Shock Spillover and Financial Response in Supply Chain Networks: Evidence from Firm-Level Data

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Question

Example: Slice of supply network between top firms in electronics industry

- How **far** do idiosyncratic shocks to production **percolate** in the **network** of firm-to-firm supply chains?
  - Can these links transmit shocks' impact to **remotely connected** firms?
  - Use textual analysis methods to **identify & quantify** the extent of supply chain shocks
  - Examine both operational & financial implications

Findings

Key Takeaway

Substantial spillover of idiosyncratic shocks to remote connections

- Impact does not significantly decay until the 4th link

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  Implication 1. Stock price response?

  - Significant post-shock abnormal returns
  - Slow reaction to remote shocks
    - Persistent return drift for 40 days

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Implication 1. Stock price response?

  - Significant post-shock abnormal returns
  - Slow reaction to remote shocks
    - Persistent return drift for 40 days

Implication 2. Corporate policy response?

  - Post-shock changes in inventory & capital
  - Heterogeneous. Larger response to close shocks

Contributions

Literature on spillovers and externalities

- Production network theories: Acemoglu et al. (2012), Gabaix (2011)...
- Production linkages: Ahern (2013), Barrot and Sauvagnat (2016), Carvalho et al. (2016), Cohen and Frazzini (2008)...
- Product competition: Hoberg and Phillips (2015)...
- Peer effects: Leary and Roberts (2014), Shue (2013)...

This paper: quantifies the extent of these externalities

- Comprehensive supply chain data with multiple links $\rightarrow$ examine spillover beyond one node
- Spillover to remote firms $\rightarrow$ larger aggregate implications
- Uncover economic mechanism behind results $\rightarrow$ motivate further theory development

Contributions

Literature on identification of firm-specific shocks

- Idiosyncratic returns shocks
- Firm-specific sales
- Structural models

This paper: directly captures the source of firm-specific shocks

- Observe actual events from textual disclosure data
- Direct way of identification
- Additional granularity helpful in uncovering economic magnitudes

Identify firm-specific shocks from textual disclosures

Start with the collection of all firm-level disclosures (1994-2015)

- Current reports: SEC Form 8-Ks (EDGAR)
- Press releases: Dow Jones Newswire
- Company news: Capital IQ

Identification **goal**: Isolate the source of firm-specific production shocks

Identify firm-specific shocks from textual disclosures

Start with the collection of all firm-level disclosures (1994-2015)

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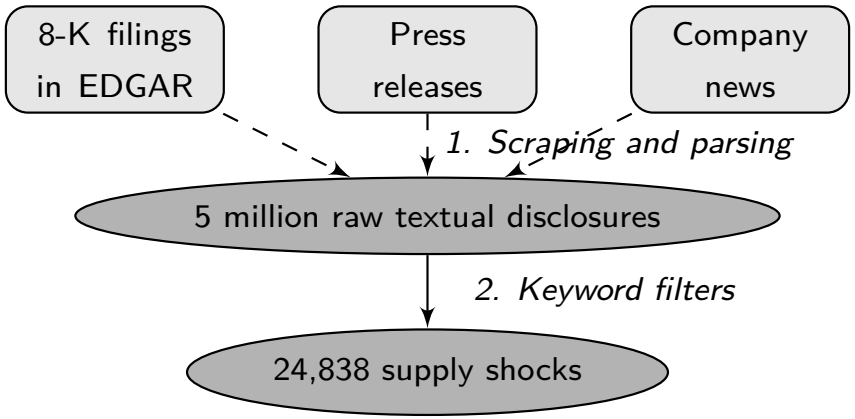
Identification **goal**: Isolate the source of firm-specific production shocks

- Automated method: Bayesian topic classification models
  - Classify disclosed shocks into different groups based on disclosure languages
  - Unsupervised learning: no training or pre-fitting required
  - Inspect & isolate the idiosyncratic groups
  - Problem: **precision, subjectivity, "black box"**
    - Statistical robustness checks + human validation

Identification step 1

Extract production shocks (of all types) from all disclosures



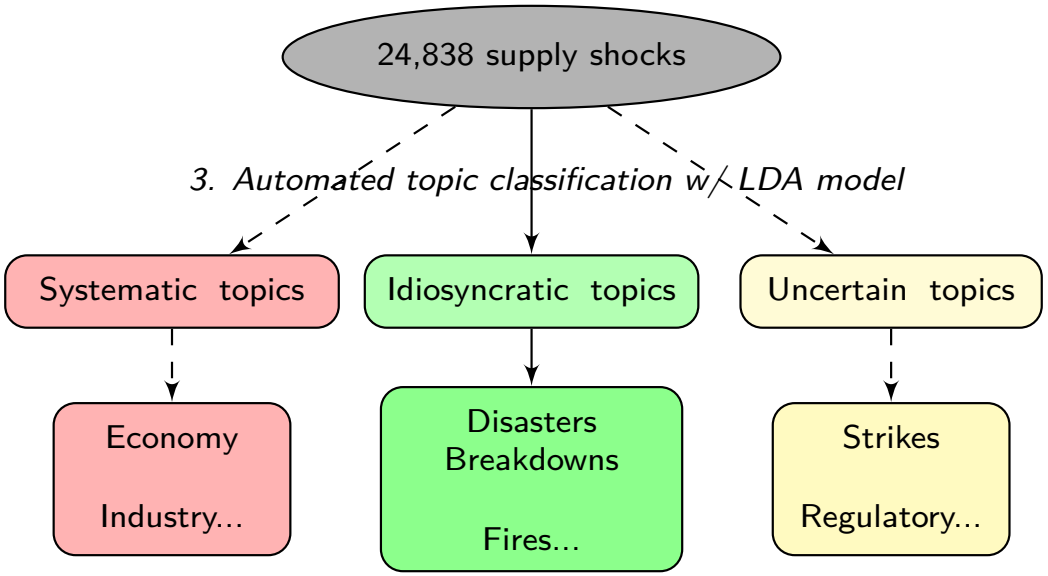
Tool: Keyword filters

1. Extract disclosures with keywords related to:
   - Production & supplies: *factory*, *components*, *material*...
   - Shocks: *disruption*, *interruption*, *shortage*...
2. For each captured event, identify:
   - Origin of shock
   - Date of event

Output: 24,838 shock events from 4,535 origin firms

Identification step 2

Extract shocks instigated by idiosyncratic events



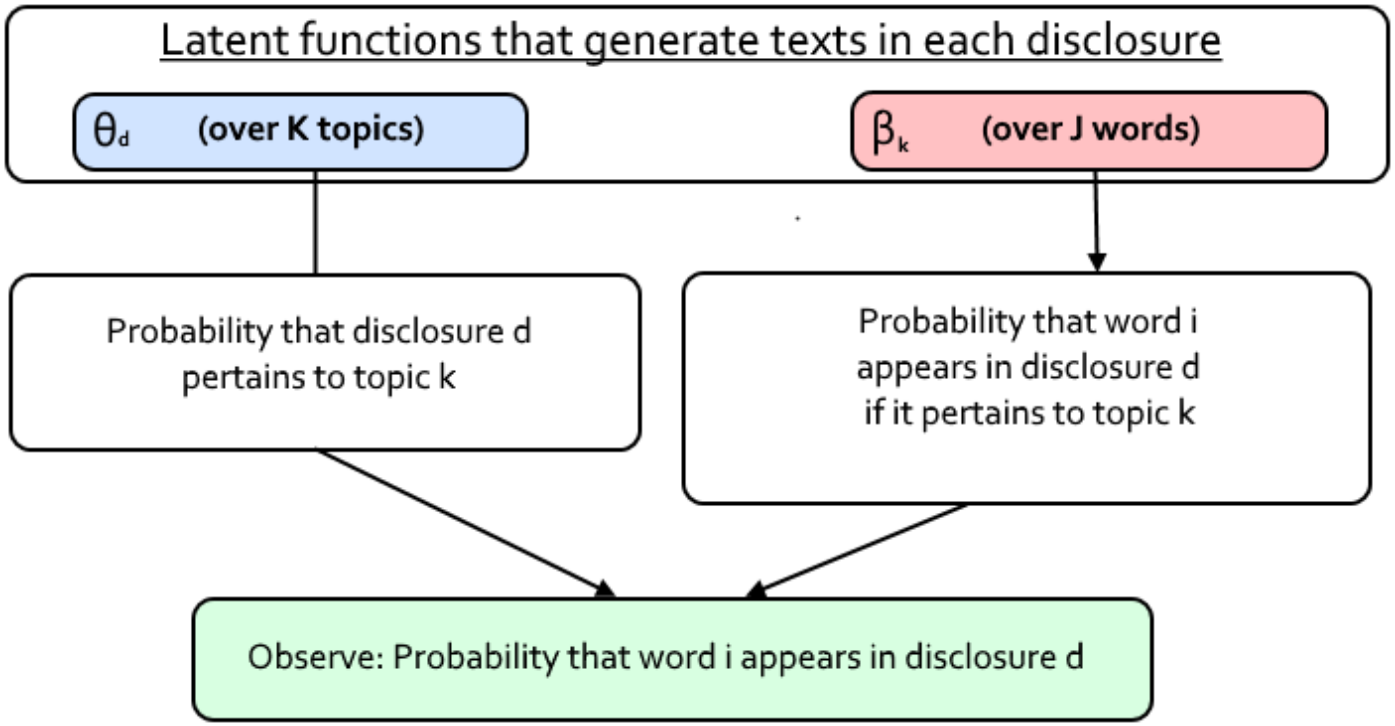
Tool: Latent Dirichlet Allocation

- Output 1: 20 topic distribution vectors, each over all words in vocabulary
  - Determines the economic content of each topic
- Output 2: 24,838 document topic mixtures, each over 20 topics
  - Proportion of topics discussed in each disclosure
- Key: High weights to important words that differentiate among topics

