design phase of a vehicle and must be solved before design and development can proceed effectively. The problems of providing effective instrumentation and data for multi-barrelled rocket engine systems, the motion and state of liquefied gaseous propellants after long periods of weightlessness, and the sloshing of propellants in large diameter booster tanks are but a few of the areas in which an intense technology effort will be conducted.

FUNDING REQUIREMENTS:

Advanced Systems Studies	1961	1962	1963
Operational and Systems Analysis	$ 4,059,000	$ 3,701,000	$ 3,950,000
Vehicle Studies	970,000	2,415,000	3,502,000
TOTAL	$ 5,029,000	$ 6,116,000	$ 7,452,000

In FY 1962, the major areas of effort were directed toward design requirements for the clustering of very large thrust engines for use in the Saturn and Nova class vehicles, and toward conceptual studies of orbital operations as a means of achieving manned earth orbit, lunar, and space exploration missions. This work has formed the basis for the current vehicle systems plans for the accomplishment of the manned lunar landing program. This effort will be continued in FY 1963 to consolidate and refine the results already accomplished; in addition, specific emphasis will be directed toward other requirements beyond the early lunar landings, as noted below.

Operational and Systems Analysis

This effort will include the operational and systems analysis required to establish future missions and system requirements with respect to vehicle design criteria, applications, and environment. During FY 1963 a major effort will be directed toward defining the vehicle systems that will be required after the first manned lunar landing. In this area, particular attention will be given to the requirements for lunar bases, earth-lunar transportation and early manned planetary flights. Current study efforts concerning the economic aspects of advanced space transportation systems will be continued as a basis for developing cost optimization standards.

Vehicle Studies

Vehicle studies will be conducted to analyze and evaluate advanced propulsion systems and their applications to stage or vehicle design; to establish conceptual and preliminary design requirements; to determine optimum stage sizes; and to evolve performance evaluation methods and techniques. In FY 1963, specific attention will be given to the Advanced Saturn class with a nuclear upper stage and to the post Nova vehicle.

RDO 15-2

EXAMPLE: 1963 LAUNCH VEHICLE TECHNOLOGY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1963 ESTIMATES

LAUNCH VEHICLE TECHNOLOGY

SUMMARY OF REQUIREMENTS:

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Technical problems characteristically arise during the design phase of a vehicle and must be solved before design and development can proceed effectively. The problems of providing effective instrumentation and data for multi-barrelled rocket engine systems, the motion and state

RDO 15-1

of liquefied gaseous propellants after long periods of weightlessness, and the sloshing of propellants in large diameter booster tanks are but a few of the areas in which an intense technology effort will be conducted.

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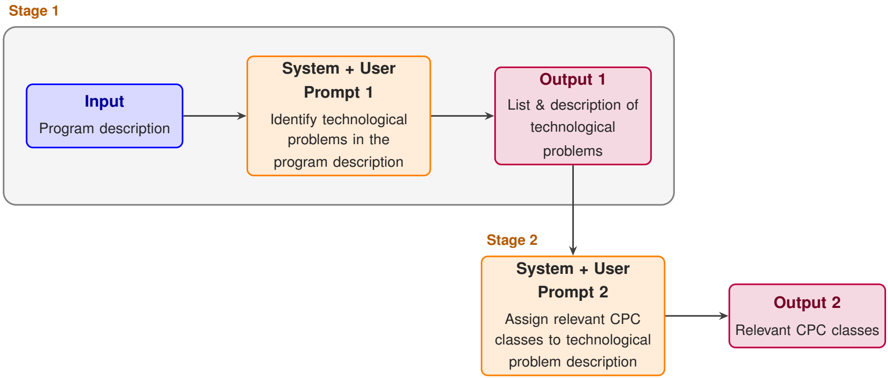
RDO 15-2

Program / Sub-Program / Sub-Sub-Program

Measurement:
LLMs to Assign NASA treatment

Assigning NASA Treatment: Flowchart



Stage 1 System Prompt

You are a scientific research analyst. You specialize in identifying discrete technical challenges embedded in government research and development program descriptions.

You treat every input as an anonymous specification with no assumed institutional context. You reason about what is technically novel relative to the state of the art in a given year, and you consider adjacent fields — disciplines not explicitly mentioned — that would need to advance for the program to succeed.

You always describe problems in general technical terms. State the underlying engineering or scientific challenge, not the specific artifact named in the source text. Never carry proper nouns — program, project, mission, vehicle, instrument, or system names — from the input into your output. Translate any named item into its generic technology category (e.g., a named spacecraft becomes "a crewed reentry vehicle"; a named engine becomes "a high-thrust liquid-fuel propulsion system").

Important: In this step you only identify and describe technical problems. Provide concise, focused responses.

You always return structured JSON and nothing else.

Details:

- Claude Opus 4.6 API, model temperature $t = 0$, batch prompting
- **Anonymous specification**: Claude is not told the text is from NASA – avoids prior-driven CPC matches (everything aerospace).
- **Adjacent fields**: explicit mandate to surface disciplines the text doesn't name

Stage 1 Prompt: Extract technical problems

The text below is a government program description from {YEAR}. You must complete two tasks:

Task 1a — Identify explicit technical problems. Identify the discrete technical problems that are directly stated or clearly implied by the text. State each problem in one sentence. Each problem must be technically distinct; do not list variants of the same underlying challenge as separate problems (e.g., "cryogenic pressure sensors" and "cryogenic temperature sensors" should be a single problem about cryogenic instrumentation). List as many problems as you find genuinely relevant.

