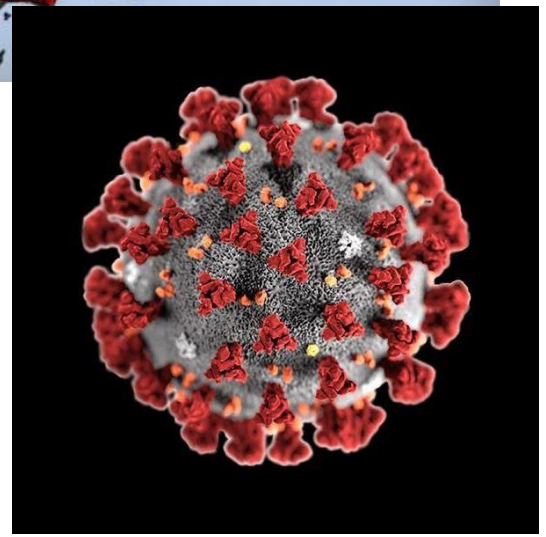
Uncertainty, Technological Competition, and Industry Dynamism

Strategy Science

D. Daniel Keum

Columbia Business School

Uncertainty is bad for business…



…and paralyzes investment activities

Famous Economist & Policy Maker

If energy prices will trend higher, you invest one way; if energy prices will be lower, you invest a different way. **But if you don't know what prices will do, often you do not invest at all.**

Is this always true?

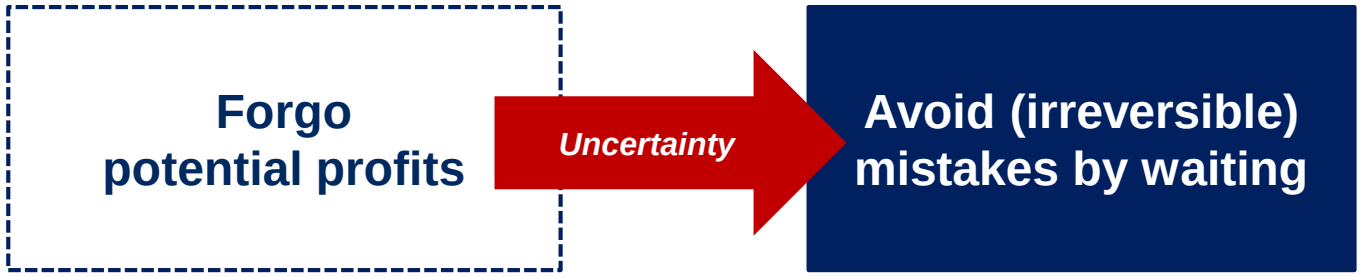
* March 13, 2009

Research Question: How does uncertainty affect…

- Investment and output → **Delays or cancels**
- Innovation → **?? Mixed results**
- Industry concentration → **????**

Prior Research: Three Competing Channels

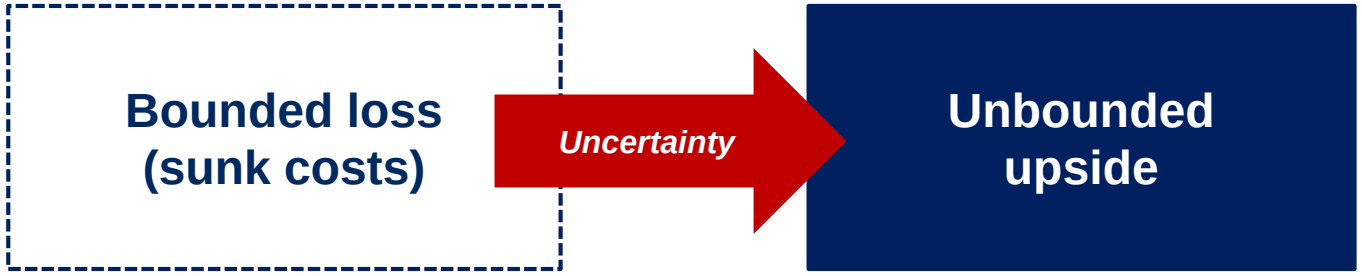
⊖ Real options



Empirical evidence

- Czarnitzki and Toole (2011)
- Goel and Ram (2001)
- Minton and Schrand (1999)