LDA inference intuition

▸▸ detailed LDA formulation

Classify a collection of $\{d\}_{d=1}^{D}$ disclosure documents with a vocabulary of $\{j\}_{j=1}^{J}$ unique words into K topics:



LDA Estimation

- Basic unit of input: words within each disclosure document
  - Particularly: which words occur together
- Assume θ_d and $\beta_n \sim Dirichlet$ & Estimate parameters of θ_d and β_n

LDA implementation

Step 1: Generalize this example to my shock disclosure sample

- $D = 24,838$ unique paragraphs, $J = 9,237$ unique words, $N = 20$ topics

Step 2: Functional forms to the topic-word (β_n) and paragraph-topic (θ_d) distributions

- $\theta_d \sim Dirichlet_{20}(\mu)$, $\beta_n \sim Dirichlet_{9237}(\phi)$
- θ_d is a vector that describes the probability distribution that a particular paragraph pertains to each of the topics
- β_n is a vector that describes the probability distribution that a particular word appears when the paragraph is about a certain topic

Step 3: Specify the choice of each word within a paragraph:

- $W_{d,i} | \left(\{\beta_n\}_{n=1}^{N}, Z_{d,i} \right) \sim Multinomial(\beta_{Z_{d,i}})$, $Z_{d,i} | \theta_d \sim Multinomial(\theta_d)$

$\Rightarrow$ joint distribution for the observed words: $P\left(\{\beta_n\}_{n=1}^{N}, \{\theta_d\}_{d=1}^{D}, \{Z_d\}_{d=1}^{D}, \{W_d\}_{d=1}^{D} \right)$

◂ lda description

LDA implementation

Step 4: Observe the actual words $\Rightarrow$ apply Bayes theorem:

$$P\left(\{\beta_n\}_{n=1}^{N}, \{\theta_d\}_{d=1}^{D}, \{Z_d\}_{d=1}^{D} | \{W_d\}_{d=1}^{D}\right)$$

Step 5: Compute posterior expectations of:

- Topic composition (over words) $\hat{\beta}_n$
- Paragraph mixture (over topics) $\hat{\theta}_d$

Step 6: Preliminary validation with human readers

◂ lda description

Topic keywords

Group 1: Systematic Types

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6
global	uncertainty	economy	consumer	sector	retail
systematic	global	condition	economic	industry	distributor
markets	risk	recession	demand	competitive	sales
widespread	region	expansion	capacity	cost	seller
countries	property	growth	consumption	price	third-party

Group 2: Middle Types

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6
worker	union	government	research	transportation	quality
labor	strike	legal	intellectural	channel	design
strike	organization	regulation	property	logistical	warranty
stoppage	wage	licence	dispute	development	flaw
employee	relation	regional	restriction	oursourcing	recall

Group 3: Firm-specific Types

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6	Topic 7	Topic 8
disaster	flood	fire	hurricane	accident	breakdown	IT	failure
destruction	water	outage	weather	machinery	equipment	breach	install
earthquake	recovery	accident	tornado	production	assembly	information	equipmen
damage	damage	power	storm	suspend	factory	sensitive	manufactu
catastrophe	disaster	electricity	sustain	shutdown	outage	intrusion	maintainar

Identification step 2

Infer topic's economic content based on top keywords

1. Definitely systematic: economy- and industry- related topics
   - Top keywords: economy, consumption, industry, demand...
   - Example: "We experienced severe shortages in [hard] drive parts from our suppliers, due to unusually high demand from the personal PC sector..."
2. Suspiciously idiosyncratic: labor- and regulatory-related topics
   - Top keywords: labor, union, strike, license, regulation...
   - Example: "A strike in the plant...of our supplier...has disrupted our input shipments."
3. Likely idiosyncratic: natural and man-made disasters, unexpected glitches, power outages...
   - Top keywords: disaster, accident, fire, flood...
   - Example: "A blaze occurred at a factory for SK Hynix...It will take at least half a year before SK Hynix's damaged clean room is fully rebuilt...substantial shortages could lead to higher prices"

Identification step 2

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- Keep only single-topic disclosures (>95% one topic)
- Keep only idiosyncratic topics
- Eliminate shocks w/ potential supply chain-wide effects details

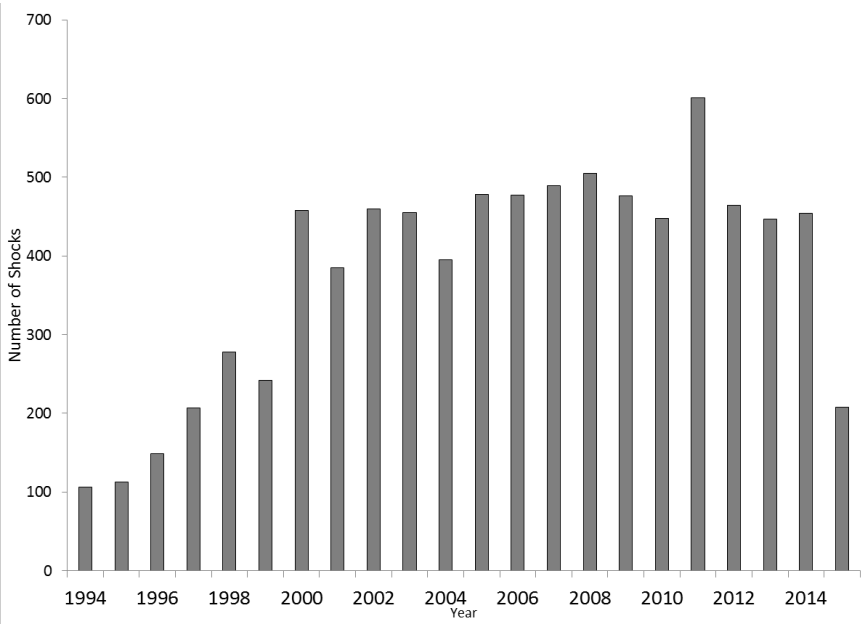
→ Sample of 8,000 localized, firm-specific shocks

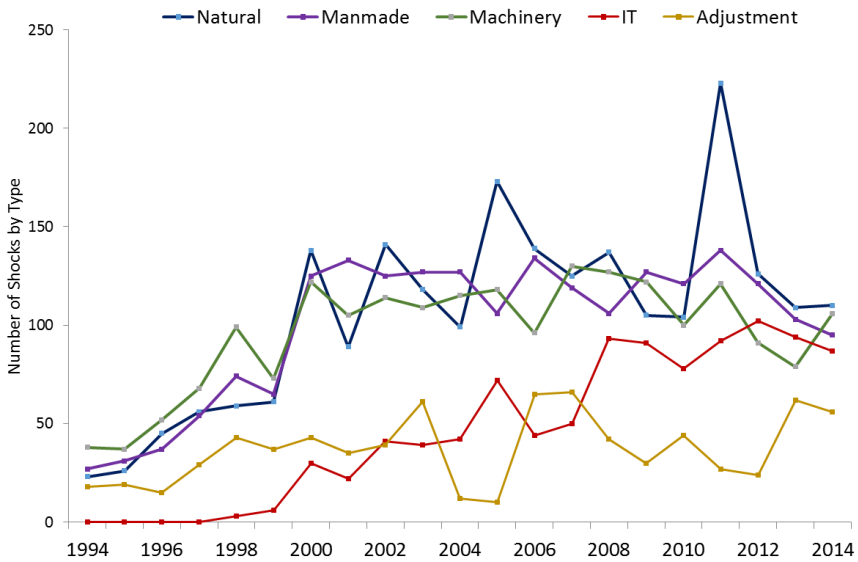
Example of output

- **Example:** *Alcan's Laterriere Works aluminium smelter...suffered a significant power outage yesterday...leaving the plant without the adequate energy required to continue operating at full capacity...one of two production lines has been suspended...in the coming weeks...will mobilize the necessary resources to restore the suspended line.*