Task 1b — Identify adjacent-field problems. Identify additional technical problems in disciplines NOT explicitly mentioned in the text but which must be solved for the program to succeed. Consider fields such as: materials science, manufacturing processes, computing architecture, thermal management, human factors, ground infrastructure, and any other discipline you judge relevant. Mark these with ‘"is_adjacent_field": true‘. Pay attention to what the program **requires** but does not name — a program that mentions "large manned vehicles" implies structural, safety, manufacturing, and ground support challenges even if it only discusses instrumentation. List as many as you find genuinely relevant.

Example: Stage 1 Prompt

Input: Program Description

Launch Vehicle Technology: The purpose of the Launch Vehicle Technology program is to advance the technology which will be required to support design and development of future launch vehicles . . .

Vehicle Technology: . . . In FY 1963, the emphasis will shift to the new class of large vehicles . . .

Instrumentation and Test: . . . development of new instruments and test methods for launch vehicles including mass flowmeters, simple leak detectors, failure detection systems, reliable engine-out detectors, automatic checkout equipment, propellant instrumentation, and transducers for launch vehicle flight tests.

→

LLM System + User Prompt

Identify technological problems in the program description

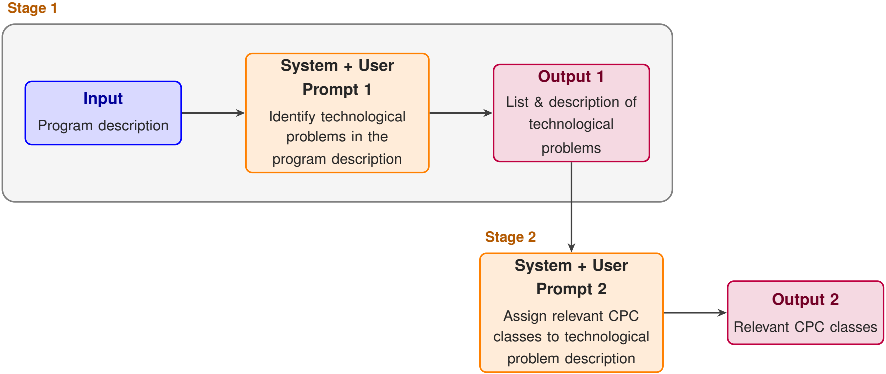
→

Output: Tech. Problems

1. Cryogenic propellant behavior after prolonged weightlessness
2. Controlling propellant sloshing in very large booster tanks
3. Instrumentation for multi-engine clusters & engine-out decisions
4. Electronics surviving long-duration lunar/planetary missions
5. Liquid-hydrogen storage & boil-off management in flight

⋮

Assigning NASA Treatment: Flowchart



Stage 2 prompt: Problems to CPC classes

System prompt:

You are a patent classification specialist. You have deep expertise in the Cooperative Patent Classification (CPC) taxonomy and can accurately map technical problems to the most relevant CPC subclasses.

You apply CPC selection methodology — verifying candidate groups against their scheme notes and definitions, ranking by completeness of coverage, and applying the scheme's own priority rules (LPPR/FPPR) to order equally-relevant candidates.

Important: You must take the list of technological problems as given, no updating that list. Your ONLY tasks are to assign CPC codes to each problem.

You always return structured JSON and nothing else

Stage 2 prompt: Problems to CPC classes

User prompt:

Below is a list of technical problems identified from a government program in {YEAR}. You must complete one task:

Task — Assign CPC codes per problem. For each problem, identify up to 5 CPC codes at the maingroup level that are genuinely relevant to that specific problem. Return only as many as substantively apply. Rank them from most to least relevant for that problem. Use the format shown in the example below (e.g. '"B64G1/00"'). A single technical problem often spans multiple patent classes — for example, a cryogenic fuel pump involves fluid machinery, cryogenic engineering, and sealing technology.

IMPORTANT: Please give the CPC MAINGROUP code ONLY (the level ending in /00) — not a higher-level 4-digit subclass and not a lower-level subgroup. For example, you may classify an item as associated with code B64G1/00, but make sure NOT to classify it as B64G1/10 (too specific, that is a subgroup) and NOT to classify it as B64G (too broad, that is only the subclass). The code MUST end in /00.

Return 1–5 codes per problem, ranked by relevance. Include only maingroups that substantively cover the problem — do not pad to reach 5.

Classification methodology. For each problem, identify candidate maingroups and rank them:
1. Verify. For each candidate, confirm its notes/references/definition don't exclude the subject matter and the maingroup is in active use. Discard those that fail. . . .

