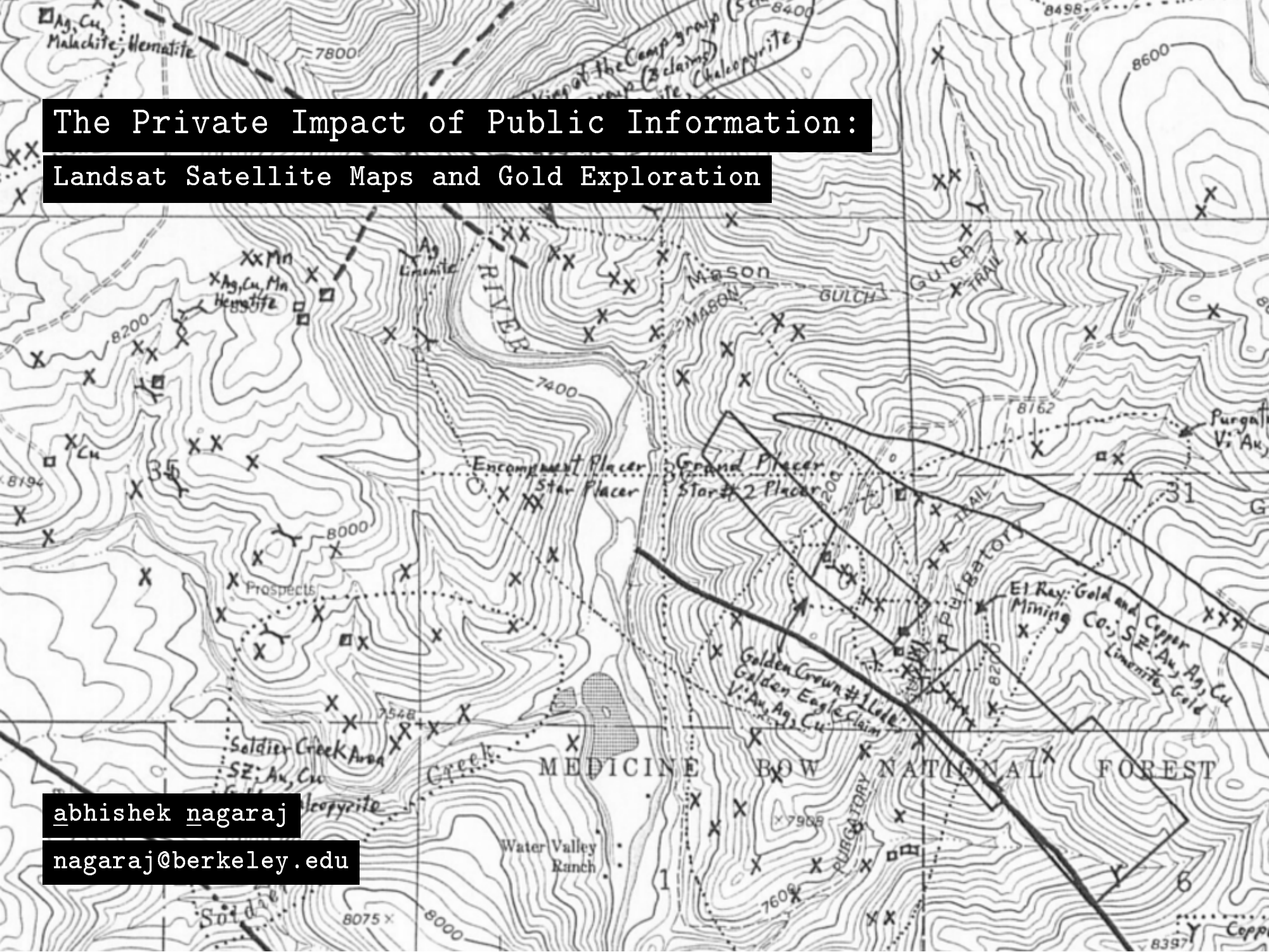
The Private Impact of Public Information:

Landsat Satellite Maps and Gold Exploration



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The Private Impact of Public Information: Landsat Satellite Maps and Gold Exploration

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1st March 2019

NBER Economics of Infrastructure

Government Shutdown Negatively Impacts Our Infrastructure

Wall Street and businesses find their way in the dark as shutdown delays key economic data

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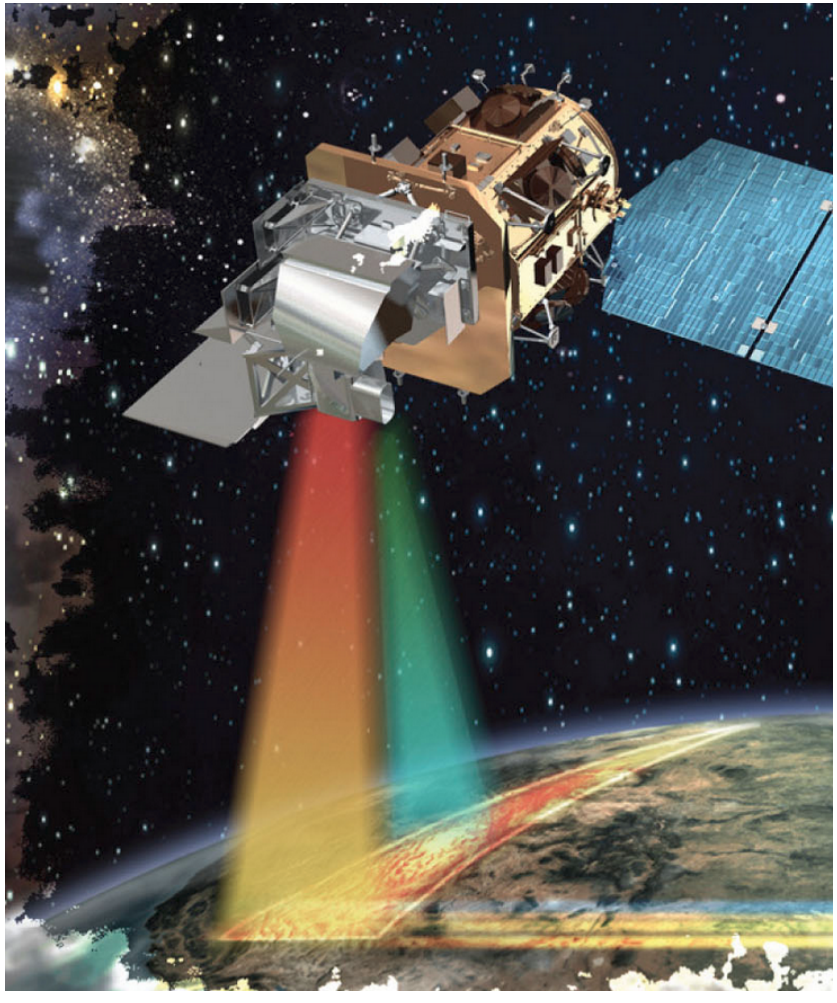
Government Shutdown Raises Fears of Scientific Data Loss, Climate Research Delays

Research Question

Does the public provision of *information infrastructure* affect private-sector productivity?