⏩ par ⏩ ovr ⏩ fal1 ⏩ fal2 ⏩ evneg ⏩ evpri ⏩ evc2s

Summary statistics for firm-specific shock data





Types of Identified Shocks	# of Events	Percent
Natural disasters	2256	27.20%
Manmade disasters	2145	25.86%
Production disruption	2076	25.03%
IT breakdown & cyberattacks	1032	12.44%
Adoption failures	786	9.48%
Total	8295	100.00%

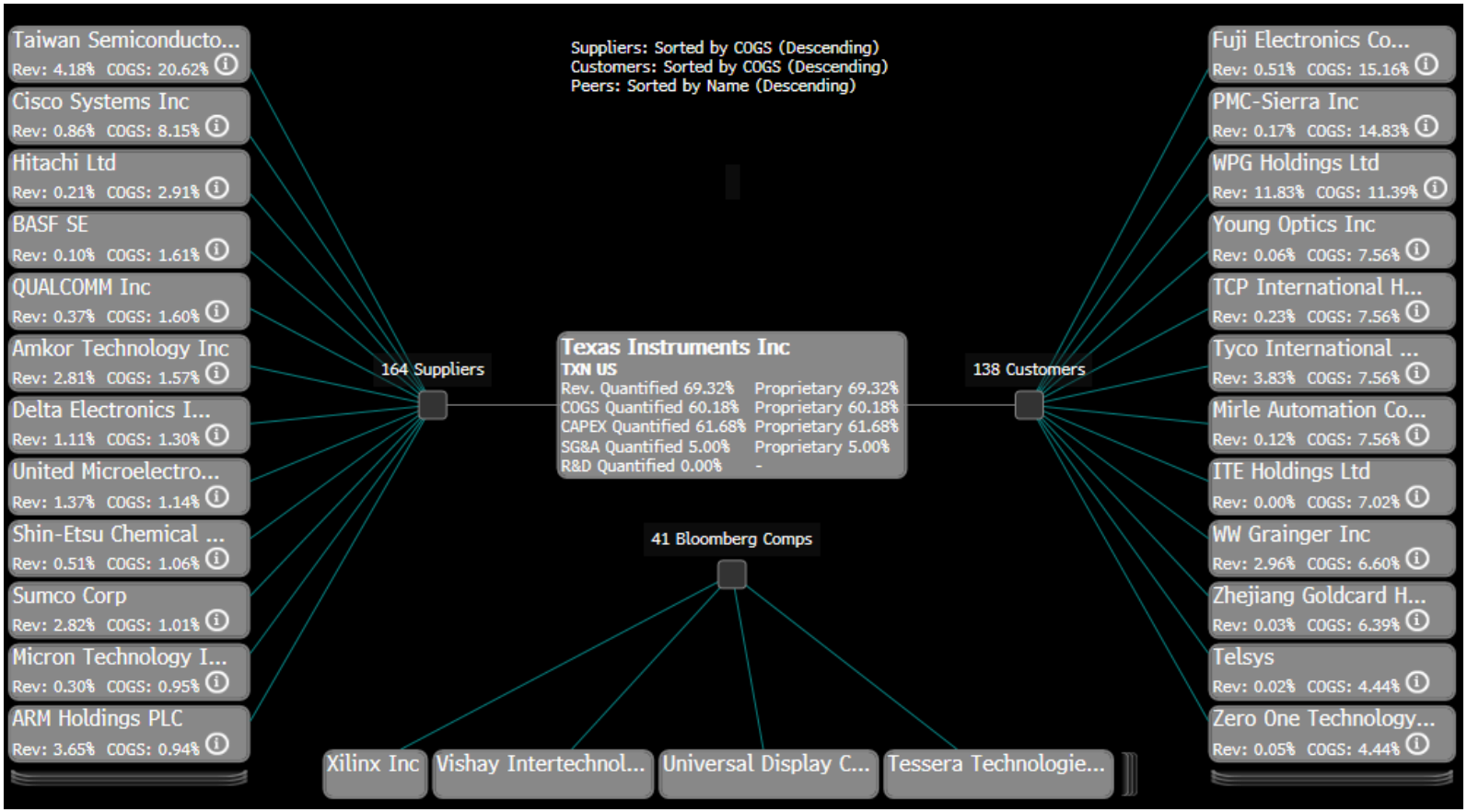
⏩ treated vs. untreated
⏩ voluntary ⏩ placebo ⏩ evpri

Firm-to-firm supply network

Data Sources

Extract firm-to-firm supply chain relations btn publicly companies globally:

1 Bloomberg & Revere Data Systems:



Firm-to-firm supply network

Data Sources

Extract firm-to-firm supply chain relations btn publicly companies globally:

2 8-K and other firm disclosures:

UTC Aerospace Systems to Supply Composite Components for 10 Virginia Class Submarines

CHARLOTTE, N.C., April 29, 2015 /PRNewswire/ -- UTC Aerospace Systems has entered into an agreement with Newport News Shipbuilding, a division of Huntington Ingalls Industries (NYSE: HII (http://studio-5.financialcontent.com/prnews?Page=Quote&Ticker=HII)) to provide a number of composite components for the next 10 Virginia Class nuclear attack submarines, collectively referred to as Block IV. The agreements cover deliveries through 2020 to the shipbuilder. Work will be performed by the Engineered Polymer Products (EPP) team in Jacksonville, Florida, which is part of the Aerostructures business unit. UTC Aerospace Systems is a unit of United Technologies Corp. (NYSE: UTX (http://studio-5.financialcontent.com/prnews?Page=Quote&Ticker=UTX)).

Firm-to-firm supply network

Summary Statistics

Statistic	Mean
# of Firms	10505
# of Domestic firms	6934
Links/Year	314246
Links/Firm	30.49
# of Suppliers	16.37
# of Customers	14.12
Supplier share (subsample)	33.89%

- Data on both suppliers & customers of all sizes
- Goes back to 1994
- Broad (90% CRSP with controls) and deep (34% COGS) coverage

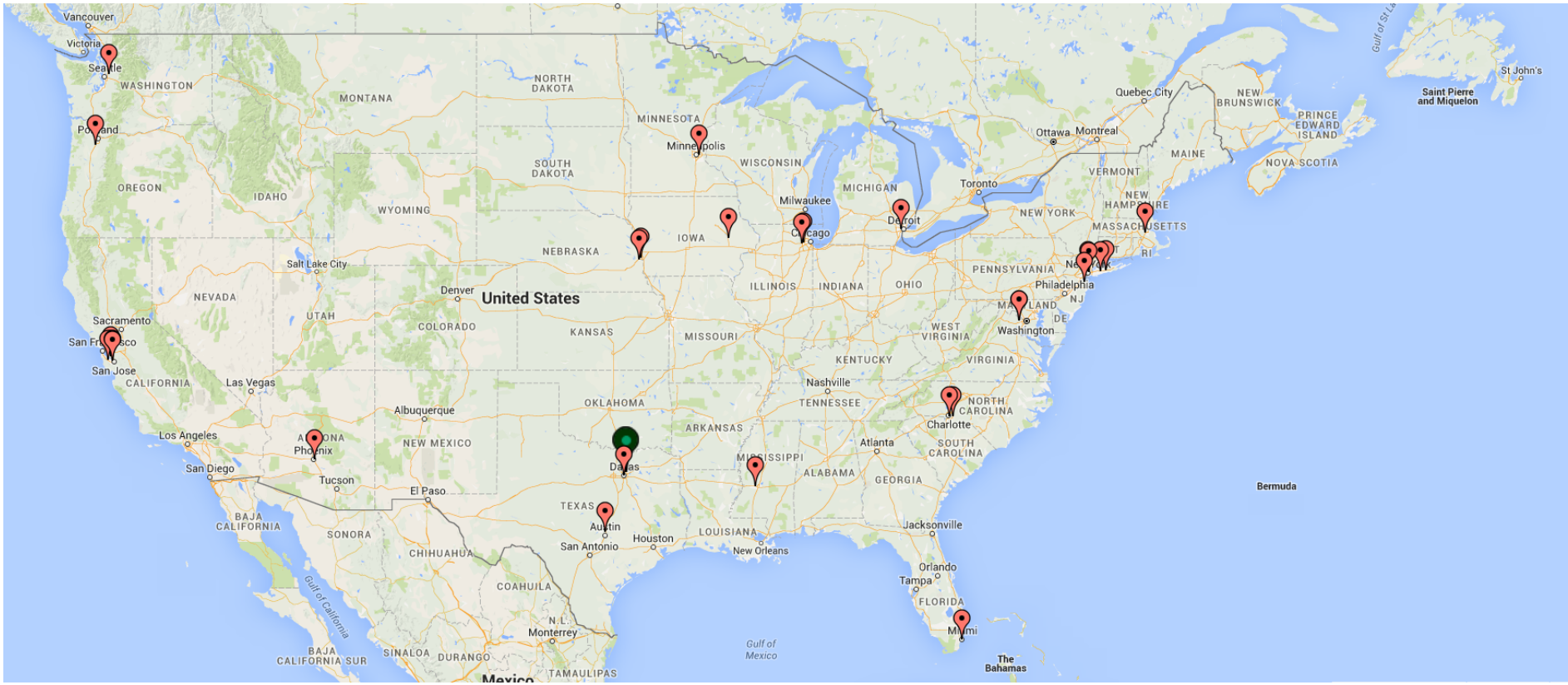
$\Rightarrow$ More complete network $\rightarrow$ can look beyond one node