⊕ Growth options*: innovation



- Kraft, Schwartz, and Weiss (2018)
- Atanassov, Julio, and Leng (2015)
- Stein and Stone (2013)

⊙ Time-to-Build

Limitations in Current (Empirical) Research

- **Examines "representative" firms** – with mixed results

- **Especially bad for struggling firms**
  - Flight-to-quality, penalizing laggards
  - Periods of inaction and the status quo

Firms that are behind (i.e., laggards) benefit from the uncertainty

Limitations in Current (Empirical) Research

- Incorporating **competitive interaction** is critical to understanding how uncertainty affects firm innovation
  - Draw from IO models of R&D races
  - Examine the strategic interaction between two (groups of) firms: ***leaders*** and ***laggards***

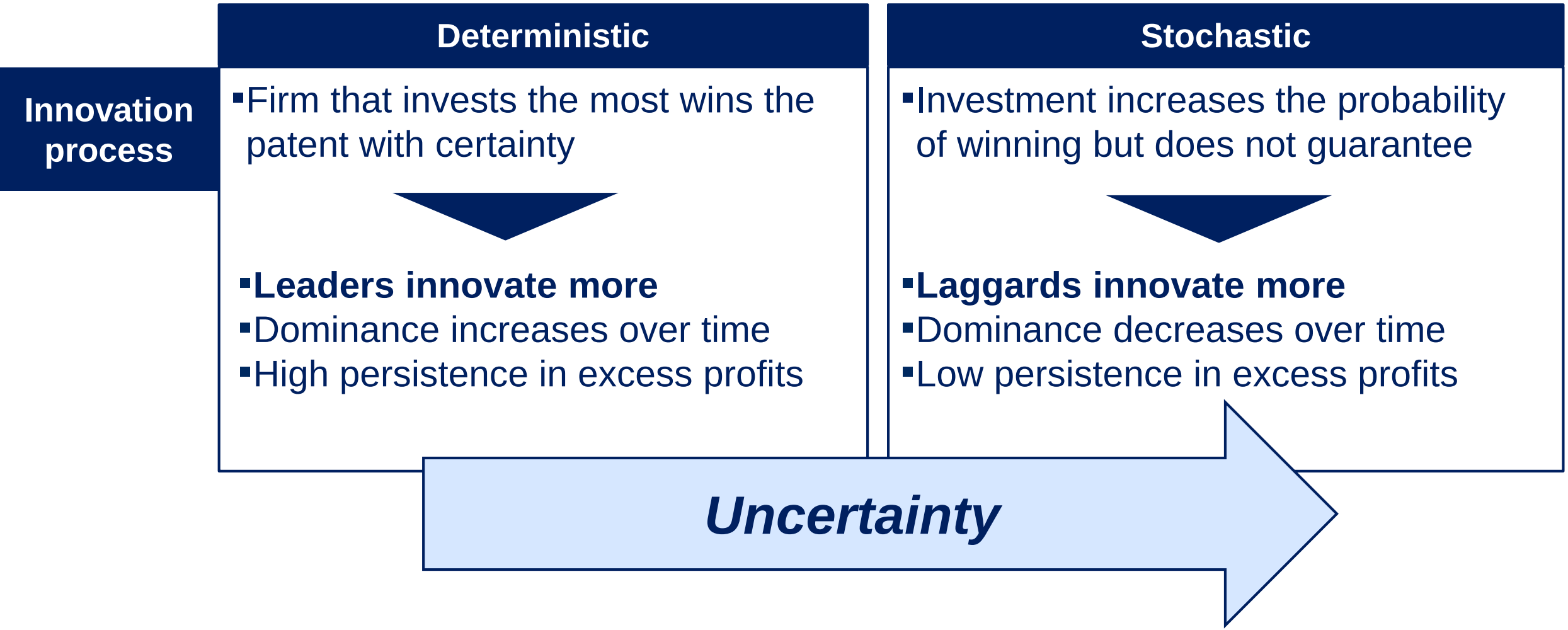
Models of R&D races

- **Races**: Winner-takes-all
- (Extremely) complex, stylized, and often intractable
- Large number of models that predict exactly the opposite

Can I overtake the leader or is it game-over?