- Focus on two different margins:
  (a) Discovery of opportunities at the regional level
  (b) Distribution of opportunities between larger and smaller firms

NASA Satellite Mapping Program – Landsat



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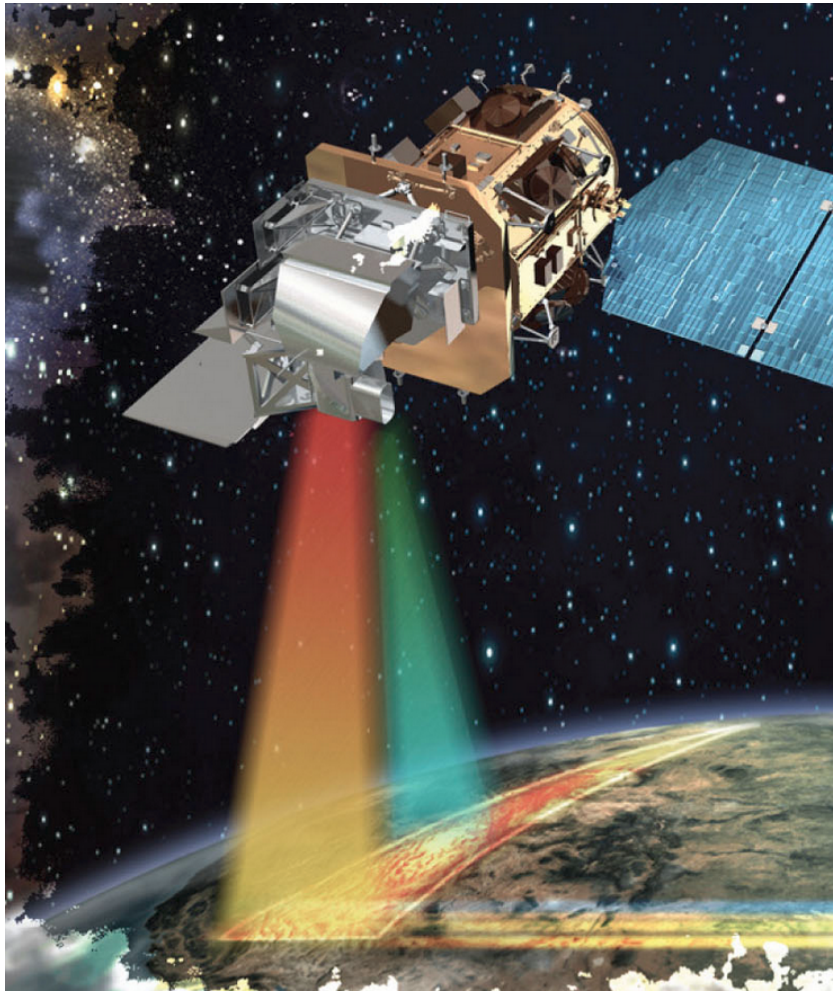

Satellite Imagery and Gold Exploration

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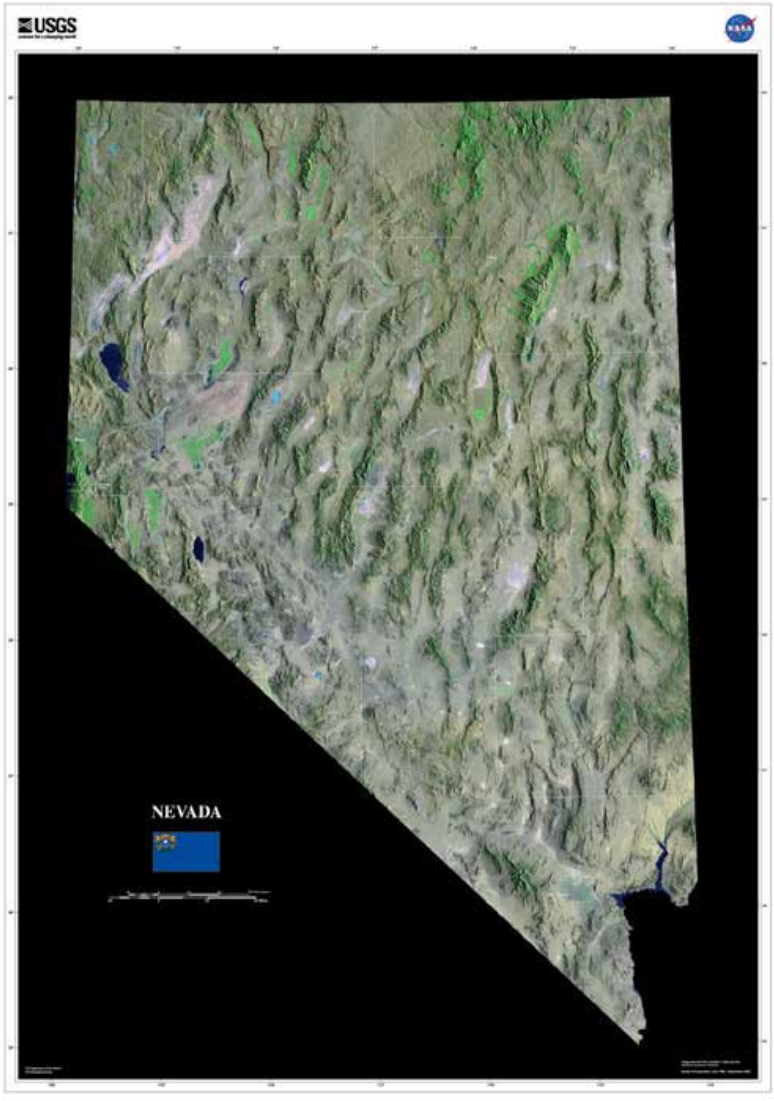

(from: Rowan & Wetlaufer 1975)

Research Design

- **Ideal Experiment**$\rightarrow$
  Randomly assign mapping information to some regions and not others and collect discovery data

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Research Design: New Discoveries

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Research Design: Larger and Smaller Firms