⏩ fal2 ⏩ sub ⏩ alt ⏩ evpri

Test illustration

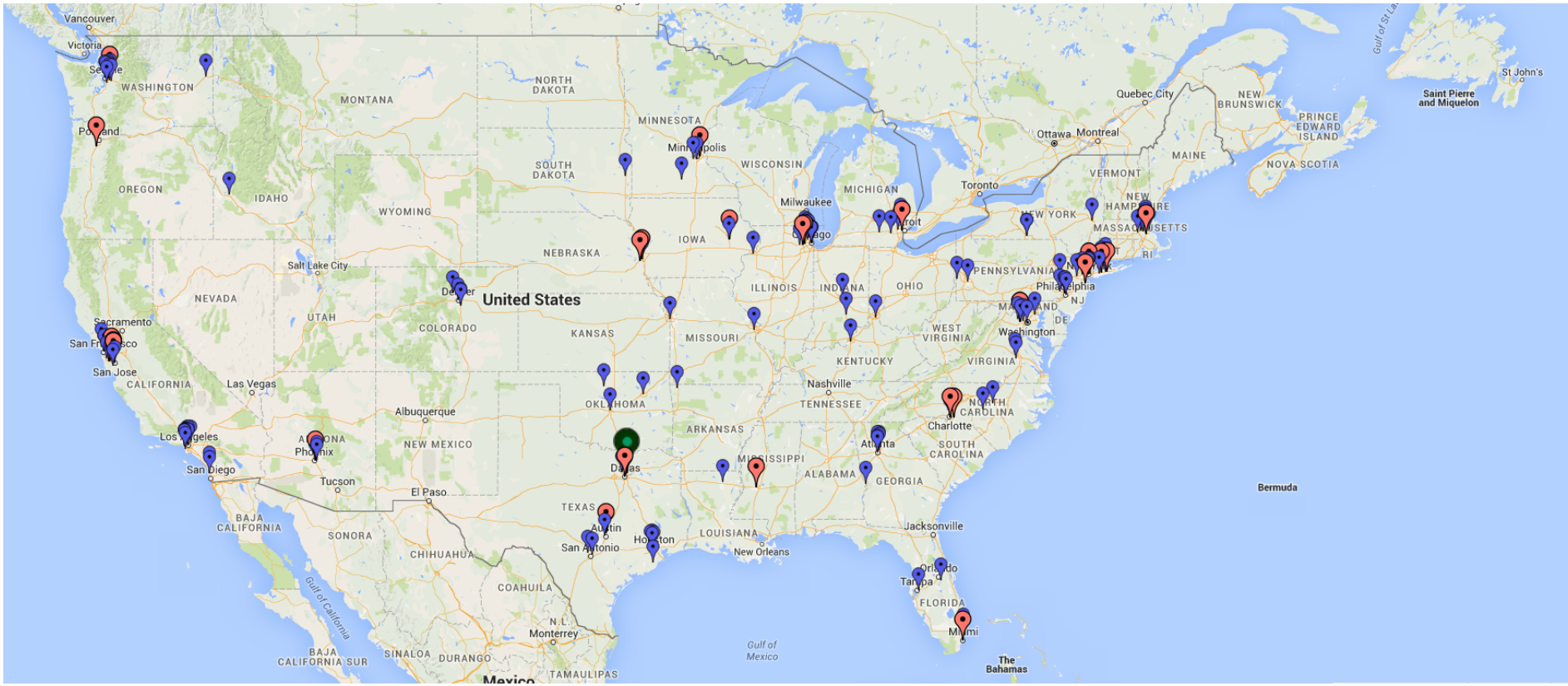
- Trace the shock origin
- Original impact: Assess shock impact on origin firms

Test illustration



- Map direct connections
- Direct spillover: Assess shock impact on first-tier connections

Test illustration



- Locate firms further connected to these customers
- Remote spillover: Assess shock impact on higher-tier connections

Empirical setup for tests on economic outcomes

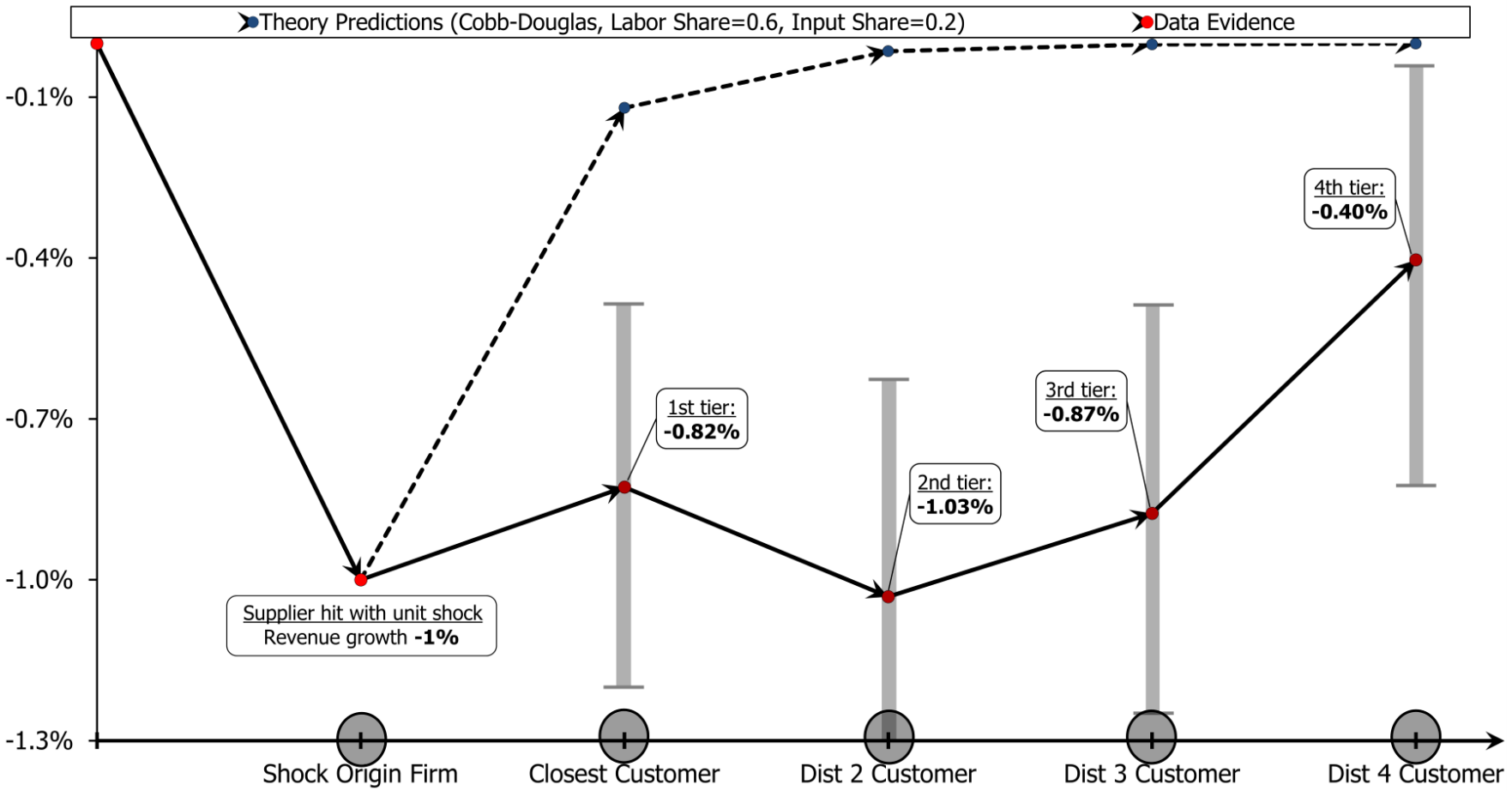
Avg diff btn rev growth rates of firms: 1) with distance-n shocks, & 2) w/o shocks

$$Y_{it,t+k} = a + \sum_{n=0}^{10} b_n \; D_{i,t}^{n} + cX_{i,t} + F_t + \epsilon_{i,t}$$

- $Y_{it,t+k}$: k-quarter growth rate in (1) revenue, (2) cash flow, (3) margins
- $D_{i,t}^{n} = 1$ if any distance-n supplier hit with a shock:
  - $\hat{b}_0$: Average shock impact on origin
  - $\hat{b}_1$: Spillover to closest connections
  - $\hat{b}_{2,3,4,\ldots}$: Spillover to remote connections
- $X_{i,t}$: vectors of controls
  - $Size$, BM, PE, ROA, leverage ratio, and inventory
- Fixed effects F_t: absorb variations across industry, time, location, report period
  - Fiscal quarter, industry×year, state/country
- Main tables: use $k = 4$ qtrs, multiple subsamples

Significant spillover of firm-specific shocks

Results in a Graph



Significant spillover of firm-specific shocks

Results in Tables

	Distance from Shock Origin (in # of Connections)				
	Origin	n=1	n=2	n=3	n=4
A: Revenue Growth					
Shock	-0.0258***	-0.0229**	-0.0377***	-0.0325***	-0.0125*
	(-3.32)	(-2.67)	(-4.22)	(-3.85)	(-2.18)
No. Obs			335337		
$Adj.R^2$			0.166		
B: Operating Income Growth					
Shock	-0.0543***	-0.0475**	-0.0598***	-0.0543***	-0.0219**
	(-3.46)	(-2.89)	(-3.65)	(-3.18)	(-2.37)
No. Obs			254322		
$Adj.R^2$			0.106		
C: Change in Gross Margin					
Shock	-0.0192*	-0.0154*	-0.0207**	-0.0261**	-0.0108*
	(-2.14)	(-2.05)	(-2.75)	(-2.94)	(-2.12)
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Why?

