Measuring Value
…of R&D

2019 NSF ERC Planning Grant Workshop

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DISCLAIMERS: *Any opinions and conclusions expressed herein are those of the author(s) and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed*

My life before academia

Hughes at the Knowledge Frontier

Raytheon $9.5B

BOEING® $3.75B

Radar Systems

Missile Systems

HUGHES AIRCRAFT

Hughes Research Lab

Electro-Optical and Data Systems

Space and Communications

Laser

Transistor

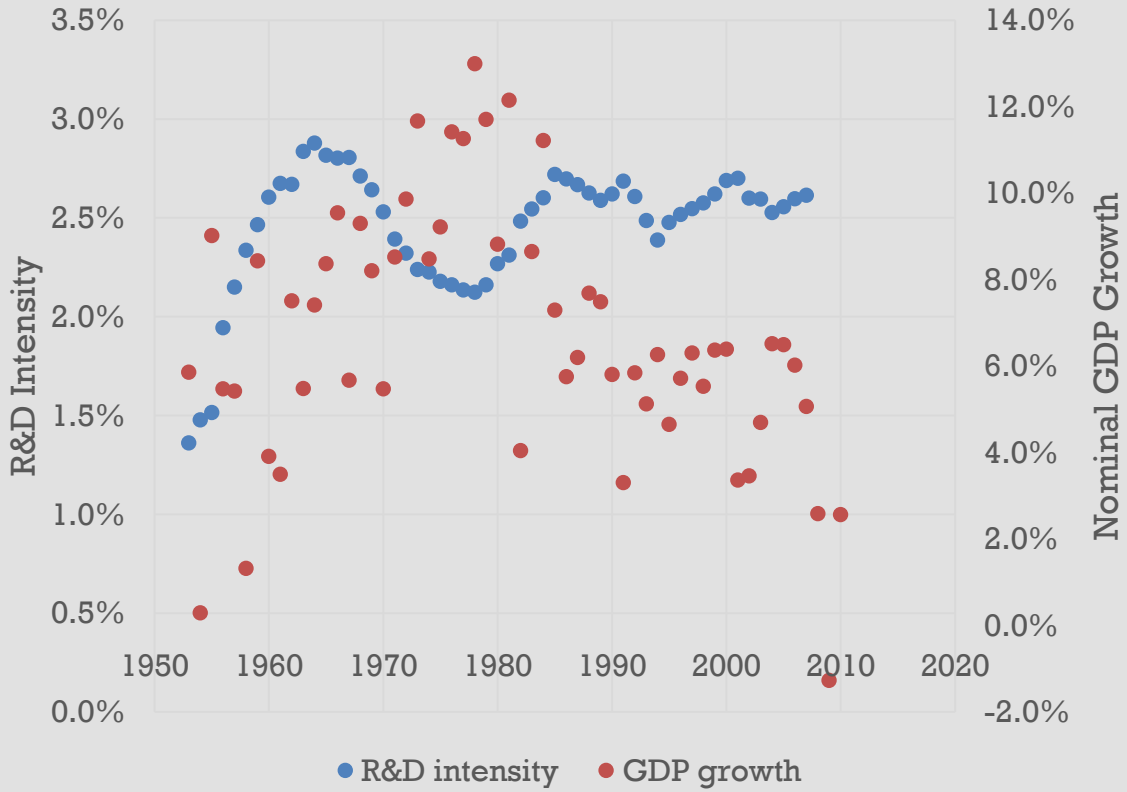
Synchronous-orbit Satellite

Ground Systems

$26B

ECHOSTAR

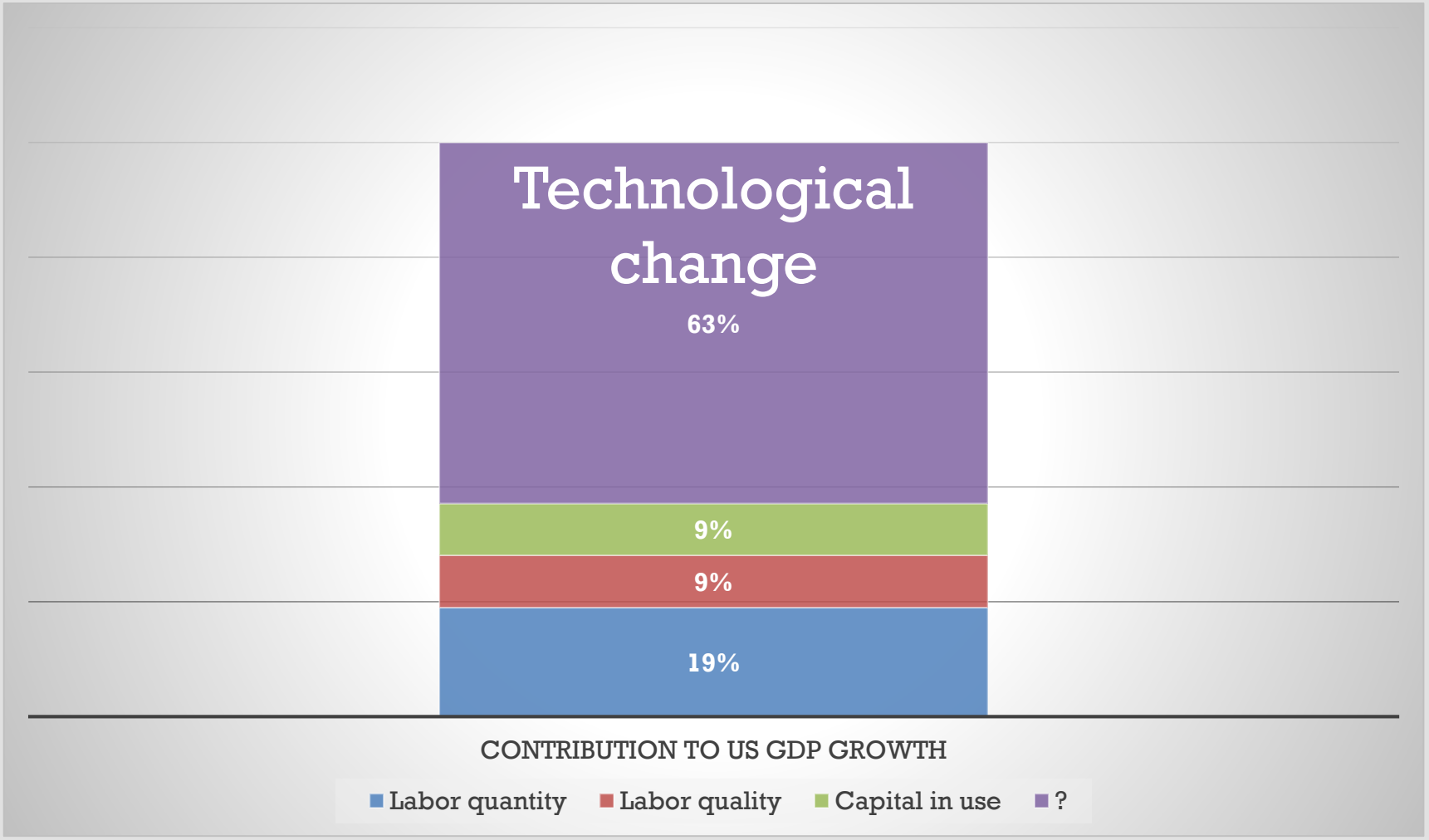
US Innovation Engine is Broken



Why is Growth Important?