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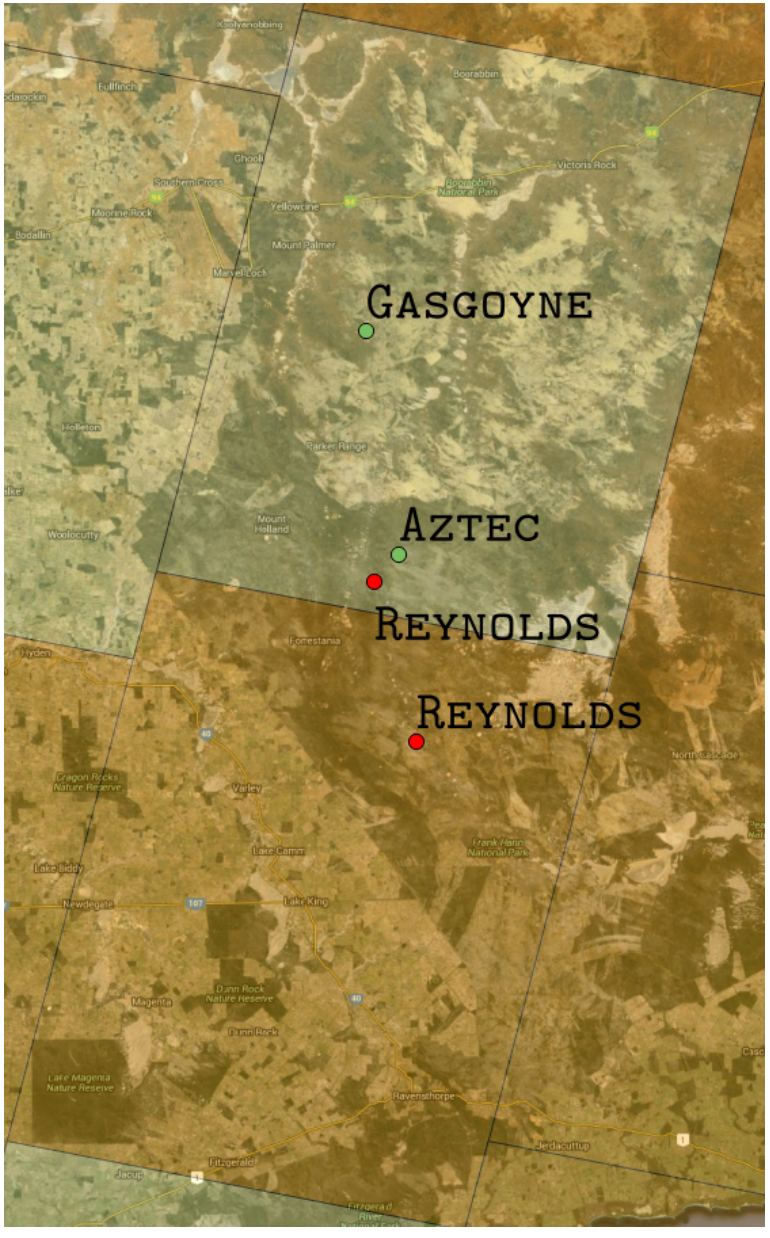
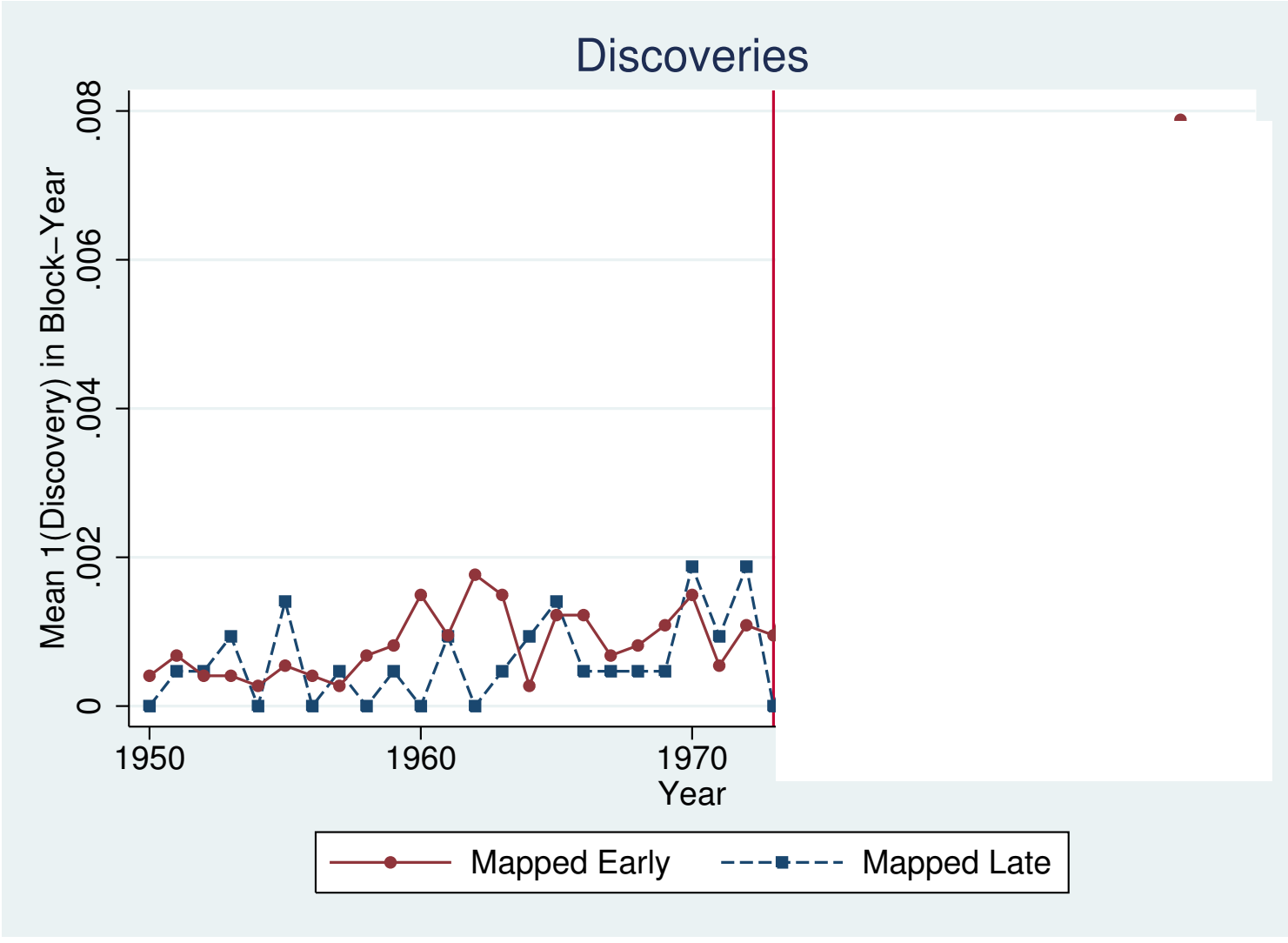