Example: Stage 2 Prompt

Input: Tech. Problems

(Output from stage 1)

1. Cryogenic propellant behavior after prolonged weightlessness
2. Controlling propellant sloshing in very large booster tanks
3. Instrumentation for multi-engine clusters & engine-out decisions
4. Electronics surviving long-duration lunar/planetary missions
5. Liquid-hydrogen storage & boil-off management in flight

⋮

→

LLM System + User Prompt

Assign relevant CPC classes to each technological problem

→

Output: CPC Classifications

1. Cryogenic propellant in weightlessness:
`F17C13/00` *Vessel details*
`B64G1/00` *Cosmonautic vehicles*

2. Propellant sloshing:
`B64G1/00` *Cosmonautic vehicles*
`F17C13/00` *Vessel details*

3. Multi-engine instrumentation:
`F02K9/00` *Rocket-engine plants*
`G01M15/00` *Testing of machines*

4. Long-duration electronics:
`B64G1/00` *Cosmonautic vehicles*
`H01L23/00` *Semiconductor details*

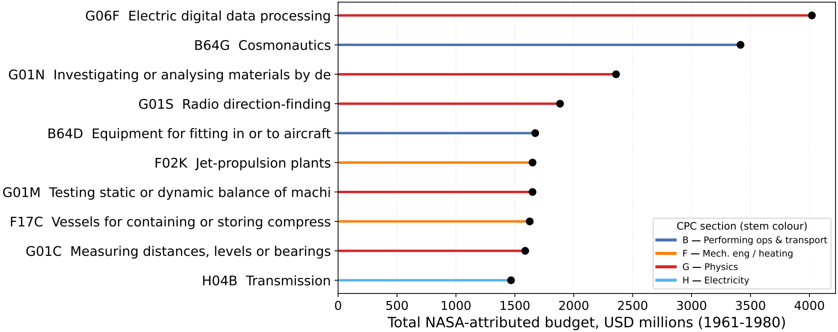
5. Hydrogen storage & boil-off:
`F17C3/00` *Vessels not under pressure*
`F17C13/00` *Vessel details*

⋮

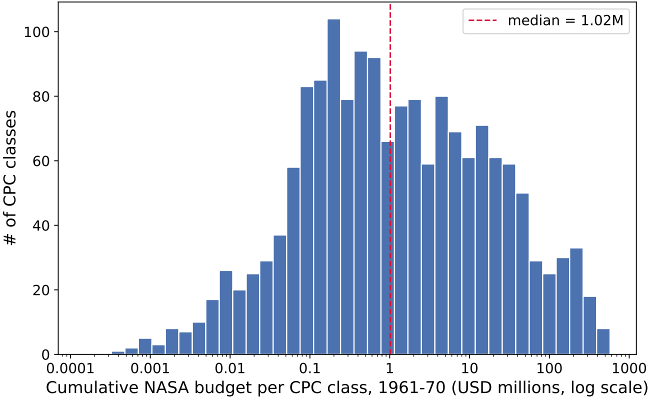
DESCRIPTIVE STATISTICS

Patent Classes with Highest Budget Allocation

Methodology: Allocate budget $s equally across all CPCs identified through **budget line** ⇒ **problem** ⇒ **CPC**



Distribution of Budget to CPC Classes



Top Treated CPC Classes

		Average annual patents	
CPC class	Technology area	1950–59	1960–69
C08K5/00	Use of organic ingredients	102	186
H03K3/00	Circuits for generating electric pulses; Monostable, bi. . .	77	182
A61K31/00	Medicinal preparations containing organic active ingred. . .	49	145
H03K17/00	Electronic switching or gating, i.e. not by contact-mak. . .	34	139
H01R13/00	Details of coupling devices of the kinds covered by gro. . .	65	132
G01S13/00	Systems using the reflection or reradiation of radio wa. . .	55	122
E02F3/00	Dredgers; Soil-shifting machines (for special purposes . . .	96	122
F02K9/00	Rocket-engine plants, i.e. plants carrying both fuel an. . .	26	109
G01N27/00	Investigating or analysing materials by the use of elec. . .	53	108
G11B15/00	Driving, starting or stopping record carriers of filame. . .	33	105
B65D83/00	Containers or packages with special means for dispensin. . .	52	105
H03M1/00	Analogue/digital conversion; Digital/analogue conversio. . .	27	105
C10L1/00	Liquid carbonaceous fuels	55	104
G05D23/00	Control of temperature	77	104
G06G7/00	Devices in which the computing operation is performed b. . .	48	103

Red: Top 15 in government patenting; **Blue:** Top 15 in NASA patenting.

Top Control CPC Classes

CPC class	Technology area	Average annual patents 1950–59	Average annual patents 1960–69
B65D5/00	Rigid or semi-rigid containers of polygonal cross-secti. . .	153	208
C07F9/00	Compounds containing elements of Groups 5 or 15 of the . . .	87	189
E21B43/00	Methods or apparatus for obtaining oil, gas, water, sol. . .	59	145
C08L2666/00	Composition of polymers characterized by a further comp. . .	61	119
C08F4/00	Polymerisation catalysts	40	107
B65G47/00	Article or material-handling devices associated with co. . .	60	95
E21B33/00	Sealing or packing boreholes or wells	57	93
C08G63/00	Macromolecular compounds obtained by reactions forming . . .	29	89
A47J37/00	Baking; Roasting; Grilling; Frying (bakers' ovens, non-. . .	75	80
C08G59/00	Polycondensates containing more than one epoxy group pe. . .	23	79
E06B3/00	Window sashes, door leaves, or like elements for closin. . .	94	79
B65H2701/00	Handled material; Storage means	57	78
C07F7/00	Compounds containing elements of Groups 4 or 14 of the . . .	57	76
C09K8/00	Compositions for drilling of boreholes or wells; Compos. . .	38	74
G03B7/00	Control of exposure by setting shutters, diaphragms or . . .	5	73

Red: Top 15 in government patenting; **Blue:** Top 15 in NASA patenting.