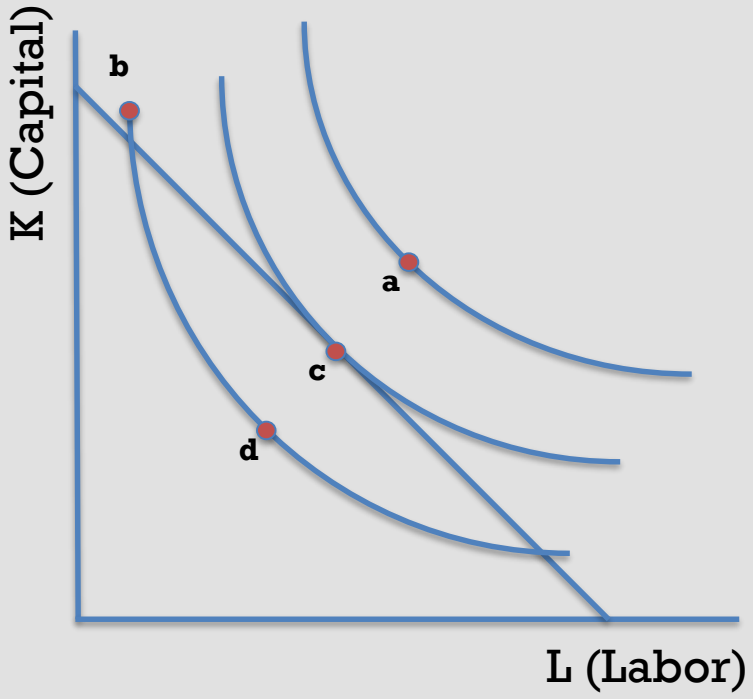
US 1900		US 2000
47.3 years	Life expectancy at birth	76.8 years
58 hours	Workweek	34.5 hours
$490	Household Income	$57,790
4.9 people	Household size	2.5 people
120%	Expenditures/income	79%
43%	Food share	13%*
19%	Home ownership	67%
1%	Indoor plumbing	100%
horse	Primary transport	car

Where does growth come from

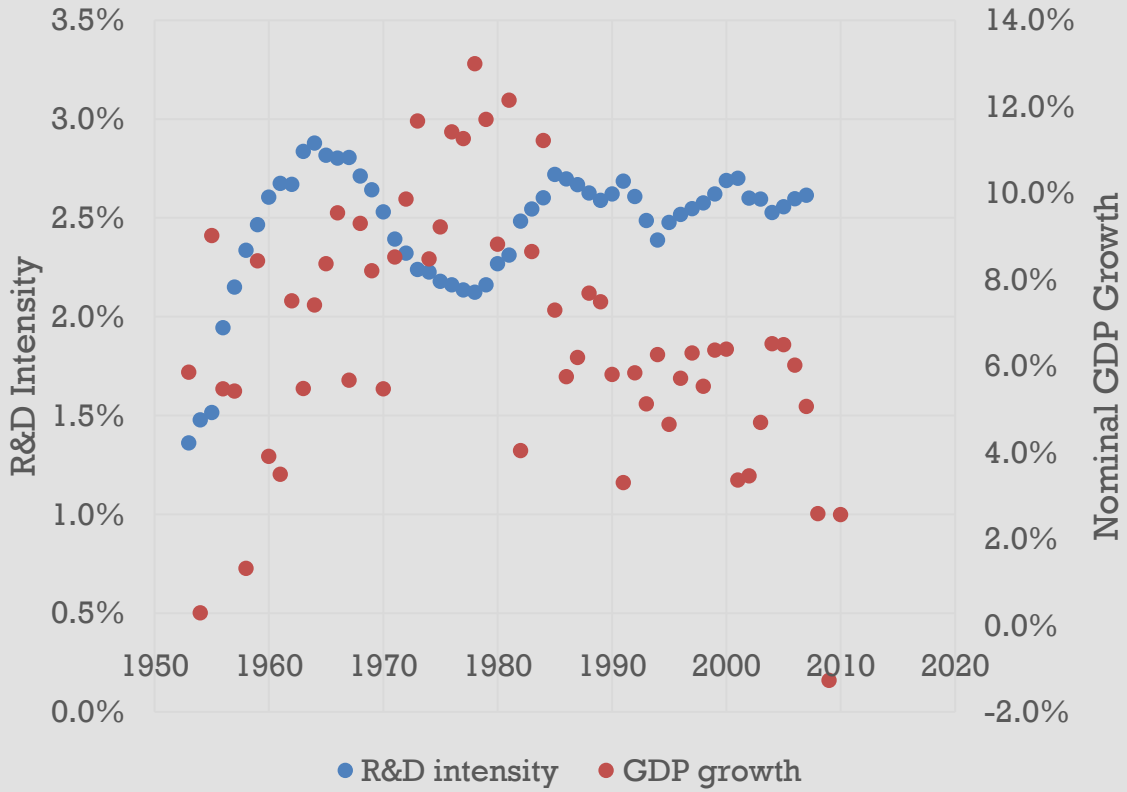


Romer's endogenous growth theory links R&D to growth

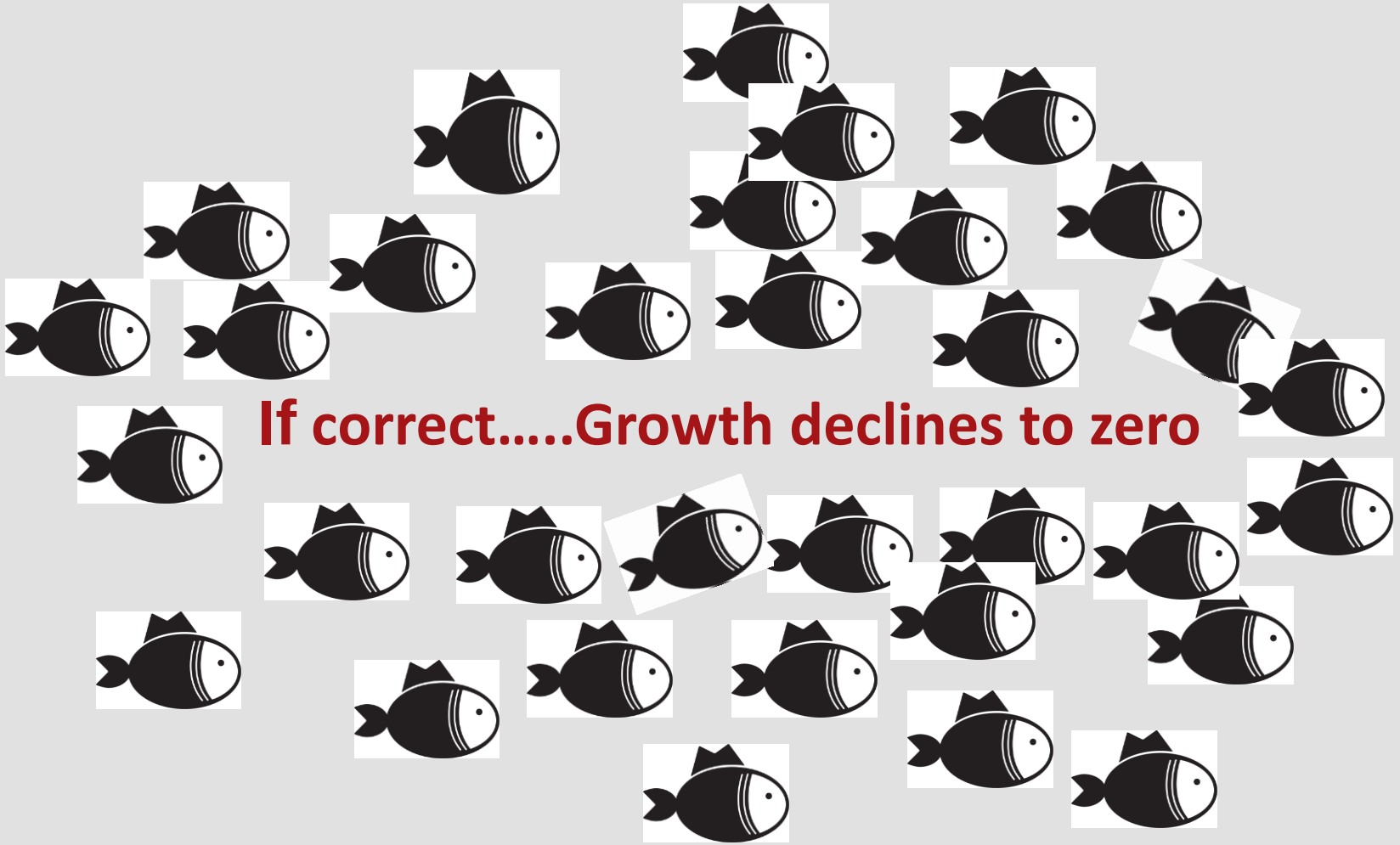
- Adds knowledge, *A*, to the production function:
  - $Y=K^{\alpha}L^{\beta}A$
- Which comes from R&D, *R*:
  - $A'=\delta AR$
- Most important conclusions:
  - Economy grows in perpetuity
  - Scale effects: doubling *R* doubles *g:*
    - $g_Y = g_A = \delta R$