Poorly Mapped and Well-Mapped Blocks Over Time



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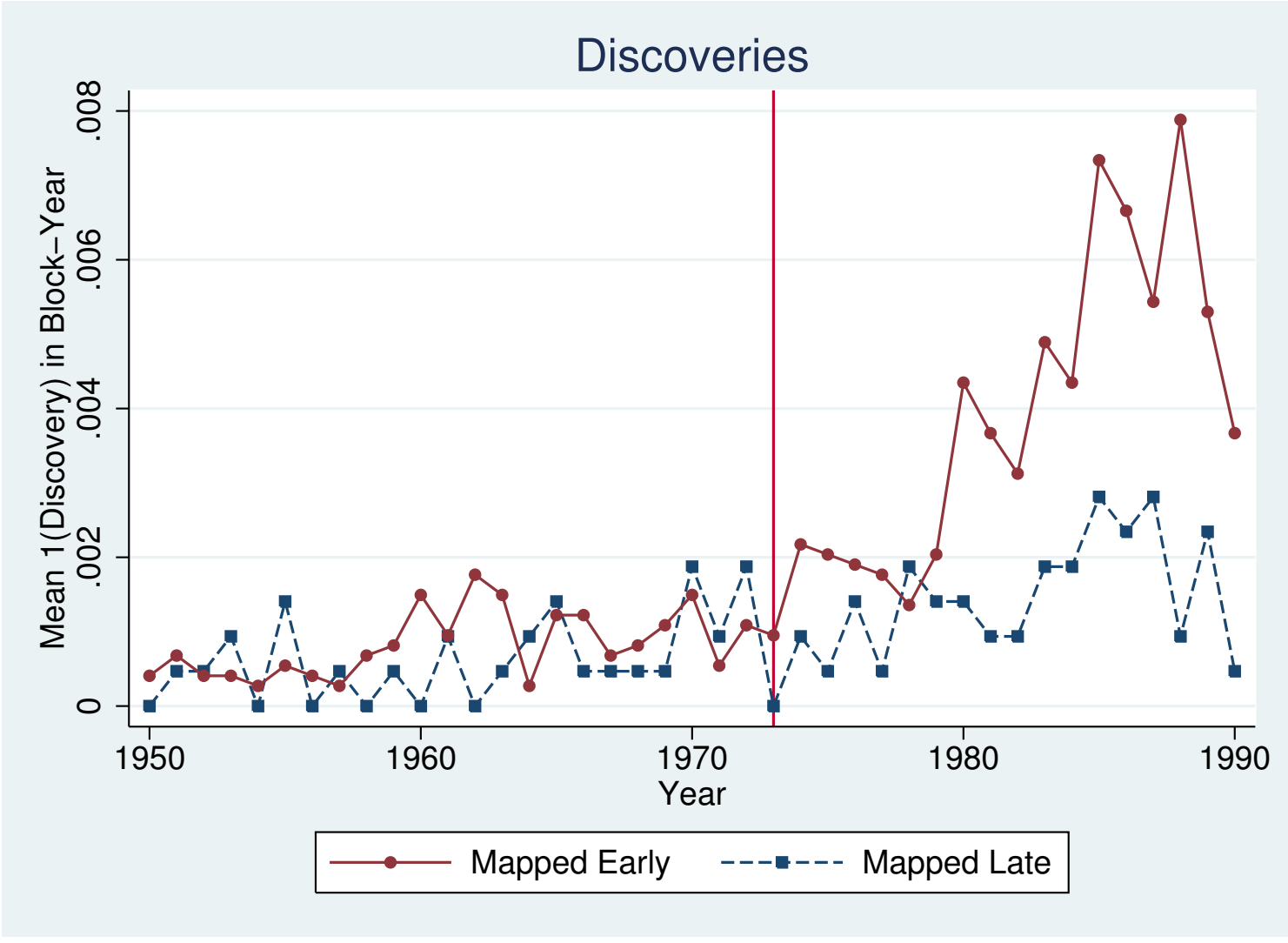

Preview of Results

1. Empirical results show that Landsat information approx. *doubles* the likelihood of new gold discoveries in mapped regions as compared to yet-to-be-mapped regions

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2. Mapping program *does not* raise performance equally.

   - Smaller firms more likely to increase their rates of discovery (increase market share from 10% to 25%)
   - Benefits of public information vary across regions

Outline

1. Theoretical Framework
2. Setting and Data
3. The Impact of Landsat Maps on Gold Exploration
4. Differential Impact of Landsat Maps
5. Conclusion

Outline

Prior work on public infrastructure

- Public infrastructure is a key determinant of private-sector investment (Munnell and Cook, 1990), productivity (Aschauer, 1989), and economic growth (Barro, 1990)

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- But the public sector spends billions of dollars in the production of *information infrastructure* that is widely used many firms and industries
- This paper is focused on highlighting the possible role of this channel in shaping private sector and regional outcomes

What is Information Infrastructure?

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- Three prominent types:
  - Geographic information: aerial/satellite imagery, census data, geological maps, weather information
  - Administrative data: public insurance records, medical records, social security and tax data, patent applications (Card et al. 2010, March et. al 2015)
  - Scientific information: Human genome sequences, Hubble telescope, BRAIN mapping (Williams 2013, Stephan 2012)

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  - Administrative data: public insurance records, medical records, social security and tax data, patent applications (Card et al. 2010, March et. al 2015)
  - Scientific information: Human genome sequences, Hubble telescope, BRAIN mapping (Williams 2013, Stephan 2012)
- Significant budgets: Census Bureau ($3.8 billion), NOAA which provides weather and disaster maps ($1.35 billion); and USGS ($859.7 million) (Office of Management and Budget, 2018; U.S. Geological Survey, 2018).

Debate on the Value of Public Information

- Proponents suggest public information helps "to make better decisions and improve the quality of lives" making it an "important source of economic growth, new forms of entrepreneurship and social innovation" (Ubaldi, 2013, p.4).

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- For example, efforts to defund the Landsat program (Popkin, 2018, Borowitz 2017) or the cancellation of the long-form census in Canada.

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- For example, efforts to defund the Landsat program (Popkin, 2018, Borowitz 2017) or the cancellation of the long-form census in Canada.
- Bottomline: empirical work needed on the role of public information investments

Mechanism: Public information as a decision-support tool for investment

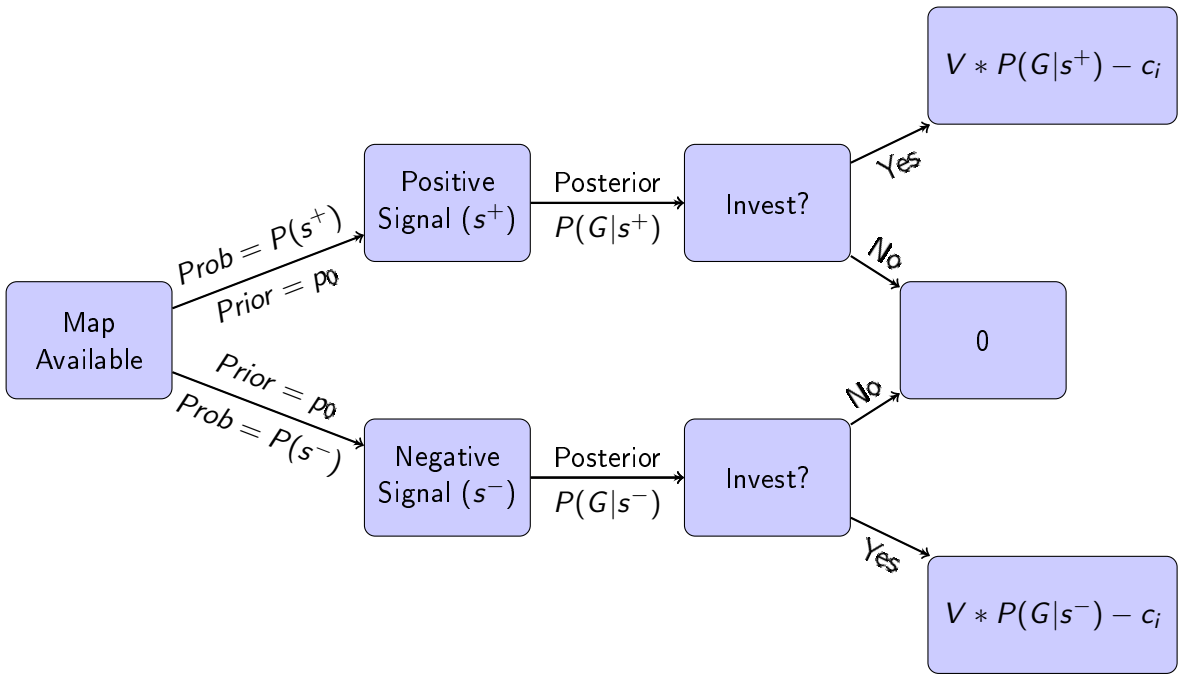
> "A map is not something that tells you where to go, it's a tool that lowers the risk involved in your journey ... [it] is the ultimate tool of investment because it derisks a process."