TOP NASA CPC CLASSES (ALL TREATED)

		Average annual patents	
CPC class	Technology area	1950–59	1960–69
B64G1/00	Cosmonautic vehicles	0.00	5.78
F02K9/00	Rocket-engine plants, i.e. plants carrying both fuel an...	0.00	3.13
G01S3/00	Direction-finders for determining the direction from wh...	0.00	1.40
G01M9/00	Aerodynamic testing; Arrangements in or on wind tunnels	0.00	1.32
H03K3/00	Circuits for generating electric pulses; Monostable, bi...	0.00	1.18
B23K9/00	Arc welding or cutting	0.00	1.00
H05H1/00	Generating plasma; Handling plasma	0.00	0.83
A61B5/00	Measuring for diagnostic purposes (radiation diagnosis ...	0.00	0.66
G01J5/00	Radiation pyrometry, e.g. infrared or optical thermomet...	0.00	0.62
F03H1/00	Using plasma to produce a reactive propulsive thrust (g...	0.00	0.60
H04B7/00	Radio transmission systems, i.e. using radiation field ...	0.00	0.60
H02M3/00	Conversion of DC power input into DC power output	0.00	0.58
G06G7/00	Devices in which the computing operation is performed b...	0.00	0.58
G01L1/00	Measuring force or stress, in general (measuring force ...	0.00	0.53
G01N3/00	Investigating strength properties of solid materials by...	0.00	0.53

Empirical Results

Estimating equation

Dynamic-DID specification:

$$p_{it} = \sum_{\substack{h=-H \\ h\neq -1}}^{H} \beta_h \left(\text{EverTreatedNASA}_i \times \mathbf{1}(\text{year} = 1961 + h)\right) + \alpha_i + \alpha_t + \varepsilon_{it}$$

P_{it}: patent counts in CPC class i in year t

Extensive margin: EverTreatedNASA$= 1$ iff $\exists i$ s.t. Budget$_{it} > 0$

h is years relative to 1961.

The omitted reference period is $h = -1$ (year 1960).

β_h: dif. btw. treated–control at horizon h relative to 1960.

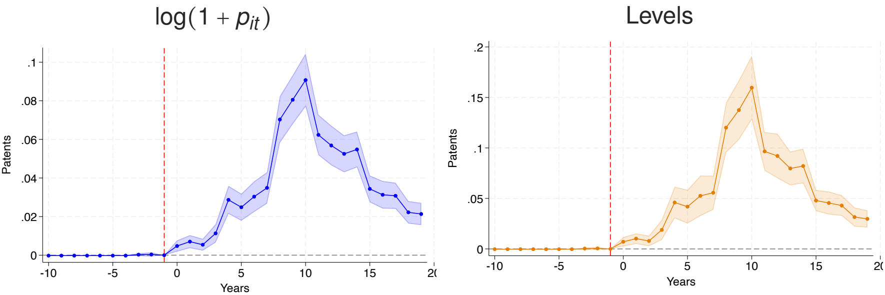
Specification robust to staggered and continuous treatment concerns.

Several specifications to address $log(0)$ problem.

In $log(1 + p_{it})$ spec. extensive margin $\equiv$ going from 10 to 21 patents.

VALIDATION / "FIRST STAGE"

NASA Patents in treatment vs. control CPCs

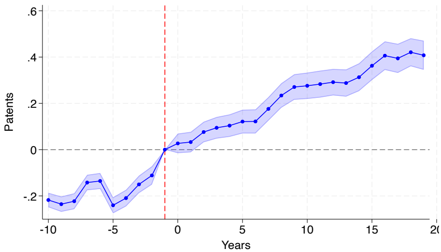


Intensive margin | Extensive margin | Poisson | IHS | Raw time series

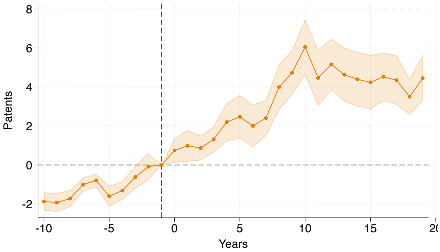
Event Study: First Pass

Total Patents (private + government) in treatment vs. control CPCs

$\log(1 + p_{it})$



Levels



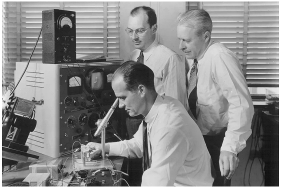
Strong pre-trends!

Raw time series

NASA RIDES ON IMPORTANT 50S INNOVATIONS

Supersonic flight:

Bell X-1



Transistors:
Shockley, Bardeen, Brattain

Nobel Prize in Physics, 1956

Rocket technology:

ICBMs

Addressing Pre-Trends

Objective: Move to double-robust / Augmented Inverse Probability Weighting.

- Find CPC classes that are comparably innovative and fast growing.

Today: **Simple** but **transparent** “matching”.

- Top quartile of fastest growing patent control group classes in the 1950s.
- Representative technology: chemicals and materials science (plastics)

Addressing Pre-Trends

Top CPC in "Matched" control group remain similar...