US Innovation Engine is Broken

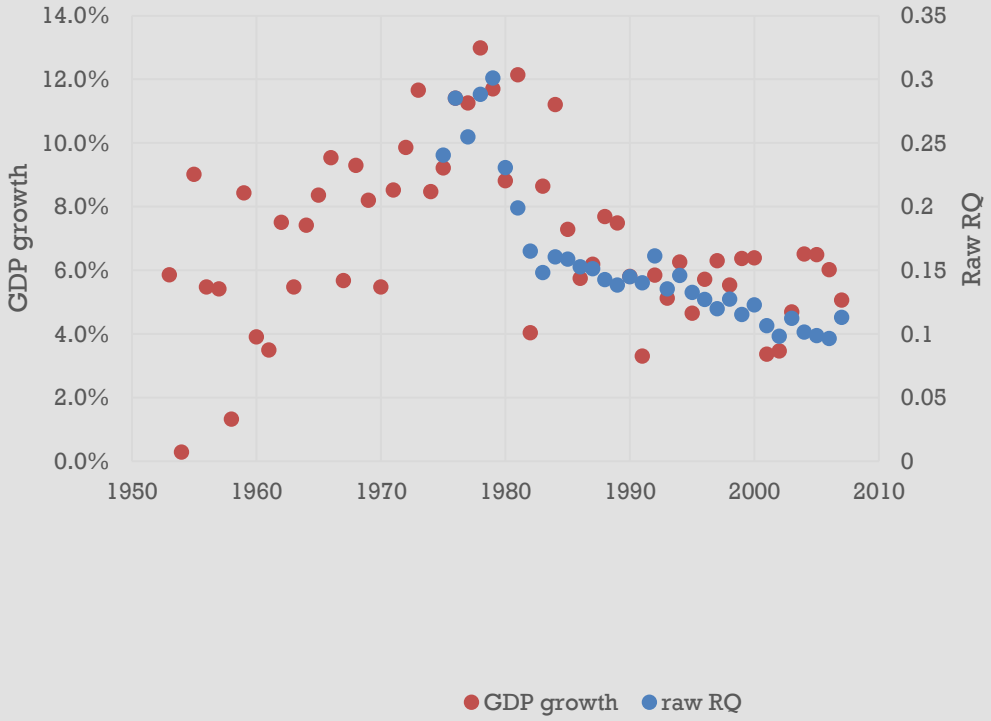


Leading explanation for broken link: R&D has gotten harder



If correct…..Growth declines to zero

My explanation: Companies have gotten worse at R&D



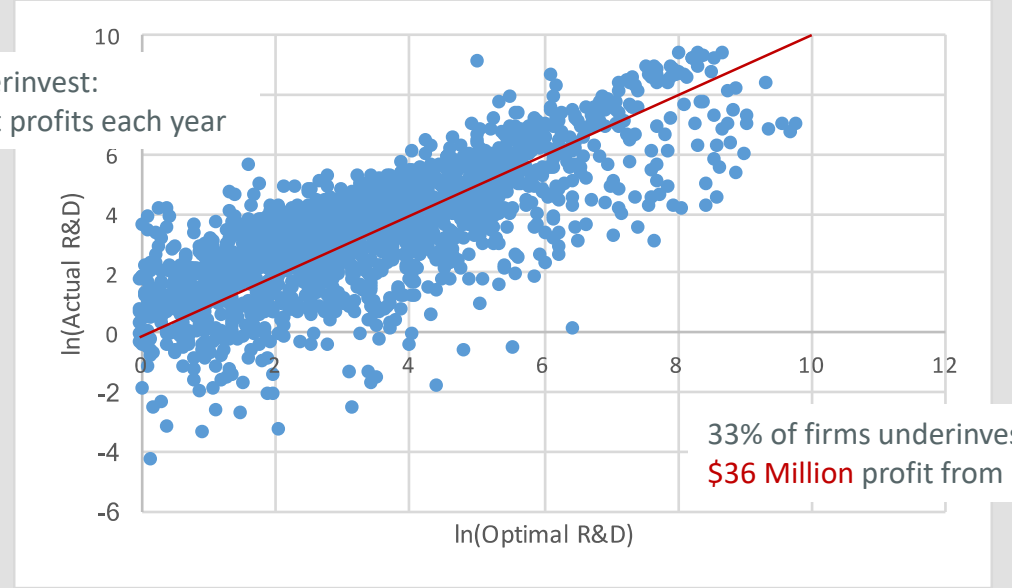
Hope: If we can restore RQ^{TM}, we can revive growth

The Problem: Everyone flying blind with respect to managing R&D

- No good measures of R&D effectiveness
  - Sales/R&D is really an *input* measure
    - (51% of firms using)
  - Patents neither *universal* or *uniform*
    - Fewer than 50% of firms doing R&D patent; *universality*
    - 10% of patents comprise 85% of economic value; *uniformity*
  - Vitality Index only captures product innovation
- None of these measures is *reliable*
  - Anomaly in relationship to market value