Can I take a little break?

Models of R&D races



Empirical Strategy

$$Y_{it+n} = \alpha_i + \beta_1 Uncertainty_t + \beta_2 Laggard_{it} + \beta_3 Uncertainty_t \times Laggard_{it} + X_{it} + \alpha_t$$

- **Innovation**
  - **Log of Number of patents$_{t+3}$, application year**
  - Log of total citations$_{t+2}$
  - Log of market value of patents$_{t+2}$
- **Y_{it+n} : with three year lags (n=2, 3)** → **Passes dynamic specification test**
- Other investments
  - CAPEX (log)t+1
  - Employment growth$_{t+1}$
  - Number of acquisitions$_{t+1}$

Empirical Strategy

$$Y_{it+n} = \alpha_i + \boldsymbol{\beta_1 Uncertainty_t} + \beta_2 Laggard_{it} + \beta_3 Uncertainty_t \times Laggard_{it} + X_{it} + \alpha_t$$

- **Economic policy uncertainty (EPU): Baker, Bloom, and Davis (2016)**
  - Search of 10 leading US newspapers for *"economic"* + *"policy"* + *"uncertainty"*
  - 11 subcomponents: fiscal policy, government spending, regulatory, etc.
  - Macro shock

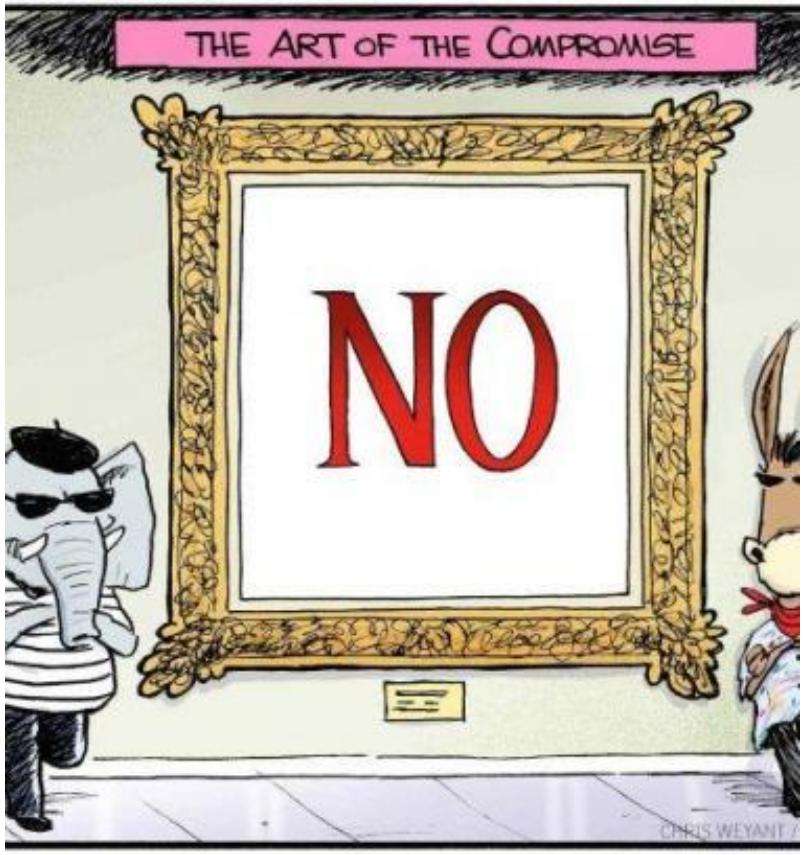
- **Renaissance of empirical research on uncertainty**

- **Monthly national measure, aggregated up to annual frequency**

Empirical Strategy: Instrumental Variable Approach

$$Y_{it+n} = \alpha_i + \boldsymbol{\beta_1 Uncertainty_t} + \beta_2 Laggard_{it} + \beta_3 Uncertainty_t \times Laggard_{it} + X_{it} + \alpha_t$$

- **Instrument** using the partisan-conflict index from Azzimonti (2018)