- Main economic channel: heterogeneous distribution of market power at different positions of the supply chain ⏩ Detailed economics
  - 2 sets of tests that link spillover magnitude $\rightarrow$ market power

List of robustness checks

1. Are my shocks well identified?
   - Prior growth trends ⏩ detail
   - Strategic reporting & reverse causality concerns ⏩ detail
   - Some shocks might have large, "systematic" impacts ⏩ detail
2. How good are the network data?
   - Are shocks correctly mapped to network? ⏩ detail
   - Would missing links significantly change the results? ⏩ detail
3. Is it okay to treat the network as exogenously given?
   - Firms endogenously select into network positions ⏩ detail
   - Would the network itself change after shocks? ⏩ detail
4. External validity
   - Only negative shocks? ⏩ detail
   - No private firms? ⏩ detail
   - What about customer $\rightarrow$ supplier shocks? ⏩ detail

⏩ skip all

Stock market responses to shock spillovers

Form three equally-weighted portfolios @ disclosure date t

1. Shock origin firms
2. Directly connected (tier-1) customers
3. Remote (tier-2) customers

Stock market responses to shock spillovers

Measurement

(1) Cumulative abnormal returns in $[t-10, t+40]$:

CRSP value-weighted index return

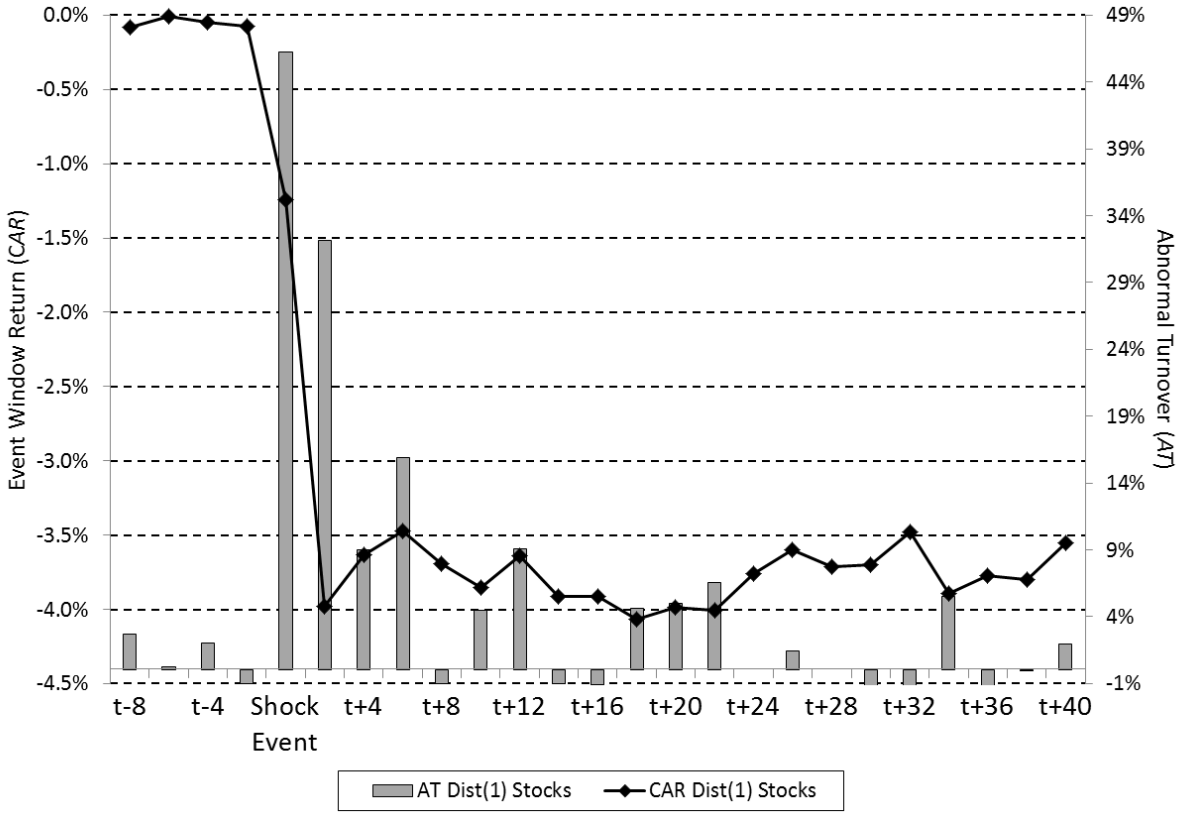
$$AR_{i,t+s} = \prod_{k=-10}^{s} Ret_{i,t+k} - \prod_{k=-10}^{s} Ret_{vw,t+k} \ ,$$

(2) Abnormal turnover in the same window:

$$AT_{i,t} = \frac{\text{Volume}_{i,t}}{\sum_{k=t-100}^{t-40} \text{Volume}_{i,k}/60} - 1, \ t \in [-10, 40]$$

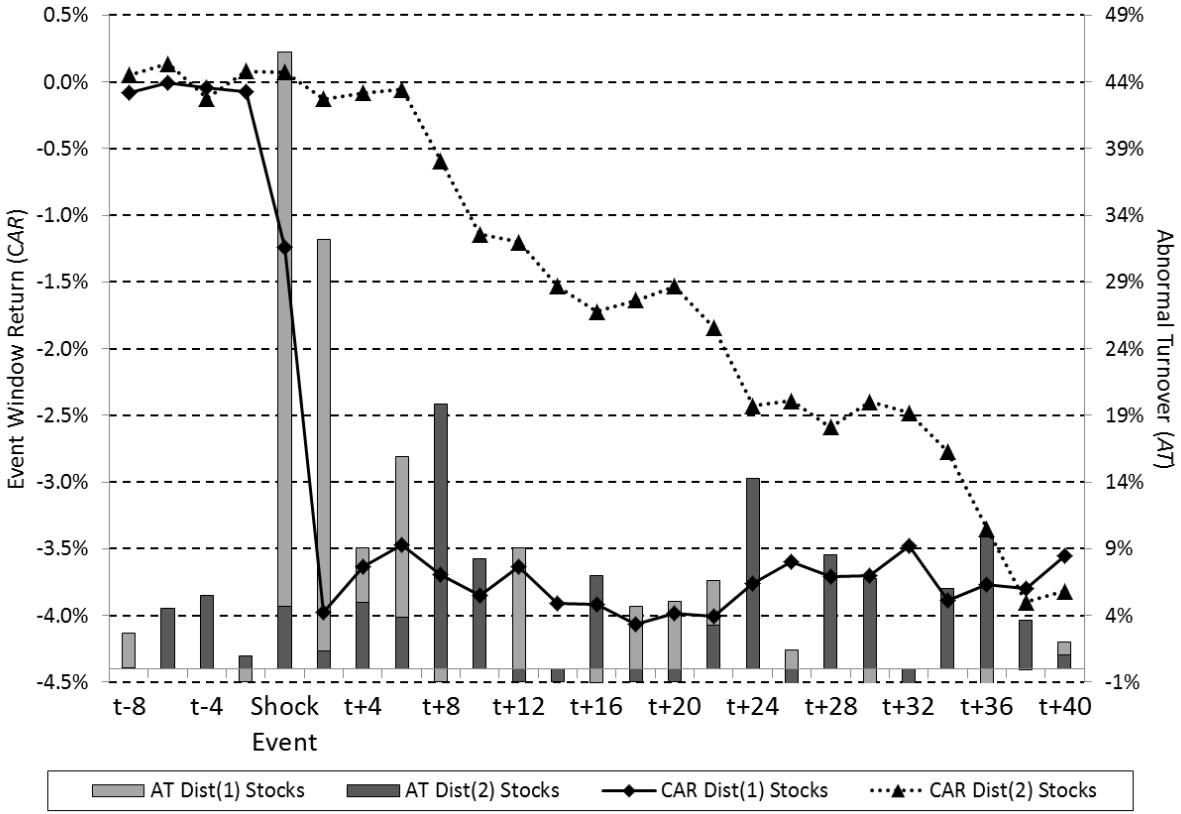
Average daily trading volume between t-100 and t-40

Immediate market reaction to direct shocks



- Solid line: CAR for origin and closest (first-tier) connections

Slower reaction to remote shocks



- Solid line: CAR for origin and closest (first-tier) connections
- Dotted line: CAR for remote (higher-tier) connections

Economic intuition behind slow reaction

Market inefficiency or risk propagation?