CPC class	Technology area	Average annual patents 1950–59	Average annual patents 1960–69
C07F9/00	Compounds containing elements of Groups 5 or 15 of the ...	87	189
E21B43/00	Methods or apparatus for obtaining oil, gas, water, sol...	59	145
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C09K8/00	Compositions for drilling of boreholes or wells; Compos...	38	74
G03B7/00	Control of exposure by setting shutters, diaphragms or ...	5	73

Strong representation of classes C07–C08: Organic chemistry and class E21: oil and gas mining

ADDRESSING PRE-TRENDS

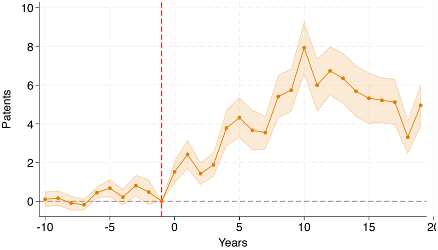
...but technologies that had previously peaked are dropped

CPC	Description	1950–1959	1960–1969
B65D5/00	Rigid or semi-rigid containers of polygonal cross-secti...	153	208
E21B33/00	Sealing or packing boreholes or wells	57	93
E06B3/00	Window sashes, door leaves, or like elements for closin...	94	79
B65H2701/00	Handled material; Storage means	57	78
C07D213/00	Heterocyclic compounds containing six-membered rings, n...	51	69
A01D34/00	Mowers (combined with apparatus performing additional o...	80	67
B60S1/00	Cleaning of vehicles (by apparatus not integral with ve...	58	64
B66F9/00	Devices for lifting or lowering bulky or heavy goods fo...	49	59
A01K97/00	Accessories for angling (fish stringers A01K65/00; land...	92	55
C07C45/00	Preparation of compounds having >C = O groups bound onl...	47	53
A47L15/00	Washing or rinsing machines for crockery or tableware	37	50
E05Y2900/00	Application of doors, windows, wings or fittings thereo...	46	50
A01D46/00	Picking of fruits, vegetables, hops, or the like; Devic...	40	49
D04B15/00	Details of, or auxiliary devices incorporated in, weft ...	28	47
H01H37/00	Thermally-actuated switches	46	45

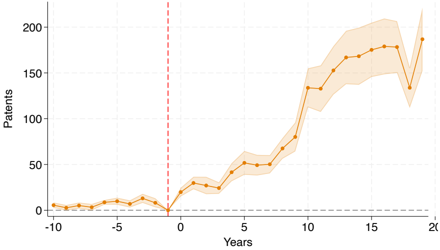
EVENT STUDY: COMPARABLE CONTROL TECHNOLOGIES

Total Patents in treatment vs. control CPCs

Count



Citation-Weighted Count

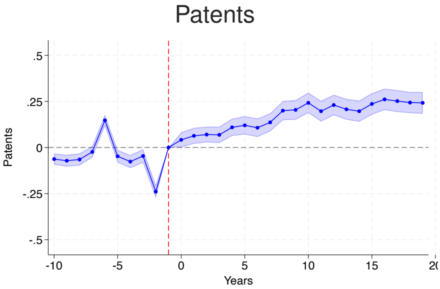


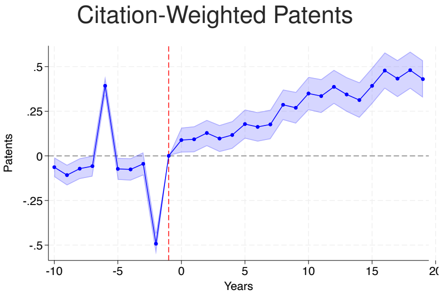
NASA induces high citations of 20 compared to average of 6 per patent.

Intensive margin | Extensive margin | Poisson | IHS | Raw time series | Doughnut

Cit. Intensive margin | Cit. Extensive margin | Cit. Poisson | Cit. IHS | Cit. time series

Total $\log(1 + p_{it})$ Patents in treatment vs. control CPCs





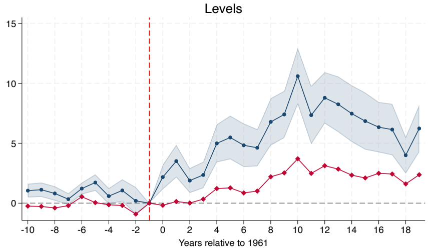
Intensive margin **Extensive margin** **Poisson** **IHS** **Raw time series**

Cit. Intensive margin **Cit. Extensive margin** **Cit. Poisson** **Cit. IHS** **Cit. time series**

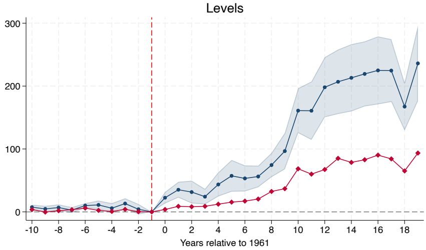
Event Study: Intensive Margin of Budget

Treated CPC classes with above / below median budget vs. control

Count



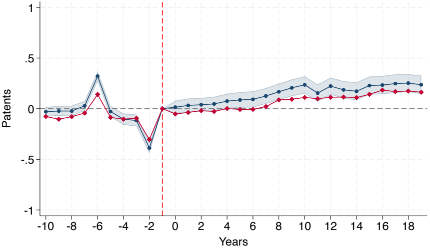
Citation-Weighted Count



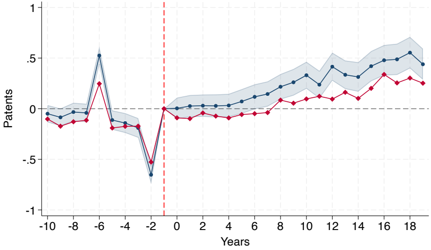
Event Study: Intensive Margin of Budget

Treated CPC classes with above / below median budget vs. control

Patents (log(1+p))