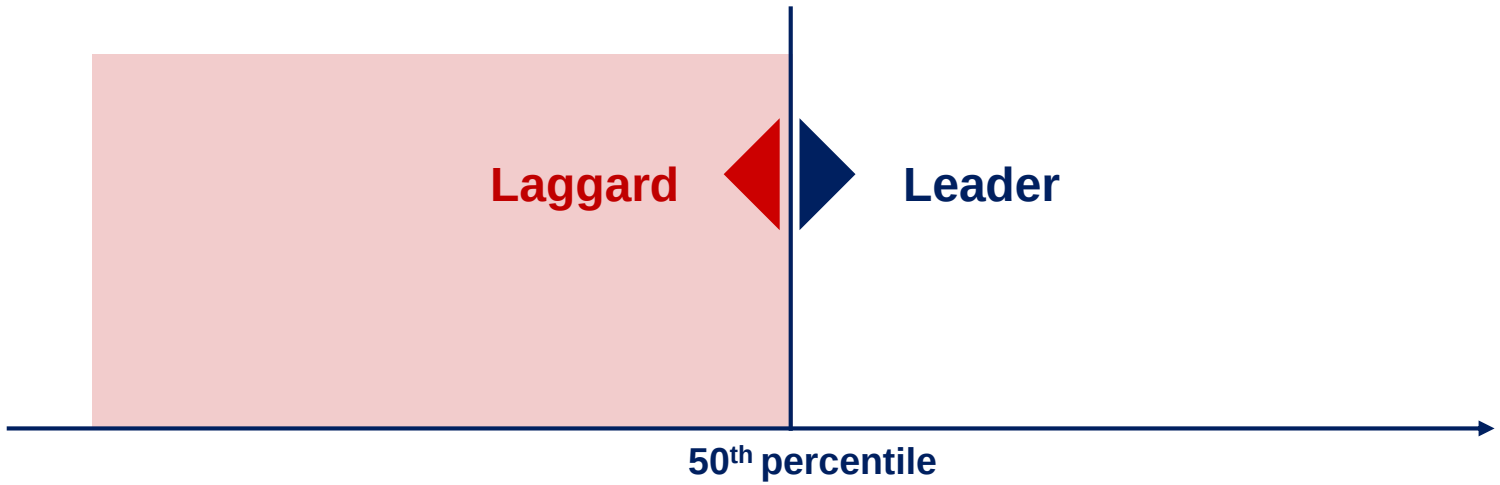


Empirical Strategy

$$Y_{it+n} = \alpha_i + \beta_1 Uncertainty_t + \beta_2 Laggard_{it} + \beta_3 Uncertainty_t \times Laggard_{it} + X_{it} + \alpha_t$$

- **Firm profitability based on ROA** (or TSR/TFP) formed at the 4-digit SIC
  - **A: Simple binary measure (1 vs. 0)**
  - B: Linear spline relative to the industry benchmark

- **Within-industry**



Empirical Strategy

$$Y_{it+n} = \alpha_i + \beta_1 Uncertainty_t + \beta_2 Laggard_{it} + \boldsymbol{\beta_3 Uncertainty_t \times Laggard_{it}} + X_{it} + \alpha_t$$