Hypothesis: Market inefficiencies related to information processing constraints:

- More remote part of the chains $\rightarrow$ more complex structure
- $\Rightarrow$ Less salient to investors
- For these remote parts, market takes longer to process:
  - Locations of links and nodes
  - Magnitude of impact
- "Complicated connections"; related to Cohen and Lou (2012)

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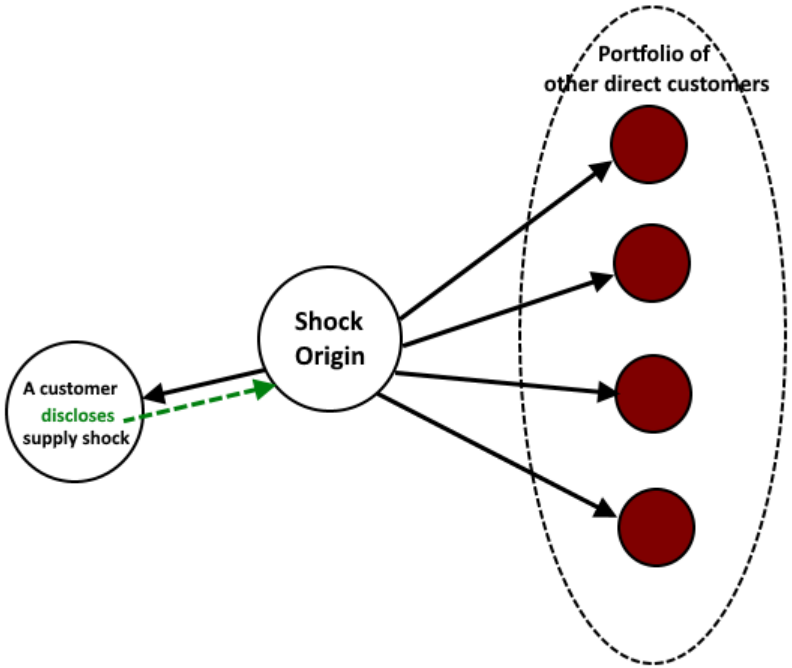
Experiment: Manipulate the difficulty in information processing and check reaction speed

Empirical evidence on the information processing channel

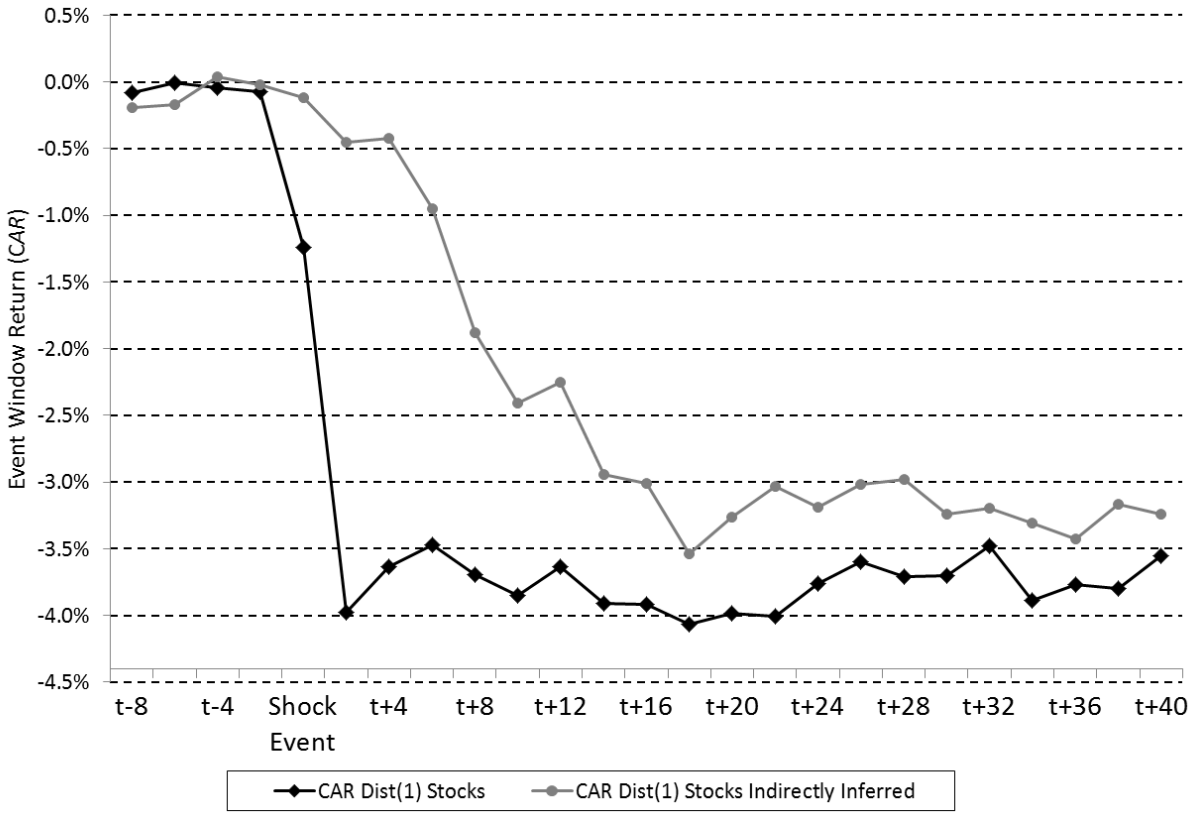
Perturbing the difficulty in information processing



Some shocks in my sample are disclosed by customers as supply shocks

- Trace the origin firms
- Identify origin's other direct customers
- Construct EW portfolio of these customers
- Compare reaction speed w/ directly disclosed shocks
  - Same distance: both are direct connections
  - Different information processing difficulty

Empirical evidence on the information processing channel



- Solid line: CAR for origin and closest (first-tier) connections
- Gray line: First-tier, **indirect** connections

Key takeaways so far

1. Infer the nature of firm-specific production shocks from disclosure texts
2. These shocks propagate to remote connections up to link 4
3. Slower market reaction to remotely-originated shocks

Corporate policy responses to shock spillovers

What firms say they would do

- Frequently appearing words in 10-K/Qs in quarters after shock:

- Changes in working capital?
- Investment in technologies to accommodate alt. suppliers?
- Concerned about financing?