Front-end implication: Firms unclear how much to spend

63% of firms overinvest:
$258 Million lost profits each year

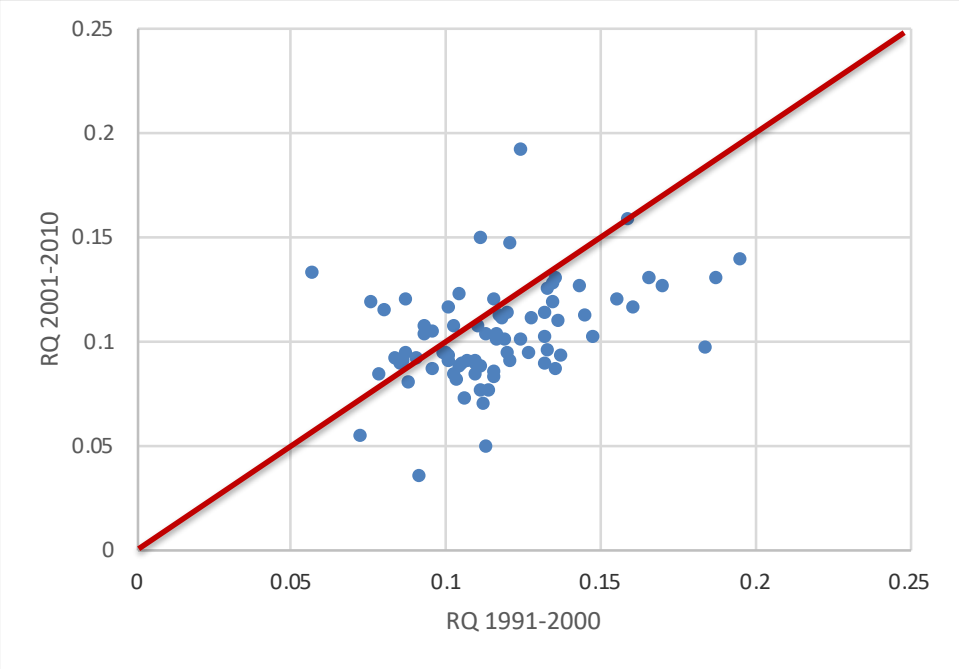


33% of firms underinvest:
$36 Million profit from 10% more R&D

Less than 5% of firms' investment is within ±10% of optimum

Back end: Not sure what makes them (or prevents them from being) effective

Increasing RQ



Decreasing RQ

Flying Blind: A real world illustration

TALKING BUSINESS

Real Reason for Ousting H.P.'s Chief

By JOE NOCERA
Published: August 13, 2010

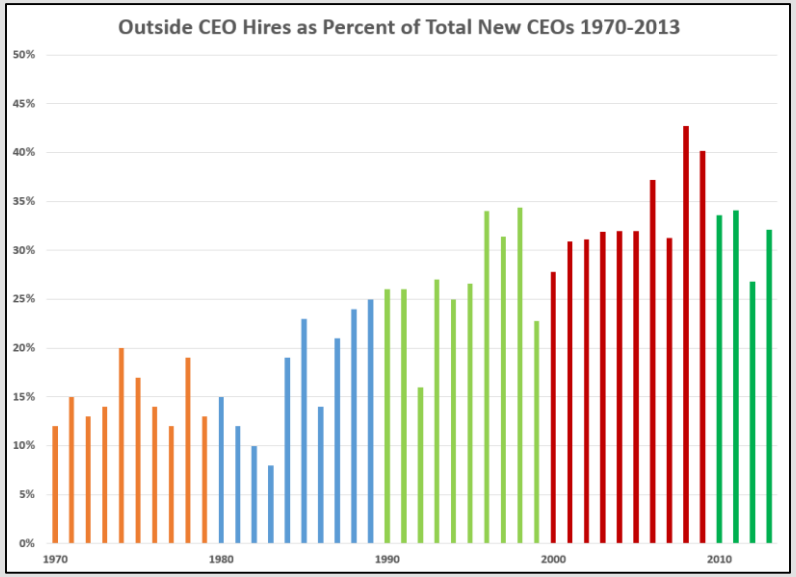
Charles House, a former longtime H.P. engineer …now at Stanford University, openly rejoiced when he heard that Mr. Hurd was leaving. "I think the sexual harassment charge was a total red herring," Mr. Hurd was systematically destroying what had always made H.P. great. … The research and development budget used to be 9 percent of revenue, … now it was closer to 2 percent.

- Is Mr House right: Did Mark Hurd destroy what made HP great?
- With existing measures, we have no way of knowing!
  - Whether R&D capability has deteriorated, or by how much
  - Whether the correct investment is 9% or 2%

Not all companies fly blind

In the past, companies were run by CEOs with in-depth knowledge of industry/technology

Now often run by outsiders, who must manage by numbers



"do the right things and profits will follow"

Pat Hyland, Hughes Aircraft Company
VP 1954 to 1976, President 1976-1984

Founder run companies typically have high RQ

RQ™ offers flight instrument for R&D

- RQ captures Romer's R&D productivity, δ
- Measured as the exponent, γ, on R&D:
  - $Y=K^{\alpha}L^{\beta}A$
    - *Original Romer equation with knowledge, A*
  - $Y=K^{\alpha}L^{\beta}R^{\gamma}$
    - *Substituting A with the R&D that produces it*
  - Technical definition*:*
    - *"firm-specific output elasticity of R&D"*
  - Practical translation:
    - *percentage increase in output from 1% R&D increase*

The theory underlying RQ™ allows you to derive outcomes

- Revenues $Y = K_{i,t}^{\alpha} L_{i,t}^{\beta} R_{i,t-1}^{\gamma}$
- Profits $\Pi = gross\ margin * [K_{i,t}^{\alpha} L_{i,t}^{\beta} R_{i,t-1}^{\gamma}] - R$
- Optimal R&D $R_i^* = \left(a\gamma_i/(1-\delta)\right)^{\frac{1}{1-\gamma_i}}$
- Market value $V = \Pi / (r\text{-}g)$
- Growth R_i^{γ}

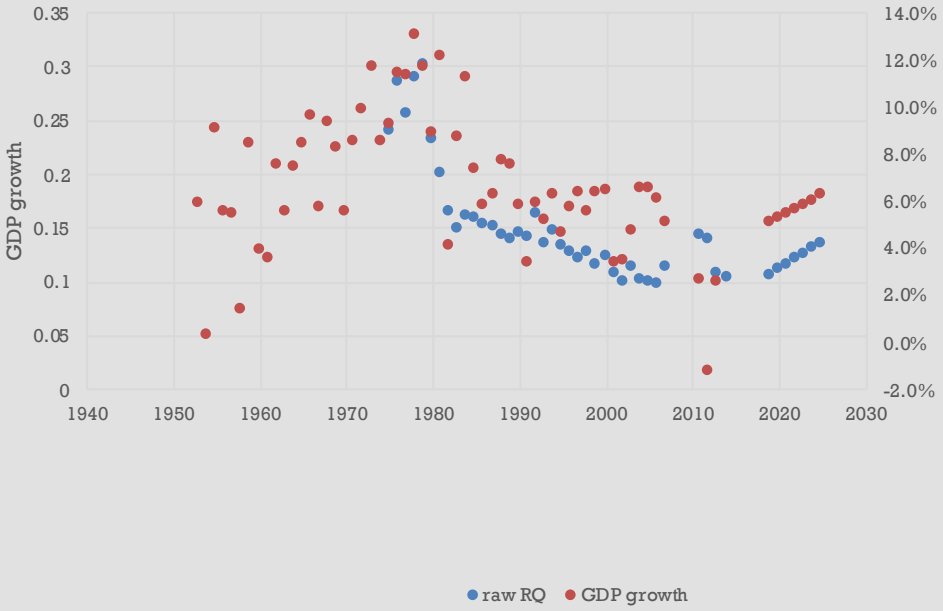
Important properties of RQ™

- *Universal*: Can estimate for any company doing R&D
- *Uniform*: Can compare companies, industries, countries
- *Reliable:* Matches theoretical expectations (over 47 years data for all US traded firms):
  - Increasing RQ increases optimal *R&D investment*
  - Increasing RQ increases *market value*
  - Increasing RQ increases *firm growth*
  - *NO OTHER MEASURE FOR WHICH ALL 3 HOLD*
    - *Patent intensity, Total Factor Productivity, Idea TFP Market response to patent approval*

What RQ can't do

- Can't measure the value of innovation in companies that don't do R&D
  - 7% of firms in BRDIS without R&D report new or significantly improved product in prior 3 years
- Can't measure the value of R&D in organizations where R&D doesn't drive revenues (universities, government labs)
  - But 71% of R&D is done in companies

So how do we reverse the RQ and GDP trends?