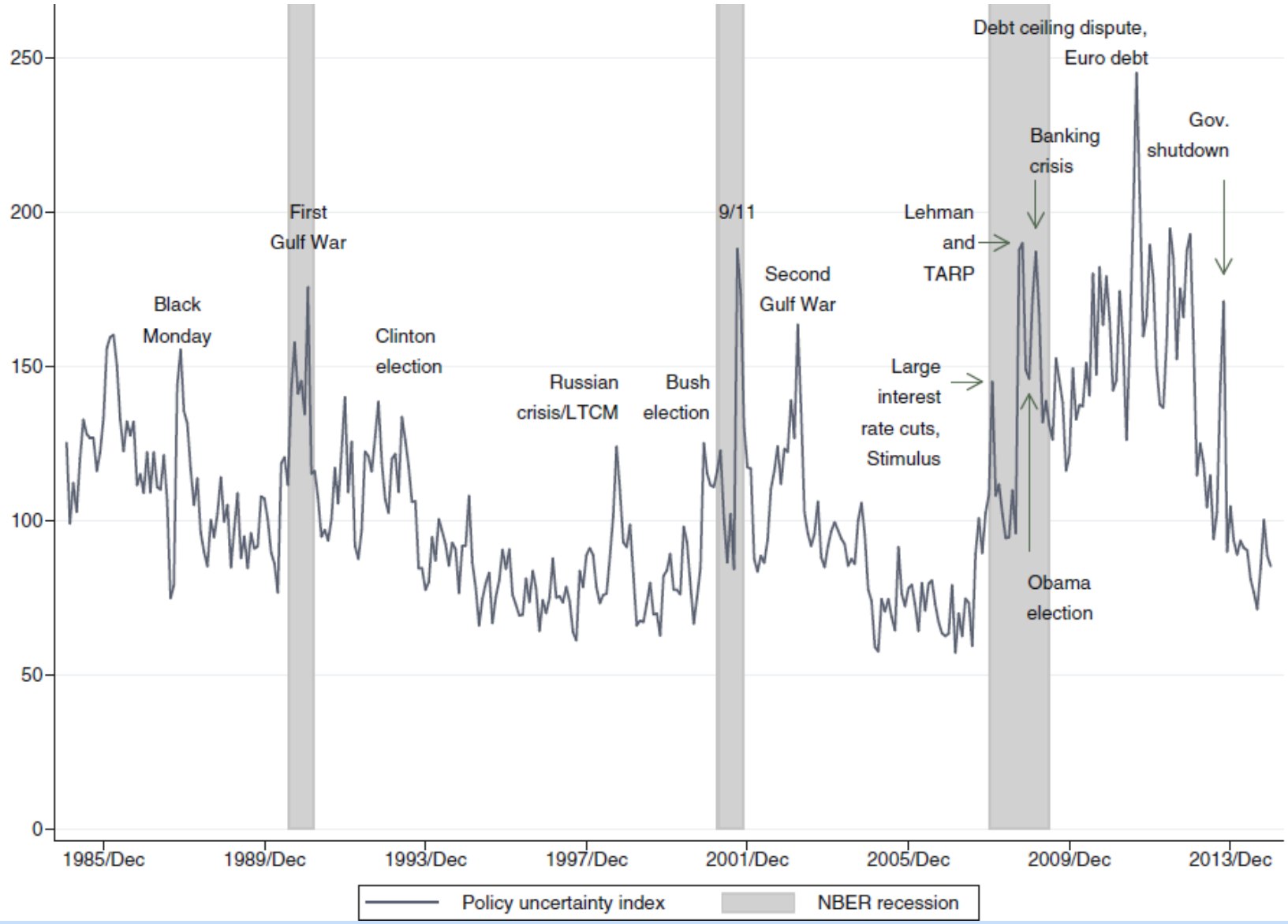
- **Main IV of interest**
- **Expect this to be positive**
- Care less about how uncertainty affects the nominal level of innovation (*Uncertainty*); focus on the relative rate of leader-laggard innovation

Empirical Strategy

$$Y_{it+n} = \alpha_i + \beta_1 Uncertainty_t + \beta_2 Laggard_{it} + \beta_3 Uncertainty_t \times Laggard_{it} + X_{it} + \varepsilon$$

- **Standard errors clustered at the firm and year level**
- Two-way block-bootstrapping

Key identification concern: uncertainty tends to increase during recessions



Mitigations…

$$Y_{it+n} = \alpha_i + \beta_1 Uncertainty_t + \beta_2 Laggard_{it} + \beta_3 Uncertainty_t \times Laggard_{it} + X_{it} + \alpha_t$$

- Include Year x SIC3 fixed effects
- Instrument uncertainty
- A series of cross-sectional tests based on theoretically specified characteristics

Sample and Summary Statistics

- All public firms recorded in Compustat between 1986 – 2006
  - Uncertainty measure: 1986-2017
  - Patent DB: 1972 – 2006

- Economic Policy Uncertainty

Mean	Std.	Min	Max
0.98	0.28	0.56	1.38

Baseline results

	DV: Patent count$_{t+3}$ (log)					DV: Capital investment (I/K)$_{t+1}$				
EPU$_t$										
Laggard$_t$										
EPU$_t$ × Laggard$_t$										
Controls	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Firm FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Year × SIC3 FE	*no*	*no*	*no*	*no*	*yes*	*no*	*no*	*no*	*no*	*yes*
Obs.	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555