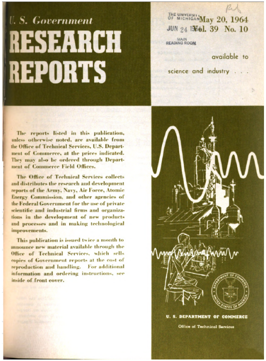
Citation-Weighted Patents (log(1+p))



In Progress:

GOVERNMENT SCIENTIFIC REPORTS

BEYOND PATENTING: SCIENTIFIC REPORTS


U. S. Government

RESEARCH REPORTS

THE UNIVERSITY OF MICHIGAN

JUN 24 1964

MAIN READING ROOM

May 20, 1964

Vol. 39 No. 10

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U. S. DEPARTMENT OF COMMERCE

Office of Technical Services

Title Page of 1964 U.S. Goverment Reports

Truman's Executive Order 9568 (1945): Mandated **public dissemination of federal scientific research**

Monthly / bi-weekly **abstracts of federally-funded R&D** reports for industry and academia

We are currently digitizing raw PDFs from 1945 to 1964.

Example Abstract

AD-753 177 PC$3.00/MF$0.95
IIT Research Inst Chicago Ill
ANALYSIS OF FACTORS AFFECTING ELECTROMAGNETIC COMPATIBILITY OF RADARS OPERATING IN THE 2700 TO 2900 MHZ BAND.
Final rept.,
Michael A. Maiuzzo. Jul 72, 193p FAA-RD-71-91, ECAC-PR-71-033
Contract DOT-FA-70WAI-175

Descriptors: (*Radar, Electromagnetic compatibility), S band, Radar equipment, Radiofrequency power, Radar pulses, Management engineering.
Identifiers: Frequency allocations.

The effect of selected technical and operational considerations on the electromagnetic compatibility of present and projected deployments of radars in the 2.7 to 2.9 GHz frequency band is analyzed. The spectrum channel width relationship to transmitter power amplifier characteristics and pulse waveform parameters is explored. The results of assigning discrete channels for individual radars are presented. (Author)

Top Institutions by Gov-funded research

Institution	Count	Percent
Department of Energy	58,186	5.60
National Aeronautics and Space Administration	33,794	3.25
Energy Research and Development Administration	14,408	1.39
National Science Foundation	13,076	1.26
Foreign Technology Div Wright-Patterson AFB OH	11,998	1.15
National Bureau Of Standards Washington D C	11,904	1.15
Massachusetts Inst. of Tech.	11,123	1.07
California Univ Berkeley	8,991	0.87
California Univ., Livermore.	8,609	0.83
Environmental Protection Agency.	8,460	0.81

SUMMING UP & NEXT HORIZONS

Mapping **Public R&D budget** ⇒ **Publicly funded research** ⇒ **patenting/innovation** ⇒ Other outcomes?

Unpacking the pre-trend

- **Current**: Causal effect of NASA
- **Future**: Defense R&D of the ’50s ⇒ NASA innovation in the ’60s
  - All knowledge builds on previous knowledge–implications for knowledge production function estimation?

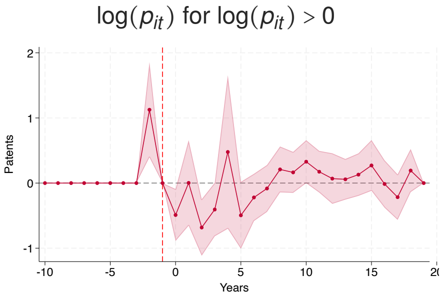
History / Political Economy

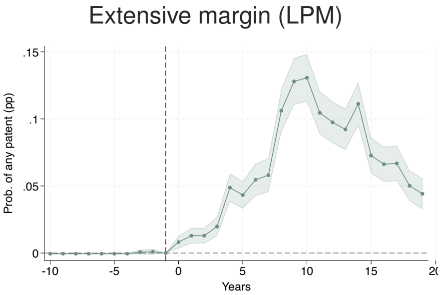
- JFK’s “We choose to do these things not because they are easy...” may not give a full picture
- What political incentives lead to basic research and GPTs?