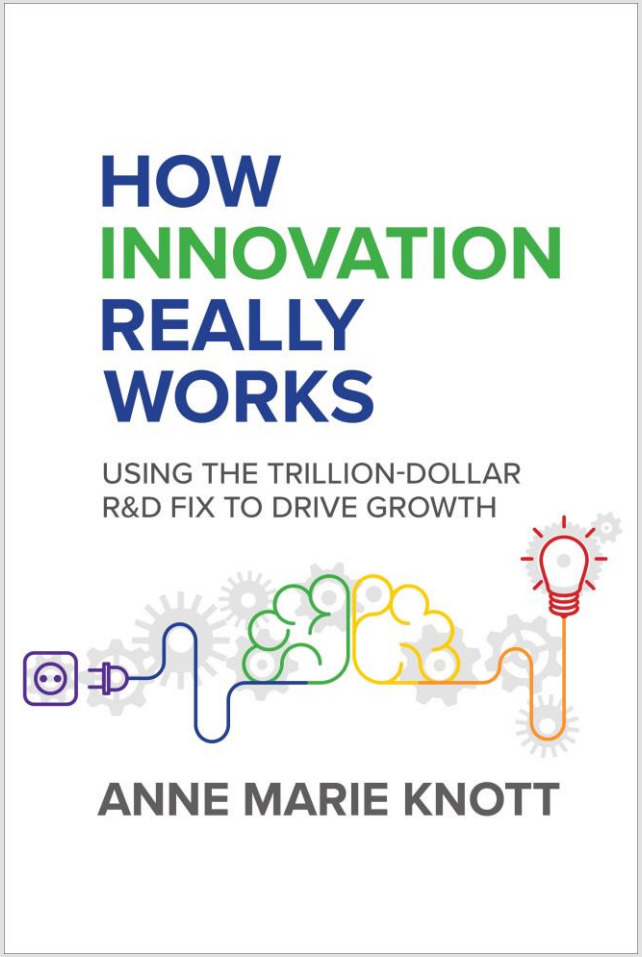


Use measurement!

…to identify and implement high RQ practices

Evidence-based prescription

- NSF grants linking companies' R&D practices to their RQs
  - NSF Award **0965147**: Firm IQ: A Universal, Uniform and Reliable Measure of R&D Effectiveness
  - NSF Award **1246893**: The Impact of R&D Practices on R&D Effectiveness



Test your intuition
Let's play "R&D Idol"!

Please text:

AnneMarieKno511

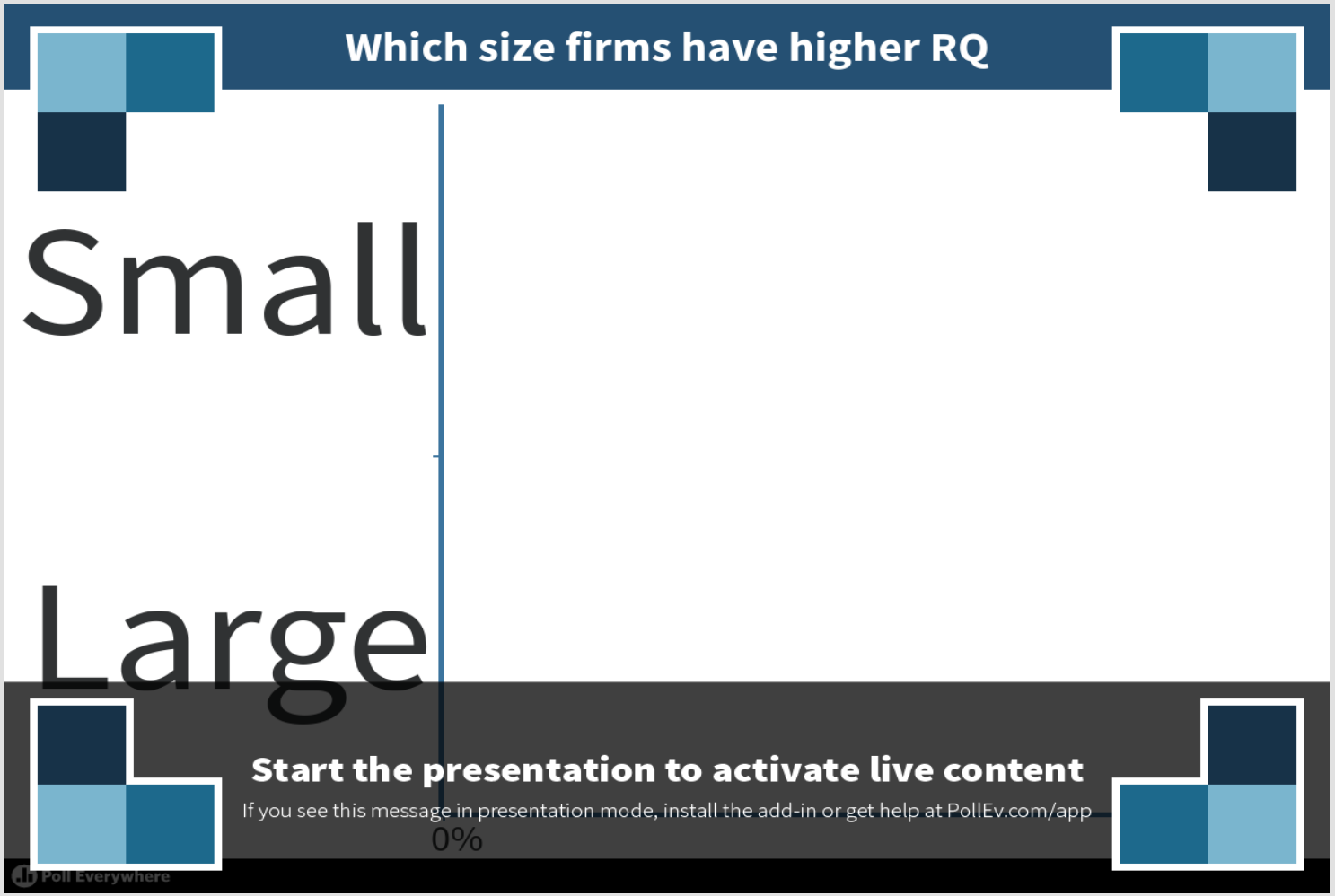
to 37607

to share them

Seven Innovation Prescriptions

1. Small Companies are More Innovative
2. Uncontested Markets are Good for Innovation
3. Spending More on R&D Increases Innovation
4. Companies Need More Radical Innovation
5. Open Innovation Turbocharges R&D
6. R&D Needs to be More Relevant
7. Wall Street Values Innovation