–Richard Jefferson, Skoll World Forum 2013

Framework

- Imagine a set of firms is each allocated to a risky opportunity that has value V with probability p_0 or zero otherwise (depending on true state of nature G or NG).
- Firms differ only in their costs. There is a continuum of large firms with $c_i \sim U[C_S, \bar{C}]$ and smaller firms with $c_i \sim U[C_J, \bar{C}]$ where $C_J > C_S$
- Public information provides an imperfect signal $s \in \{s^+, s^-\}$ depending on the true state, and firms use this info. to update their prior p_0 to a posterior $P(G|s)$ such that $P(G|s^+) > p_0 > P(G|s^-)$

Framework


Map Available
Prob = $P(s^+)$
Prior = p_0
Positive Signal (s^+)
Posterior
$P(G|s^+)$
Invest?
Yes
$V * P(G|s^+) - c_i$
No
0
Prior = p_0
Prob = $P(s^-)$
Negative Signal (s^-)
Posterior
$P(G|s^-)$
Invest?
No
Yes
$V * P(G|s^-) - c_i$

Framework

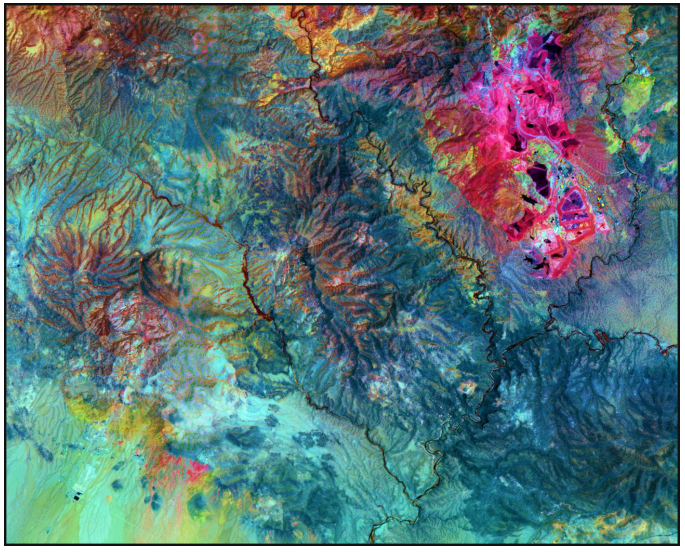
- Two types of effects: signal causes some higher-cost firms to enter, but also causes lower cost firms (who invested before) to exit
- Under reasonable distributional assumptions and bayesian updating, following predictions can be derived
  - Prediction 1: Public information could increase total number of discoveries
  - Prediction 2: Public information could increase the market share of smaller firms
  - Prediction 3: Inverted-U relationship between cost-gap ($C_J - C_S$) and increase in small-firm market share

Outline

The Gold Exploration Industry

- Economically important industry ($2.5 billion in exploration costs in 2014) with about 300 unique entities in my data

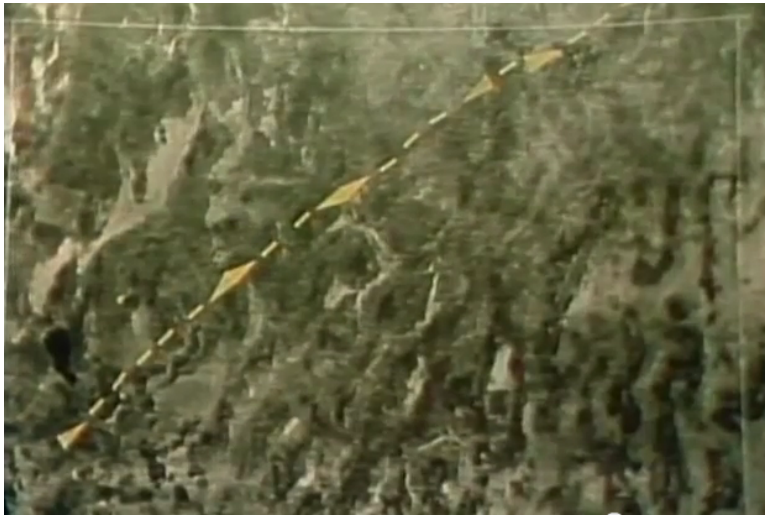
- Traditional Techniques: Existing data + aerial techniques + on-the-ground exploration
- Firms classified as juniors or seniors

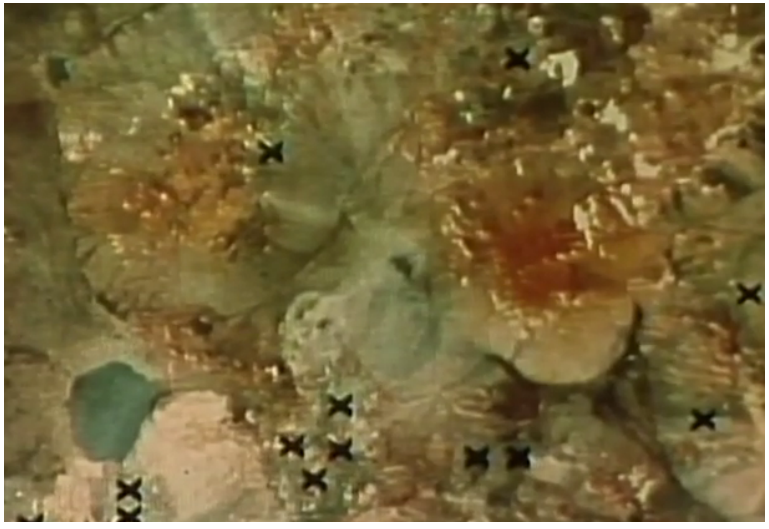


Landsat Program

- Oldest & longest running program to image the earth from space, operated by NASA and USGS
- Designed primarily for agricultural applications (crop-prediction)
- Data relayed to earth and distributed openly from EROS Center, Sioux Falls, South Dakota

Landsat and Gold Exploration





1. Identify “lineaments” or faults in the earth’s surface
2. Detect specific minerals like iron, that are often markers of gold and other valuable minerals

Uneven Availability of Landsat Maps

- **1. Technical Failures**→ Landsat program aimed for global coverage, but literature documents many coverage gaps linked to technical failures (Goward et. al, 2006)