Baseline results

	DV: Patent count$_{t+3}$ (log)					DV: Capital investment (I/K)$_{t+1}$				
EPU$_t$	-0.064		-0.064	-0.094**						
	[0.039]		[0.039]	[0.041]						
Laggard$_t$		-0.014***	-0.014***	-0.085***	-0.085***					
		[0.005]	[0.005]	[0.024]	[0.025]					
EPU$_t$ × Laggard$_t$				0.069**	0.065**					
				[0.025]	[0.025]					
Controls	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Firm FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Year × SIC3 FE	*no*	*no*	*no*	*no*	*yes*	*no*	*no*	*no*	*no*	*yes*
Obs.	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555

⊖ **Real options**

⊖ **Increasing dominance**

⊕ **Competitive interaction**

Baseline results

	DV: Patent count$_{t+3}$ (log)					DV: Capital investment (I/K)$_{t+1}$				
EPU$_t$	-0.064		-0.064	-0.094**		-0.017***		-0.017***	-0.016***	
	[0.039]		[0.039]	[0.041]		[0.005]		[0.005]	[0.005]	
Laggard$_t$		-0.014***	-0.014***	-0.085***	-0.085***		-0.018***	-0.018***	-0.016***	-0.016***
		[0.005]	[0.005]	[0.024]	[0.025]		[0.001]	[0.001]	[0.004]	[0.004]
EPU$_t$ × Laggard$_t$				0.069**	0.065**				-0.002	-0.002
				[0.025]	[0.025]				[0.004]	[0.004]
Controls	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Firm FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Year × SIC3 FE	*no*	*no*	*no*	*no*	*yes*	*no*	*no*	*no*	*no*	*yes*
Obs.	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555

Baseline results

	DV: Patent count$_{t+3}$ (log)					DV: Capital investment (I/K)$_{t+1}$				
EPU$_t$			-0.064	-0.094**		-0.017***		-0.017***	-0.016***	
			[0.039]	[0.041]		[0.005]		[0.005]	[0.005]	
Laggard$_t$		-0.014***	-0.014***	-0.085***	-0.085***		-0.018***	-0.018***	-0.016***	-0.016***
		[0.005]	[0.005]	[0.024]	[0.025]		[0.001]	[0.001]	[0.004]	[0.004]
EPU$_t$ × Laggard$_t$				0.069**	0.065**				-0.002	-0.002
				[0.025]	[0.025]				[0.004]	[0.004]
Controls	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Firm FE	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Year × SIC3 FE	*no*	*no*	*no*	*no*	*yes*	*no*	*no*	*no*	*no*	*yes*
Obs.	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555	79,555

⊕ Comp. interaction

Mechanisms (1/3): Learning

	DV: Patent count$_{t+3}$	
	All	
Past R&D Investment$_t$		
EPU$_t$ × Past R&D Investment$_t$		
Controls	*yes*	*yes*
Firm FE	*yes*	*yes*
Year × SIC3 FE	*yes*	*yes*

- Average R&D spending (log) in the past 3 yrs
- Discounted at 15%

Mechanisms (1/3): Learning

	DV: Patent count$_{t+3}$	
	All	
Past R&D Investment$_t$	0.128***	0.211***
	[0.027]	[0.037]
EPU$_t$ × Past R&D Investment$_t$		-0.084***
		[0.025]
Controls	*yes*	*yes*
Firm FE	*yes*	*yes*
Year × SIC3 FE	*yes*	*yes*

Mechanisms (2/3): R&D races

Innovation process	Deterministic	Stochastic
	▪Firm that invests the most wins the patent with certainty	**▪Investment increases the probability of winning but does not guarantee**
	▪Leaders innovate more ▪Dominance increases over time ▪High persistence in excess profits	▪Laggards innovate more ▪Dominance decreases over time ▪Low persistence in excess profits