Your Perceptions of Firm Size



The Evidence on Company Size

1. Large firms have 13.5% higher RQ than small firm
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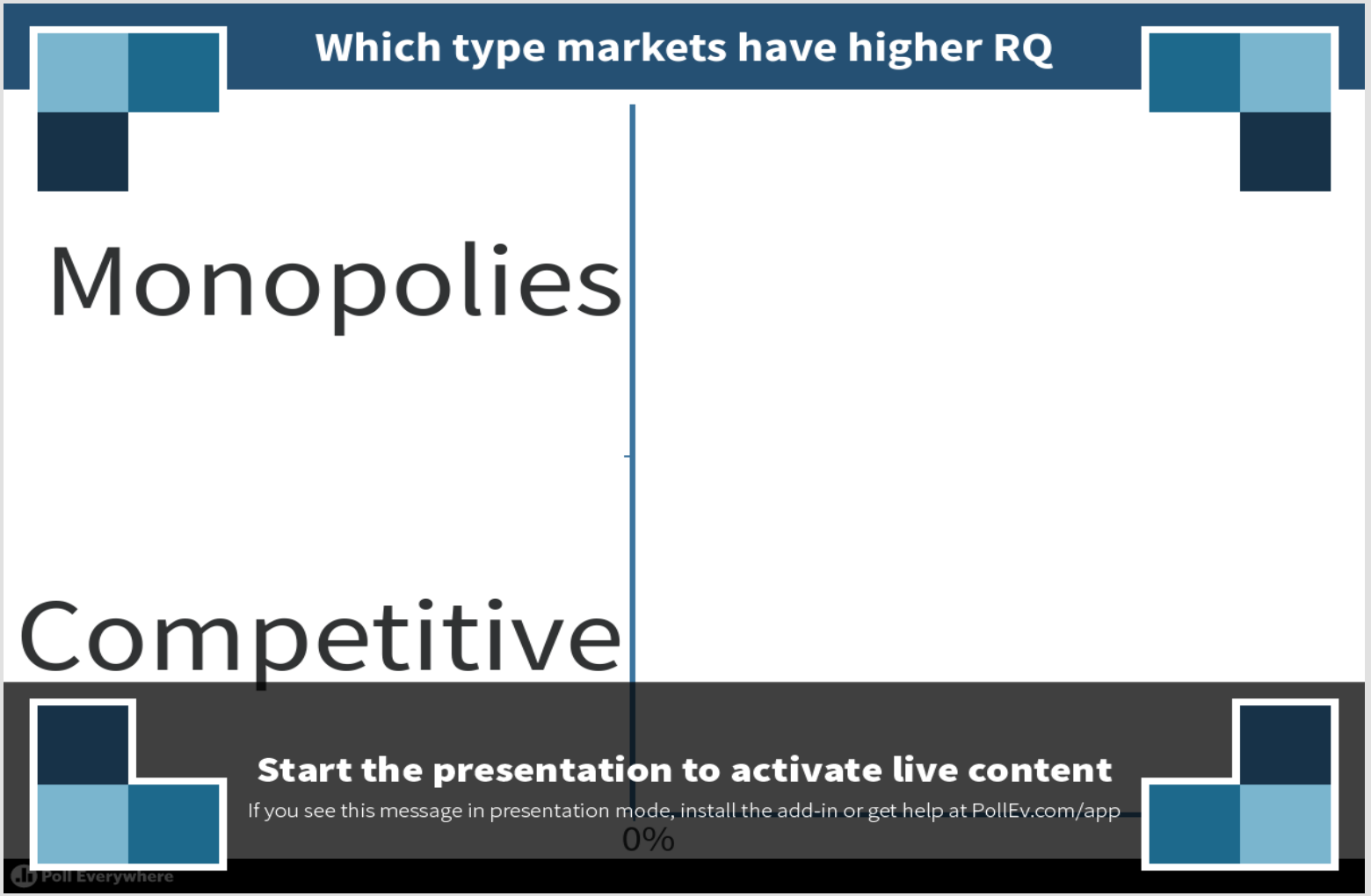
Your Perceptions of Market Type



The Evidence on Market Structure

1. Small Companies are More Innovative
2.
   - Monopolies lead to high profits, but low innovation
3. Spending More on R&D Increases Innovation
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The Evidence on Spending

1. Small Companies are More Innovative
2. Uncontested Markets are Good for Innovation
3. 63% of companies overinvest in R&D
4. Companies Need More Radical Innovation
5. Open Innovation Turbocharges R&D
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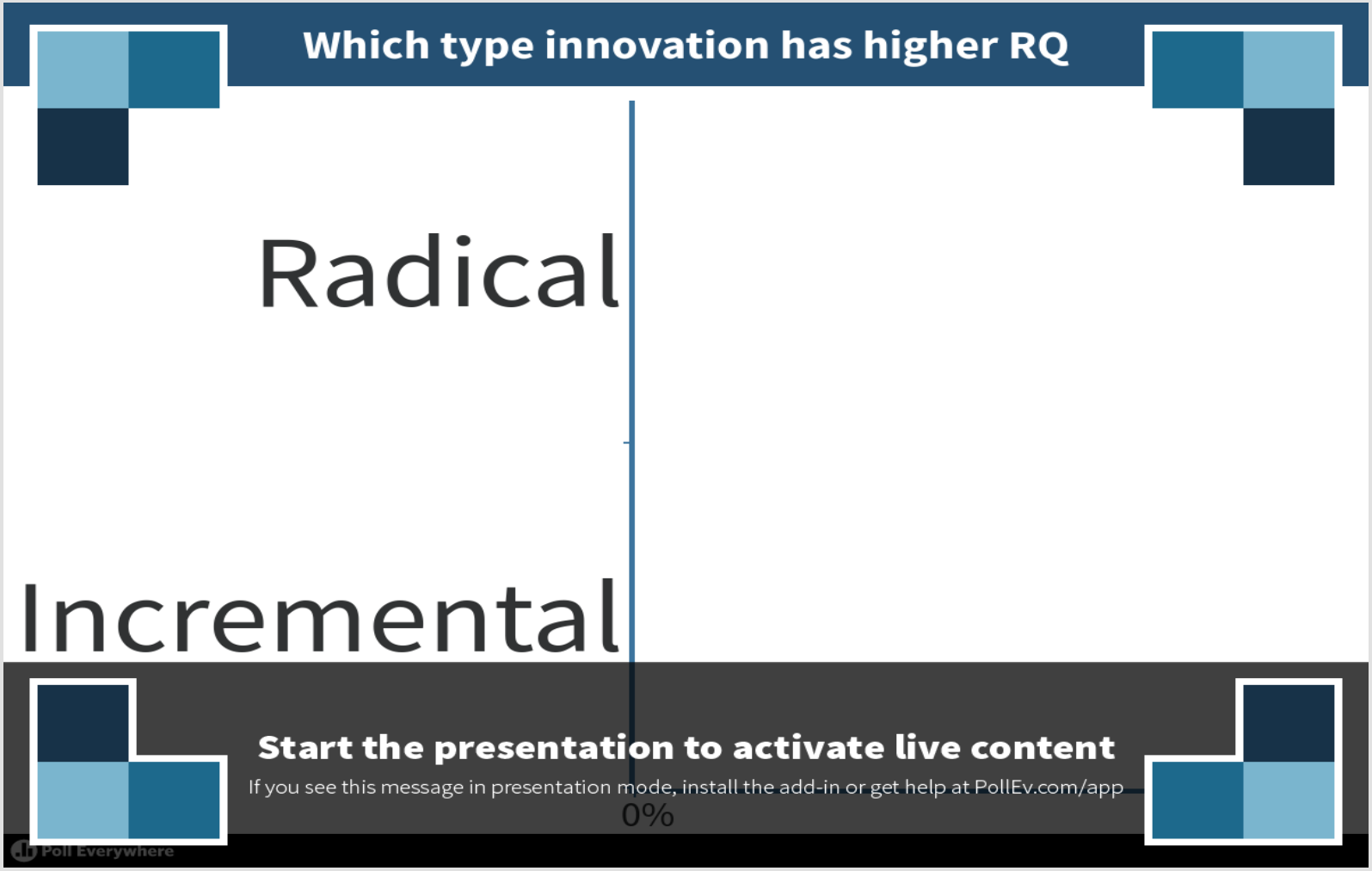
Your Perceptions of Radical Innovation