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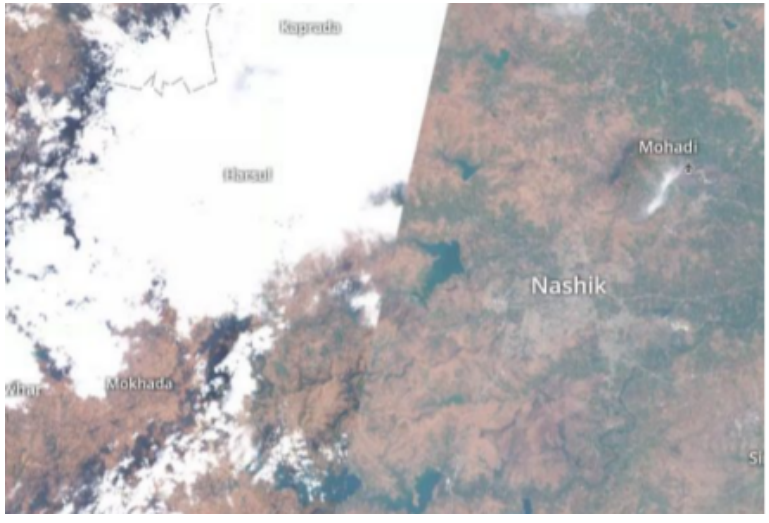
- **1. Technical Failures**→ Landsat program aimed for global coverage, but literature documents many coverage gaps linked to technical failures (Goward et. al, 2006)
- **2. Cloud-Cover in Imagery**→ Maps containing over 30% of cloud-cover practically unusuable for analysis



Summary Statistics

Panel A. Time-varying Variables (N=389213)

	Mean	SD	Median	Min	Max
Outcome					
Any Discovery (%)	0.188	4.33	0.000	0	100
Any Junior Disc. (%)	0.038	1.94	0.000	0	100
Landsat Coverage					
Post Mapped	0.409	0.49	0.000	0	1
Post Low-Cloud	0.381	0.49	0.000	0	1

Outline

Baseline Regression – Did timing affect discovery?

$$Y_{it} = \alpha + \beta_1 \times Post_{it} + \gamma_i + \delta_t + \epsilon_{it}$$

where γ_i and δ_t represents block and time fixed effects respectively for block i and year t

- $Post_{it}$ equals one when a block receives Landsat data.
- Define $Post_{it}$ in two different ways – either after a block received an image or after it received a cloud-free image
- Standard errors in all regressions clustered at the block level.

Baseline OLS Estimates

- Average Prob Discovery: 0.188

	Any Disc.	Any Disc.	Any Disc.	Any Disc.
Post Mapped	0.251***		0.152***	
	(0.0265)		(0.0294)	
Post Low-Cloud		0.267***		0.164***
		(0.0276)		(0.0274)
Block FE	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	389213	389213	389213	389213

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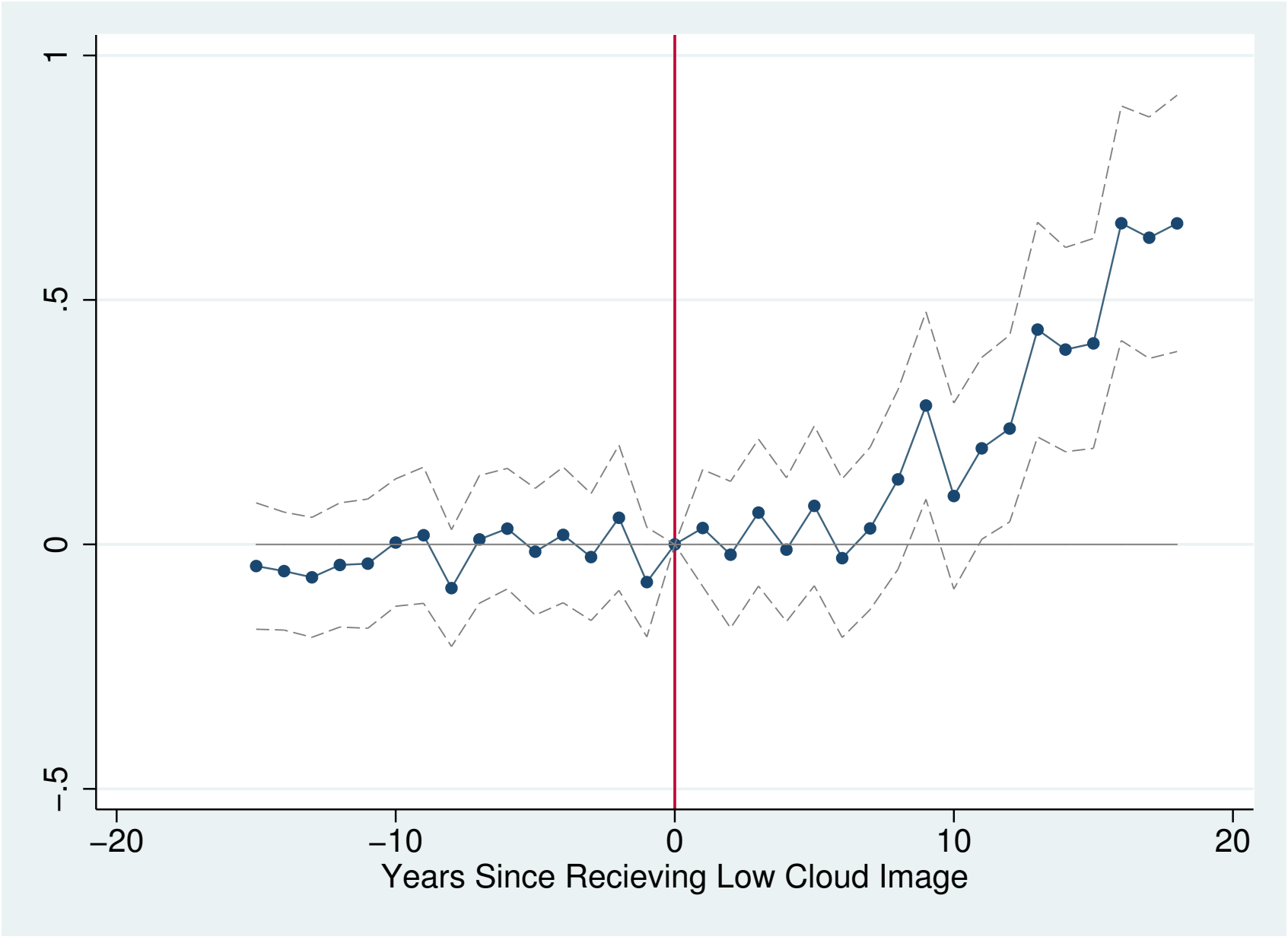
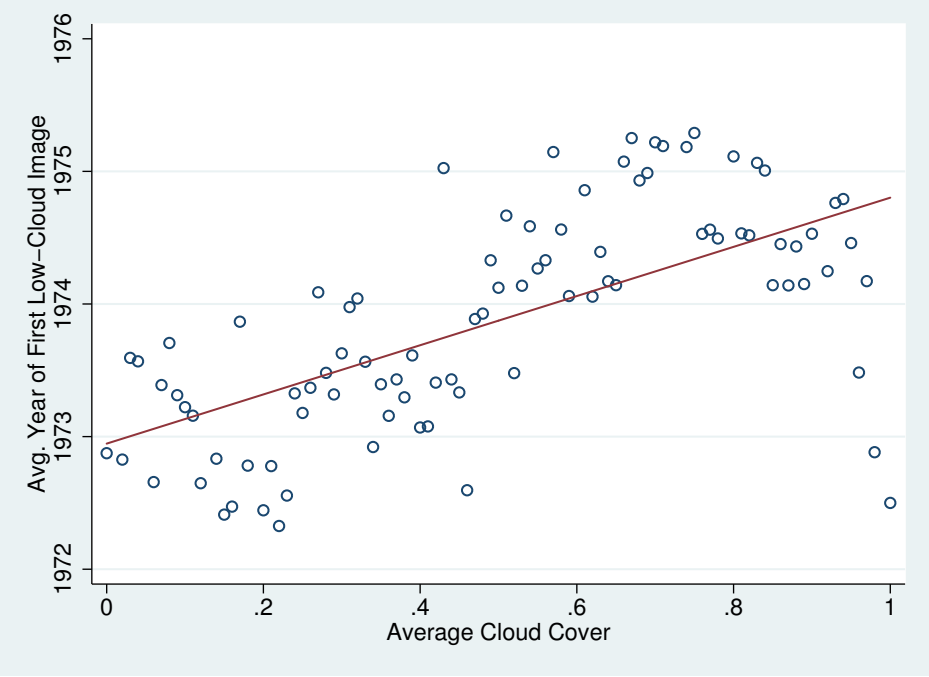
Time-varying impact of Landsat program on Gold discovery