Uncertainty

Mechanisms (2/3): R&D races

	Tech. certainty		Perf. persistence		R&D persistence	
	High	Low	High	Low	High	Low
Panel A	**DV: Patent count$_{t+3}$**					
EPU_t						
$Laggard_t$						
$EPU_t \times Laggard_t$						

- Regress each 3-digit SIC code

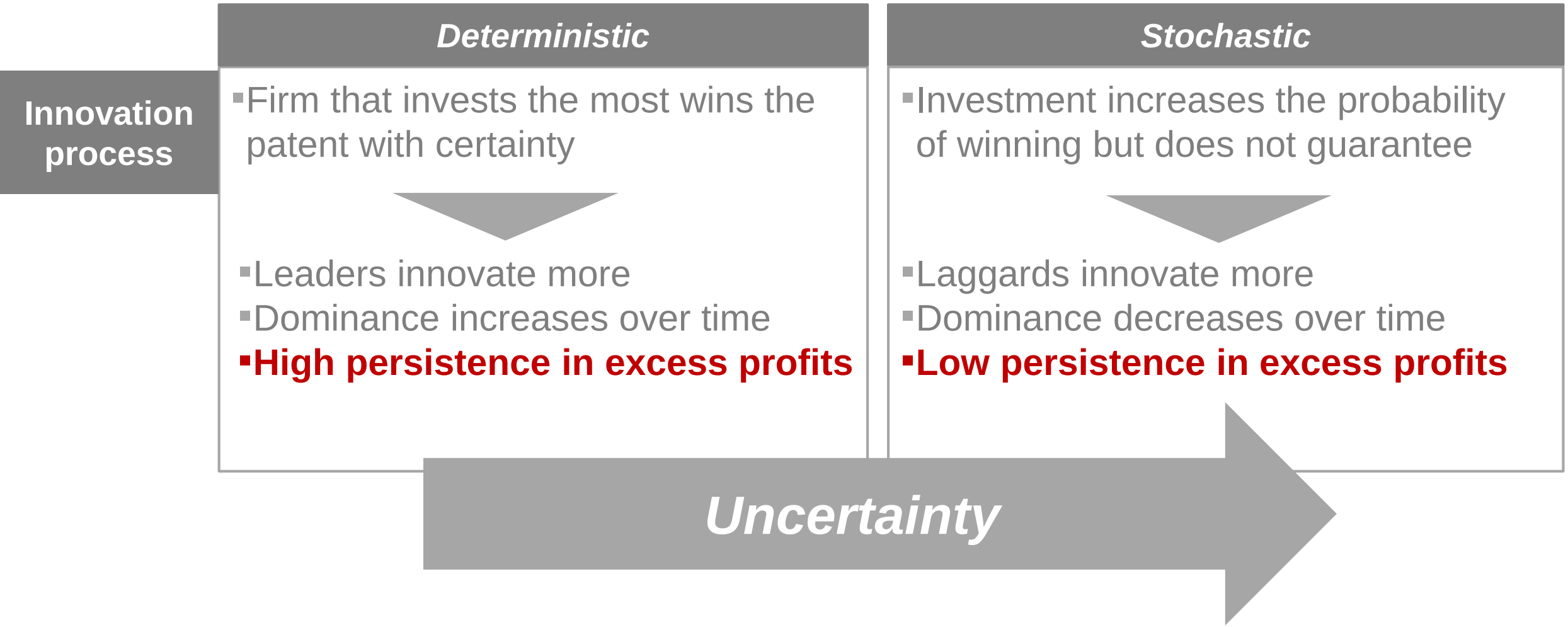
  ***Patent Market value* = β_1 *R&D spending* + Firm FE**

- Divide based on high vs. low values of β_1

Mechanisms (2/3): R&D races

	Tech. certainty		Perf. persistence		R&D persistence	
	High	Low	High	Low	High	Low
Panel A			**DV: Patent count$_{t+3}$**			
EPU$_t$	-0.122**	-0.064				
	[0.052]	[0.038]				
Laggard$_t$	-0.117***	-0.060**				
	[0.039]	[0.026]				
EPU$_t$ × Laggard$_t$	0.090**	0.054*				
	[0.039]	[0.026]				