Corporate policy responses to shock spillovers

What firms actually do in the data

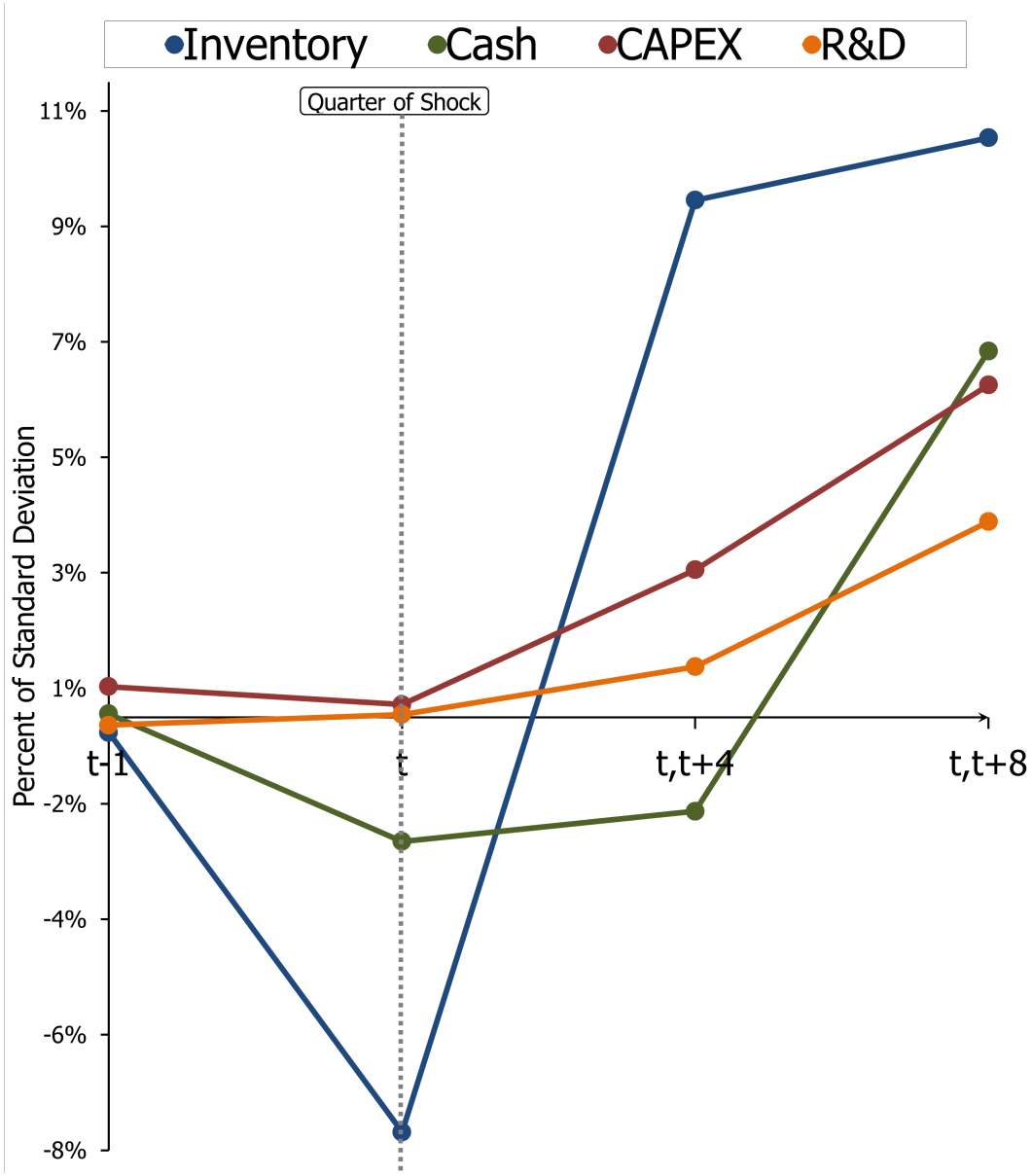
Avg difference between changes in corp policies of firms 1) w/ and 2) w/o shocks

$$CF_{it,t+k} = a + \sum_{n=0}^{2} b_n \cdot D_{i,t}^{\text{Dist(n)}} + cX_{i,t-1} + dF_{i,t} + \epsilon_{i,t}$$

Two tiers: immediate (n=1) and remote connections (n>1)

- Changes in working capital?
  - (1) Cash, (2) inventory
- Investment in technologies to accommodate alt. suppliers?
  - (3) CAPEX, (4) R&D
- How are they financed?
  - (5) Equity and debt issuance

Changes in working capital



Changes in working capital

Direct connections

- 1, 4, 8 qtrs after shock
- All depvar scaled by AT_{t-1} & standardized

	Working Capital		Investments	
	(1) Inventory	(2) Cash	(1) CAPEX	(2) R&D
t-1→t	-0.003	0.001	-0.005	-0.001
	(-1.09)	(1.24)	(-0.84)	(-0.56)
t→t+1	-0.072***	-0.022***	0.002	0.000
	(-5.31)	(-3.31)	(1.53)	(0.48)
t→t+4	0.090***	-0.016	0.026**	0.009
	(5.79)	(-1.00)	(2.90)	(1.04)
t→t+8	0.103**	0.063**	0.058**	0.034*
	(2.96)	(2.78)	(2.66)	(2.19)

Changes in capital structure

Direct connections

- 1, 4, 8 qtrs after shock

	Leverage	Financing			Payout
	(1) Long-Term	(2) Debt Issue	(3) Equity Issue	(4) Retained	(5) Dividend
t-1→t	-0.002	-0.002	-0.006	-0.013	0.004
	(-0.07)	(-0.29)	(-0.88)	(-1.23)	(0.91)
t→t+1	-0.019	0.004	0.006	-0.005*	-0.010*
	(-1.33)	(0.57)	(1.23)	(-1.85)	(-1.84)
t→t+4	0.079*	0.035**	-0.006	-0.018*	-0.012*
	(1.94)	(3.07)	(-1.47)	(-1.96)	(-2.29)
t→t+8	0.094***	0.043***	-0.003	-0.011	-0.010
	(3.36)	(3.83)	(-1.37)	(-1.52)	(-1.60)

Response to remote shocks

	WC				Investments			
	Inventory		Cash		CAPEX		RD	
	n=1	n>1	n=1	n>1	n=1	n>1	n=1	n>1
t-1→t	-0.003	-0.005	0.001	0.000	-0.005	-0.001	-0.001	0.003
	(-1.09)	(-0.82)	(1.24)	(0.25)	(-0.84)	(-0.10)	(-0.56)	(1.02)
t→t+1	-0.072***	-0.067***	-0.022***	-0.020*	0.002	0.009	0.000	-0.004
	(-5.31)	(-5.58)	(-3.31)	(-2.04)	(1.53)	(0.79)	(0.48)	(-0.63)
t→t+4	0.090***	0.003	-0.016	0.002	0.026**	-0.001	0.009	-0.001
	(5.79)	(1.12)	(-1.00)	(1.13)	(2.90)	(-0.44)	(1.04)	(-0.31)
t→t+8	0.103**	0.003	0.063**	0.001	0.058**	-0.005	0.034*	0.003
	(2.96)	(0.27)	(2.78)	(0.84)	(2.66)	(-0.72)	(2.19)	(1.10)

	Leverage		Financing					
	Long-Term		Debt Issue		Equity Issue		Retained Earnings	
	n=1	n>1	n=1	n>1	n=1	n>1	n=1	n>1
t-1→t	-0.002	0.006	-0.002	0.001	-0.006	0.011	-0.013	-0.015
	(-0.07)	(1.01)	(-0.29)	(0.24)	(-0.88)	(0.45)	(-1.23)	(-1.09)
t→t+1	-0.019	0.000	0.004	0.005	0.006	0.004	-0.005*	-0.010
	(-1.33)	(0.32)	(0.57)	(0.79)	(1.23)	(0.50)	(-1.85)	(-1.17)
t→t+4	0.079*	0.004	0.035**	-0.000	-0.006	0.001	-0.018*	-0.024*
	(1.94)	(0.67)	(3.07)	(-0.13)	(-1.47)	(0.38)	(-1.96)	(-2.22)
t→t+8	0.094***	0.003	0.043***	0.002	-0.003	-0.002	-0.011	-0.006
	(3.36)	(0.73)	(3.83)	(0.35)	(-1.37)	(-0.14)	(-1.52)	(-0.41)

Response to remote shocks

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	n=1	n>1	n=1	n>1	n=1	n>1	n=1	n>1
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	Inventory		Cash		CAPEX		RD	
	n=1	n>1	n=1	n>1	n=1	n>1	n=1	n>1
t-1→t	-0.003	-0.005	0.001	0.000	-0.005	-0.001	-0.001	0.003
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Recap of key takeaways

1. Infer the nature of firm-specific production shocks from disclosure texts
2. These shocks propagate to remote connections up to link 4
3. Slower market reaction to remotely-originated shocks
4. Some evidence of post-spillover changes in firm behavior

Appendix

Economic mechanism behind the results

- Hypothesized channel: market power

Economic mechanism behind the results

- Hypothesized channel: market power
- Real world example: (1)Nidec→(2)Seagate→(3)Dell→(4)Best Buy

Economic mechanism behind the results

- Hypothesized channel: market power
- Real world example: (1) Nidec → (2) Seagate → (3) Dell → (4) Best Buy

After firm-specific shocks to marginal costs:

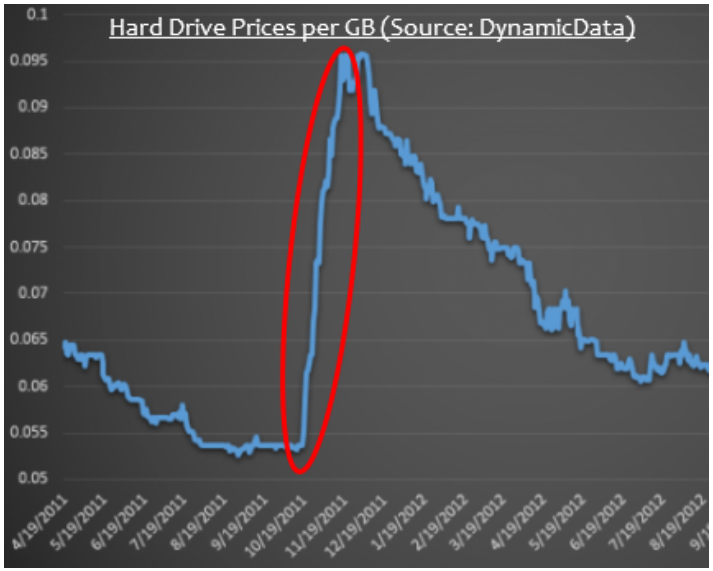
- **Example.** (Seagate): After supplier plant destroyed by flood, "significant increases in manufacturing and procurement costs" for hard drives

What if firms are not perfectly competitive?