Additional Strategy: Instrumental Variables Regression

- Additional lever to address endogenity of timing – use local cloud cover as instrument for timing of mapping



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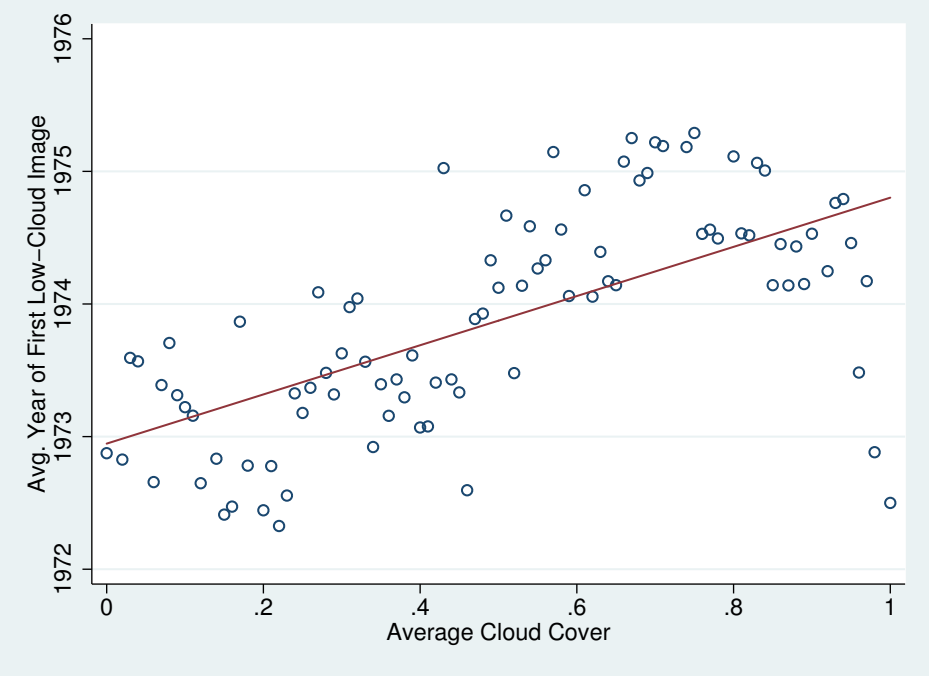

- **Findings**: Results largely consistent with the baseline OLS model, although estimates are larger in size. IV analysis

Robustness checks

1. Is the effect being driven by a handful of outliers known to be large producers of gold? i.e is this an USA or USA, Canada and Australia effect? results
2. Is it possible to control for different trends on the evolution of gold exploration for regions of different income levels? results
3. Gold Price: This was a unique time for the price of gold
4. Placebo check: Tree-covered regions

Outline

How did Landsat affect Juniors vs. Seniors?

- Reuse baseline differences-in-difference specification
- Outcome variables $1(Junior)_{it}$: Did a junior firm (or senior firm) report a discovery in block i in year t
- Scale OLS coefficient by average discoveries before Landsat to obtain elasticity

Impact of Landsat on Junior-led discovery

- Pre-Landsat average discoveries:
  - $\overline{1(Junior)}$: 0.008
  - $\overline{1(Senior)}$: 0.069
- Baseline estimate: $\approx 0.16 = 0.016$ (junior) + 0.144 (senior)

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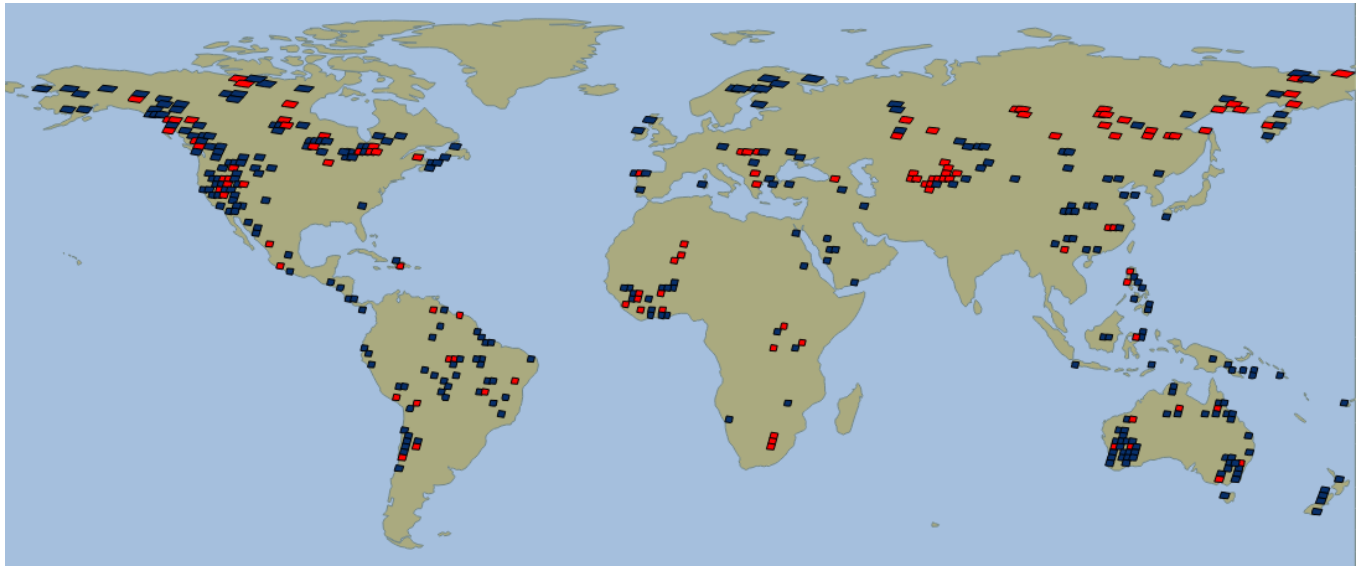
- Baseline estimate: $\approx 0.16 = 0.016$ (junior) $+ 0.144$ (senior)