Additional Materials

VALIDATION / "FIRST STAGE"

NASA Patents in treatment vs. control CPCs





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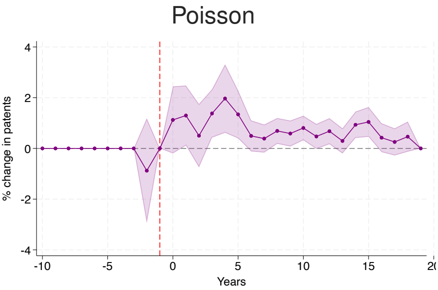
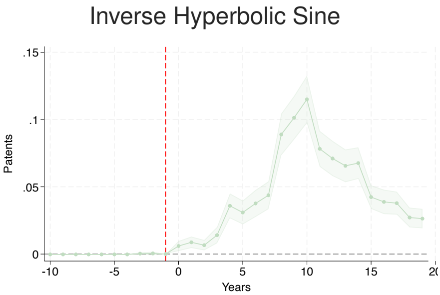
Validation / "First stage"

NASA Patents in treatment vs. control CPCs





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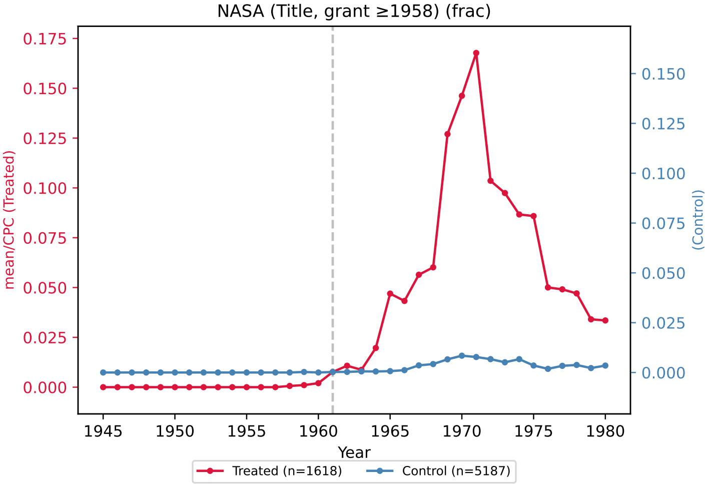
Validation / "First stage"

NASA Patents in treatment vs. control CPCs



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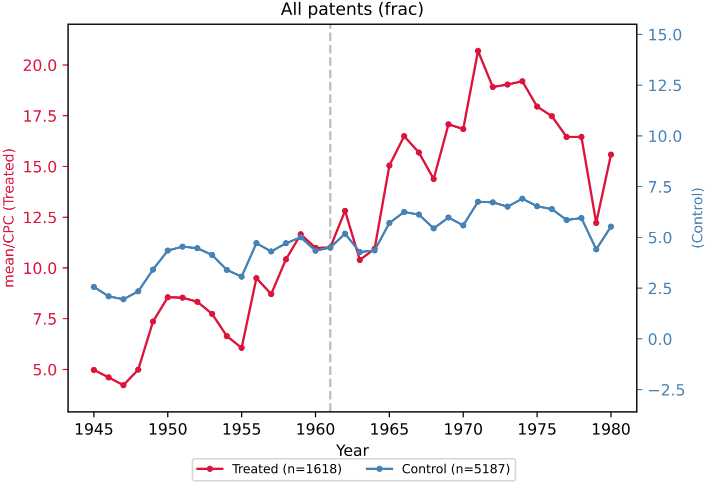
Event Study: First Pass

Total Patents in treatment vs. control CPCs



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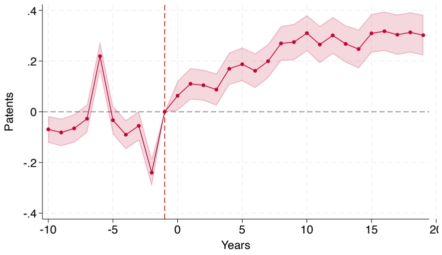
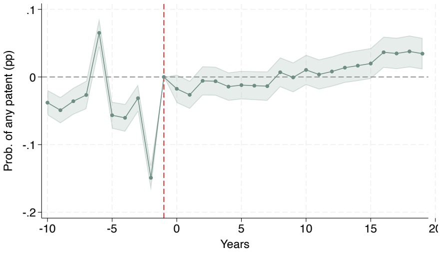
Event Study: Comparable control technologies

Patents in treatment vs. control CPCs

$\log(p_{it})$ for $\log(p_{it}) > 0$



Extensive margin (LPM)



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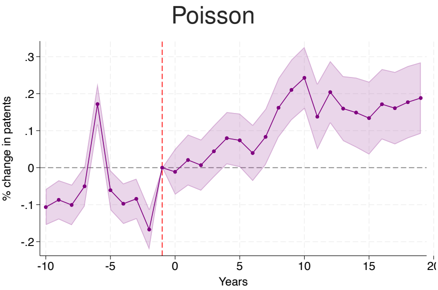
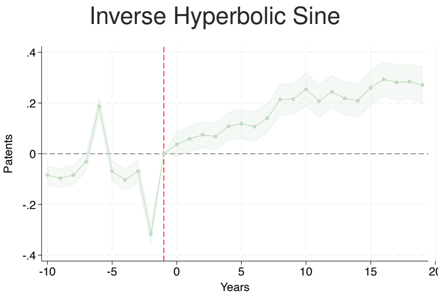
Event Study: Comparable control technologies