Mechanisms (2/3): R&D races



Mechanisms (2/3): R&D races

	Tech. certainty		Perf. persistence		R&D persistence	
	High	Low	High	Low	High	Low
Panel A			**DV: Patent count$_{t+3}$**			
EPU$_t$	-0.122**	-0.064	-0.138**	-0.034	-0.129**	-0.046*
	[0.052]	[0.038]	[0.063]	[0.020]	[0.060]	[0.024]
Laggard$_t$	-0.117***	-0.060**	-0.112***	-0.046*	-0.099***	-0.059**
	[0.039]	[0.026]	[0.031]	[0.024]	[0.030]	[0.028]
EPU$_t$ × Laggard$_t$	0.090**	0.054*	0.100***	0.027	0.084**	0.045
	[0.039]	[0.026]	[0.031]	[0.024]	[0.029]	[0.028]

Mechanisms (3/3): Competition

	R&D intensity		Pace of tech. change		Differentiation		Industry concentration		
	High	Low	High	Low	High	Low	High	Mid	Low
Panel A	**DV: Patent count$_{t+3}$**								
EPU$_t$	-0.154**	-0.045*	-0.151**	-0.048	-0.066*	-0.137**	-0.063	-0.038	-0.143**
	[0.062]	[0.024]	[0.058]	[0.032]	[0.032]	[0.057]	[0.044]	[0.045]	[0.051]
Laggard$_t$	-0.107**	-0.058**	-0.122***	-0.048**	-0.059**	-0.109***	-0.126***	-0.099***	-0.022
	[0.037]	[0.022]	[0.039]	[0.023]	[0.021]	[0.034]	[0.033]	[0.034]	[0.029]
EPU$_t$ × Laggard$_t$	0.097**	0.042**	0.105**	0.036	0.048**	0.092**	0.102***	0.084**	0.004
	[0.036]	[0.020]	[0.039]	[0.024]	[0.022]	[0.034]	[0.031]	[0.032]	[0.030]

Mean-reversion

	DV: ROA_{t+1}
EPU_t	
$Overperformance_t$	0.366***
	[0.028]
$Underperformance_t$	-0.526***
	[0.019]
$EPU_t \times Overperformance_t$	
$EPU_t \times Underperformance_t$	

Industry concentration

	All	Tech. Certainty		Pace of Tech. Change		R&D persistence		Perf. Persistence	
		High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A				**DV: HHI**					
EPU_{t-1}	-0.036	0.103	0.369*	0.067	-0.174	0.037	0.326**	0.243	0.075
	[0.275]	[0.216]	[0.197]	[0.296]	[0.327]	[0.258]	[0.150]	[0.227]	[0.190]
EPU_{t-2}	0.011	-0.228*	-0.016	-0.125	0.023	-0.269*	0.005	-0.035	-0.233*
	[0.190]	[0.112]	[0.061]	[0.087]	[0.223]	[0.146]	[0.069]	[0.115]	[0.123]
EPU_{t-3}	-0.320	-0.477**	-0.312	-0.300**	-0.312	-0.786**	-0.115	-0.387*	-0.591**
	[0.229]	[0.192]	[0.181]	[0.131]	[0.273]	[0.303]	[0.137]	[0.209]	[0.204]
EPU_{t-4}	-0.513*	-0.447**	-0.175	-0.207	-0.633*	-0.681**	-0.095	-0.402	-0.428**
	[0.282]	[0.198]	[0.250]	[0.326]	[0.323]	[0.315]	[0.160]	[0.300]	[0.191]

Conclusions

- Periods of high uncertainty: valuable window for laggards to challenge and overtake leaders
- Identify competitive interactions as a channel through which uncertainty operates and affects innovation and industry dynamism
- Silver linings to policy uncertainty
- A neglected pillar of strategy research
  - ***Declining business dynamism***
  - Role of business in society (CSR)
  - Inequality (income, gender, etc)
  - Climate change

Columbia Business School

AT THE VERY CENTER OF BUSINESS™ …

…and financial crisis, 9/11, and global pandemic

…and other world-ending events

- Independence Day (1996)
- Armageddon (1998)
- Godzilla (1998)
- The Day after Tomorrow (2004)
- I am Legend (2007)
- Avengers….

Thank you