	1(Junior)	1(Junior)	1(Senior)	1(Senior)
Post Mapped	0.0288***		0.127***	
	(0.00563)		(0.0285)	
Post Low-Cloud		0.0472***		0.121***
		(0.00651)		(0.0260)
Percent Gain	**355.68%**	**583%**	**182.39%**	**174.95%**
Block FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	389213	389213	389213	389213

Exploting Regional Variation in Costs



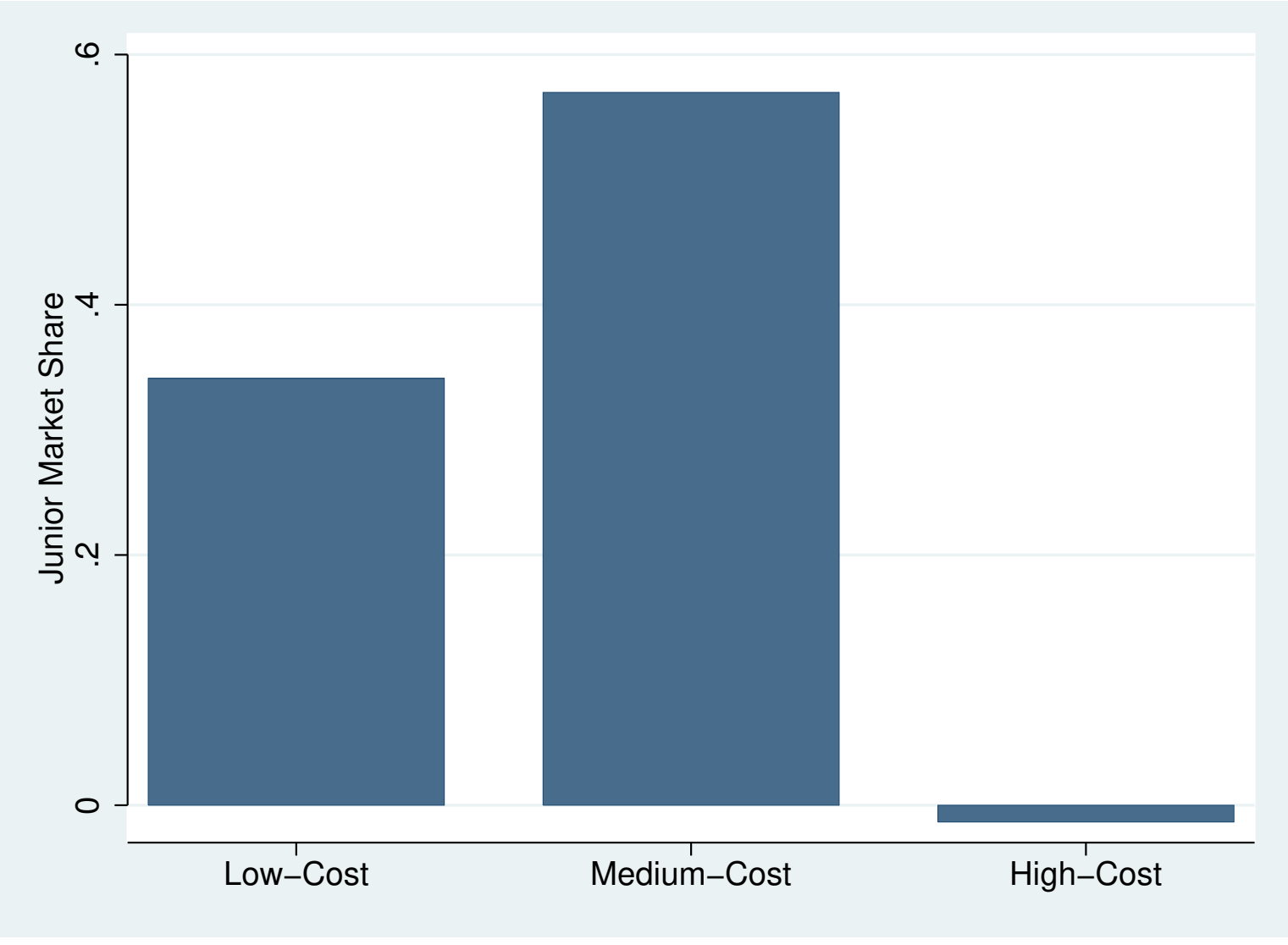
- Data from the Fraser Institute Survey of Mining Companies on the quality of local institutions (McCahon and Fredricksen, 2014) as a proxy for differences in cost between juniors and senior firms.

Measuring Expropriability

- Example questions
  1. *Legal system (legal processes that are fair, transparent, non-corrupt, timely, efficiently administered, etc.)*

High	Middle	Low
Alberta	Alaska	Spain
Ireland	France	Brazil
Namibia	Zambia	Egypt
Western Australia	Burkina Faso	Mendoza, Argentina
Chile	Mali	Poland
Finland	San Juan, Argentia	Turkey

Impact of Landsat program by Measures of Expropriability



Outline

Paper in one slide

Research Question

- Does public information infrastructure affect private sector productivity?

Data

- Landsat coverage data and gold discovery database (1950-90)

Research Design

- Simple theoretical framework for the role of public information
- Time & spatial variation from technical failures and cloud-cover in imagery

Results

- Mapped regions 2x more likely to report new, gold discovery
- Smaller firms more likely to benefit, esp. in regions with higher cost differences between larger and smaller firms

Direct Relevance to Public Policy

The New York Times

U.S. Halts Plan to Turn Off the Landsat Satellites

By JOHN NOBLE WILFORD

Chief of U.S. Geological Survey Pleads for Continued Funding

By PHILIP J. HILTS,

BILL

S.625 — 104th Congress (1995-1996)

Landsat Amendments Act of 1995

Sponsor:	Sen. Pressler, Larry [R-SD] (Introduced 03/27/1995)
Committees:	Senate - Commerce, Science, and Transportation
Committee Reports:	S. Rept. 104-81
Latest Action:	05/15/1995 Placed on Senate Legislative Calendar under
Tracker:	Introduced

BILL

H.R.2449 — 102nd Congress (1991-1992)

Landsat Continuity Act

Broader implications

- Governments routinely spend billions of dollars on the provision of information infrastructure, and such spending varies across time and space
- This channel is currently not seen as a lever to shape economic outcomes (Nagaraj and Stern, 2019), and yet it seems to have important downstream consequences
- This is only a selected case study, but the role of public information infrastructure should be studied through an economic lens

United States™ Census Bureau

thank you!

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