Patents in treatment vs. control CPCs





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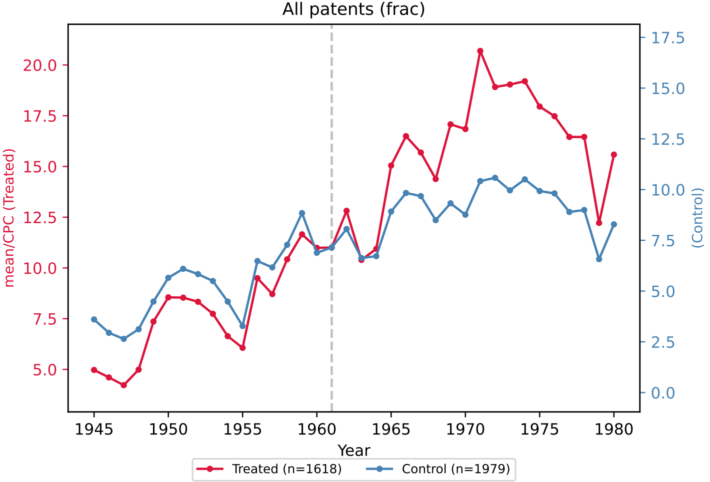
Event Study: Comparable control technologies

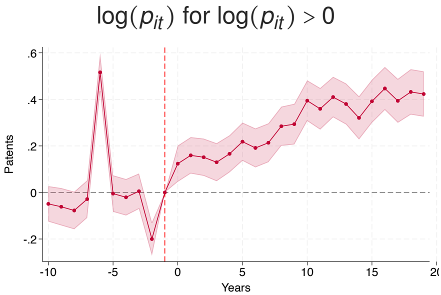
Total Patents in treatment vs. control CPCs

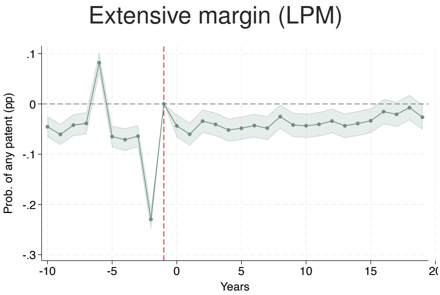


Return

Event Study: Comparable control technologies

Total citation-weighted patents in treatment vs. control CPCs





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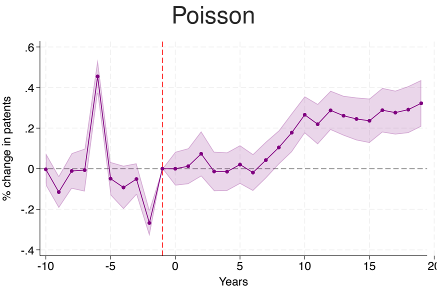
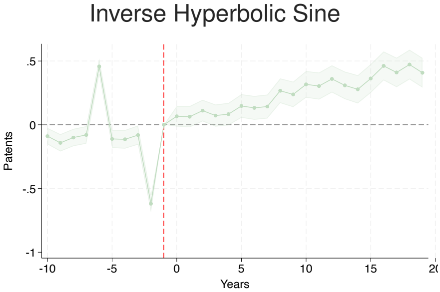
Event Study: Comparable control technologies

Total citation-weighted patents in treatment vs. control CPCs





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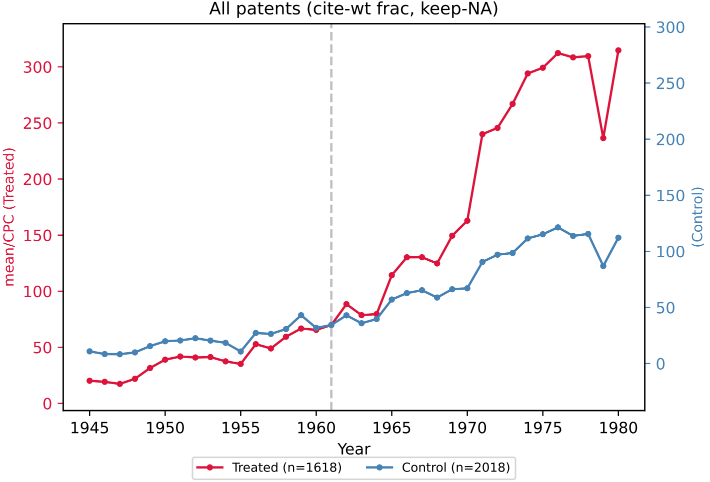
Event Study: Comparable control technologies

Total citation-weighted Patents in treatment vs. control CPCs



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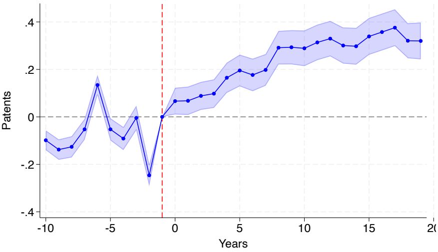
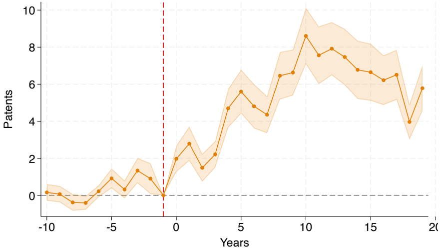
Event Study: Doughnut hole approach

Control group: Find fast-growing technologies only in 4-digit CPC classes that have **no** 6-digit treated CPCs

$\log(1 + p_{it})$



Levels



Similar magnitudes: **No evidence of substitution** away from adjacent technologies. Return