The Evidence on Radical Innovation

1. Small Companies are More Innovative
2. Uncontested Markets are Good for Innovation
3. Spending More on R&D Increases Innovation
4. Radical innovation decreases RQ
5. Open Innovation Turbocharges R&D
6. R&D Needs to be More Relevant
7. Wall Street Values Innovation

Seven Innovation Prescriptions

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4. Companies Need More Radical Innovation
5. Open Innovation Turbocharges R&D
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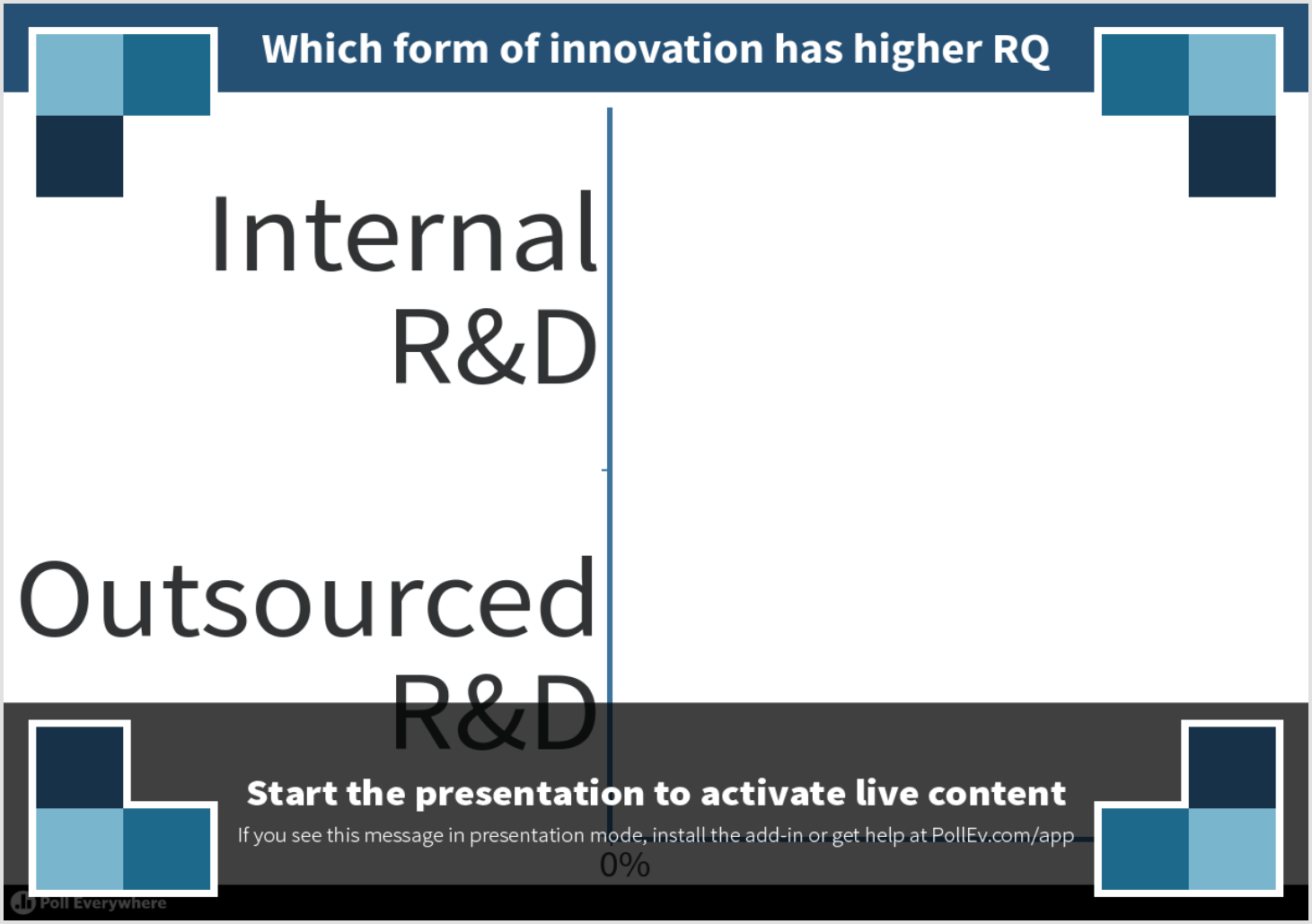
7. Wall Street Values Innovation

Your Perceptions of Open Innovation



The Evidence on Open Innovation

1. Small Companies are More Innovative
2. Uncontested Markets are Good for Innovation
3. Spending More on R&D Increases Innovation
4. Companies Need More Radical Innovation
5. The RQ for outsourced R&D is *ZERO*
6. R&D Needs to be More Relevant
7. Wall Street Values Innovation

Seven Innovation Prescriptions

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4. Companies Need More Radical Innovation
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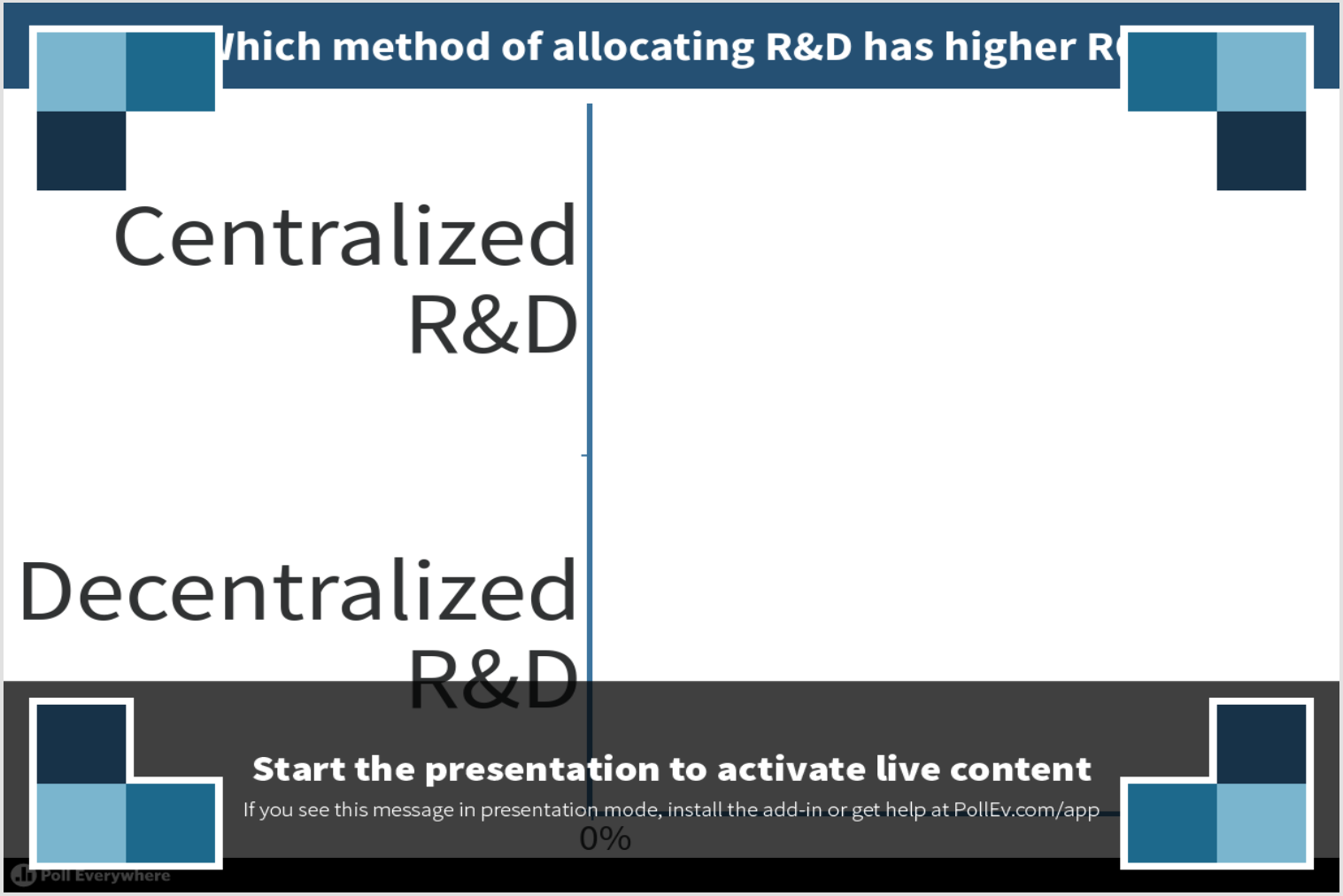
Your Perceptions of Relevance



The Evidence on Relevancy

1. Small Companies are More Innovative
2. Uncontested Markets are Good for Innovation
3. Spending More on R&D Increases Innovation
4. Companies Need More Radical Innovation
5. Open Innovation Turbocharges R&D
6. Companies with centralized R&D have 40-64% higher RQ
7. Wall Street Values Innovation

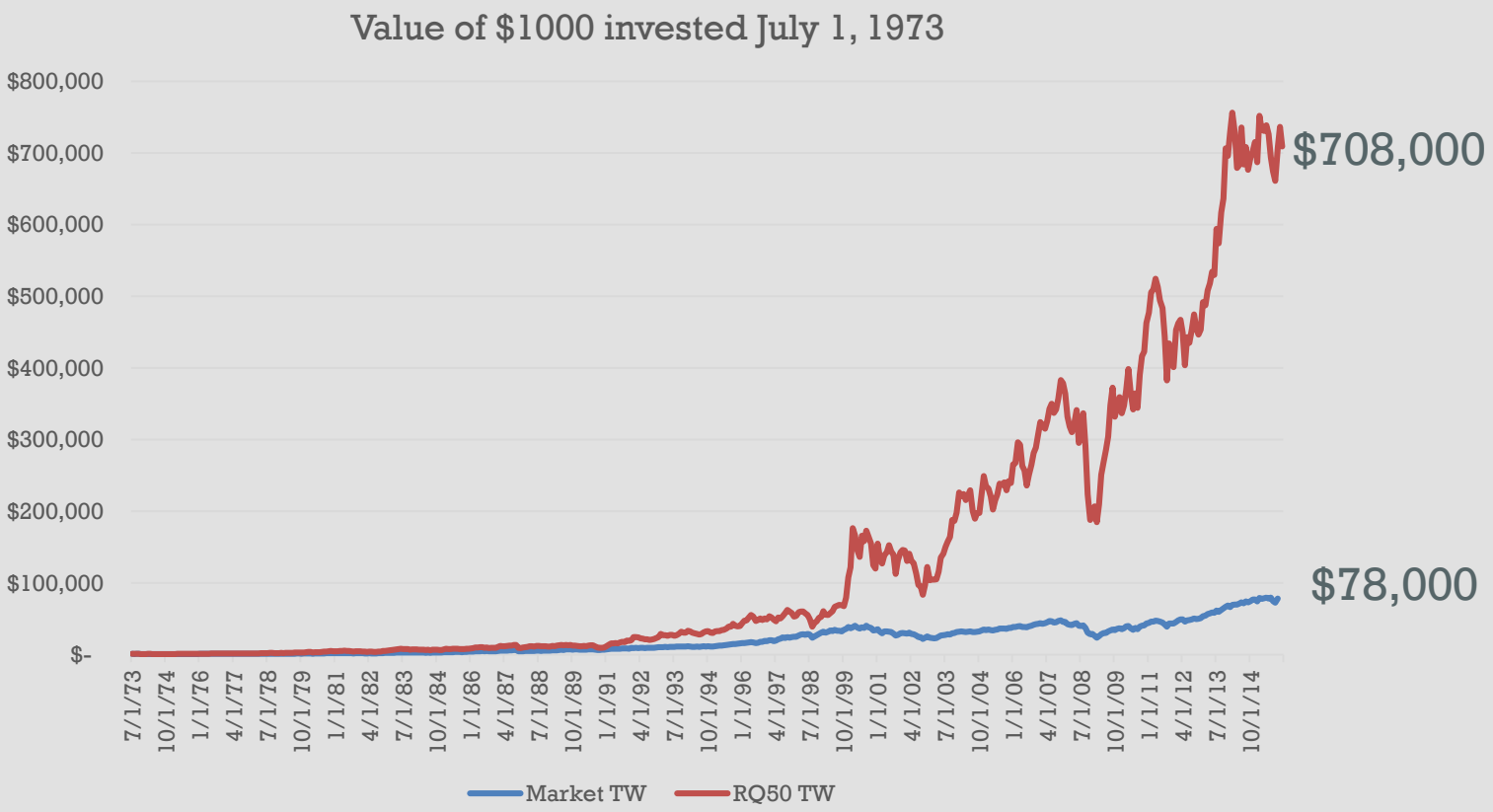
Seven Innovation Prescriptions

1. Small Companies are More Innovative
2. Uncontested Markets are Good for Innovation
3. Spending More on R&D Increases Innovation
4. Companies Need More Radical Innovation
5. Open Innovation Turbocharges R&D
6. R&D Needs to be More Relevant
7. Wall Street Values Innovation

The Evidence on Wall Street

1. Small Companies are More Innovative
2. Uncontested Markets are Good for Innovation
3. Spending More on R&D Increases Innovation
4. Companies Need More Radical Innovation
5. Open Innovation Turbocharges R&D
6. R&D Needs to be More Relevant
7. Wall Street doesn't know how to value innovation

The Most Powerful Evidence for RQ™



The more selfish firms and investors are, the closer I get to my goal