Simple economic intuition when firms have market power

▸▸ Detailed economics 2

- (S) changes price in addition to quantity
  - **Example.** (Seagate): "Supply chain disruption from the flooding...**resulting in an increase in our average selling price**."



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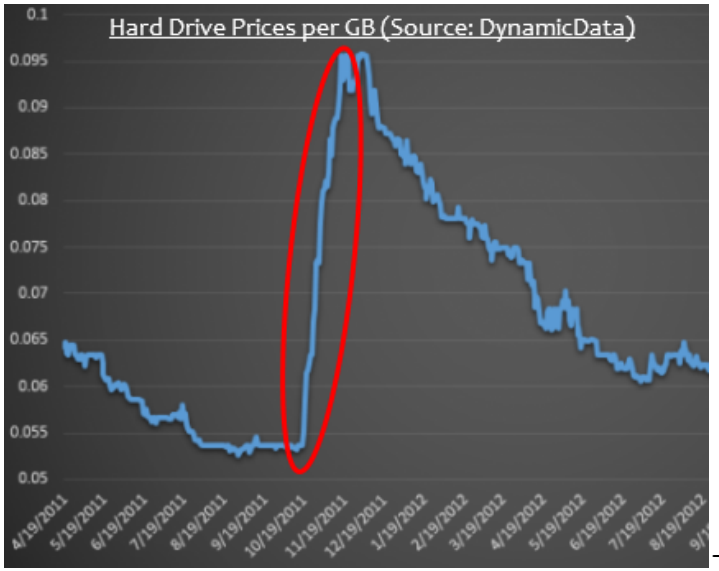
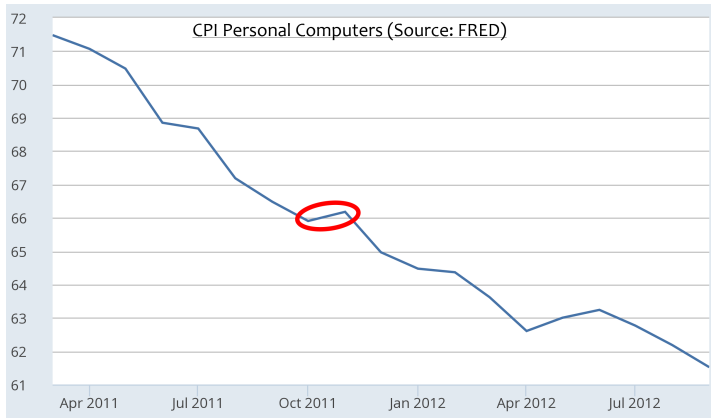




- If (C) has lower monopoly power than (S):
  - Less able to change prices to its customers
  - Faces higher-powered suppliers passing more impact
  - Dual price-quantity effect: larger percolation
  - **Example.** (HP & Dell): Disclosed to be in more competitive environment than their suppliers →less able to pass price increases to customers...→ further decline

How do we measure market power empirically?

Good measure: price mark-ups

How do we measure market power empirically?

Good measure: price mark-ups

Cruder measure: size share

- Intuition: Market power is affected by the availability of substitutes
  - # of firms producing this output matters
  - Concentration within this output segment matters
- $\Rightarrow$ Crude proxy using firm's market share within its 4-digit SIC segment: $MP_i = \frac{\text{size}_i}{\sum_{\text{j in i's SIC}} \text{size}_j}$

Empirical evidence for the market power channel

Test specification: Interaction variables

Incremental effect of market power on shock impact from distance-n supplier

$$Y_{it,t+s} = a + \sum_{n=0}^{4} b_n \; D_{i,t}^{\text{Dist(n)}} \cdot MP_{i,t}$$

$$+ \sum_{n=0}^{4} c_n D_{i,t}^{\text{Dist(n)}} + dMP_{i,t} + \tau X_{i,t-1} + F_t + \epsilon_{i,t}$$

Evidence 1: Lower own $MP \rightarrow$ more spillover impact

	Distance from Shock Origin			
	n=1	n=2	n=3	n=4
D	-0.025**	-0.041**	-0.037*	-0.014
	(-2.77)	(-3.03)	(-2.26)	(-0.85)
$D \times MP$	0.018***	0.021***	0.021***	0.005**
	(3.56)	(4.13)	(4.02)	(2.80)

◂ Go back to main results

Empirical evidence for the market power channel

Test specification: Interaction variables

Incremental effect of market power on shock impact from distance-n supplier

$$Y_{it,t+s} = a + \sum_{n=0}^{4} b_n \; D_{i,t}^{\text{Dist(n)}} \cdot MP_{i,t}$$
$$+ \sum_{n=0}^{4} c_n D_{i,t}^{\text{Dist(n)}} + dMP_{i,t} + \tau X_{i,t-1} + F_t + \epsilon_{i,t}$$

Evidence 2: Lower relative $MP \rightarrow$ more spillover impact

	Distance from Shock Origin			
	n=1	n=2	n=3	n=4
D	-0.020**	-0.029**	-0.027**	-0.008*
	(-2.49)	(-2.84)	(-2.75)	(-2.09)
$D \times MPR$	0.026***	0.037***	0.029**	0.011**
	(3.20)	(3.47)	(2.98)	(2.66)

◂ Go back to main results

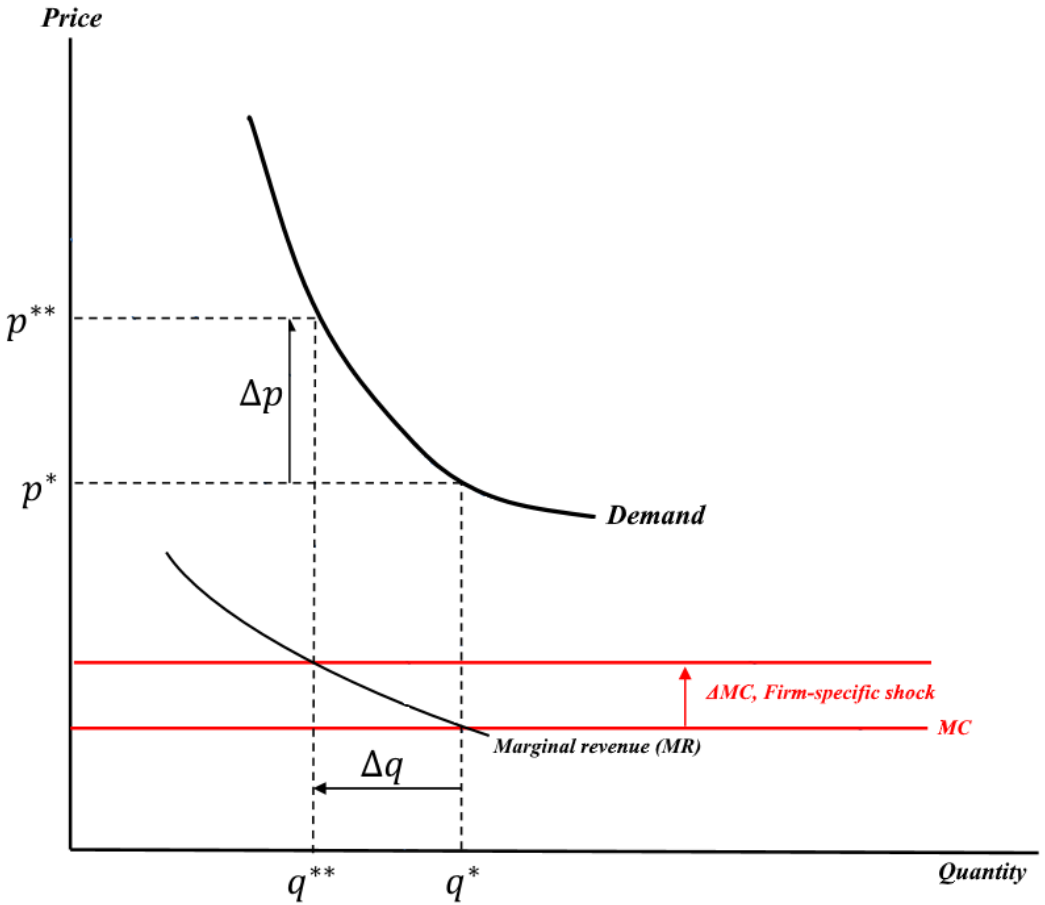
Treated vs. Untreated Firms

Observables

	Distance from Shock					
	0 (Origin)	1	2	3	4	>4 or Never
Size	2.201	2.218	1.954	1.819	1.911	2.073
BM	0.687	0.682	0.802	0.779	0.570	0.703
PE	13.902	12.871	14.043	13.198	12.984	12.981
ROA	0.087	0.108	0.130	0.105	0.109	0.112
Leverage	0.411	0.371	0.394	0.335	0.404	0.368
Inventory	0.148	0.139	0.101	0.082	0.148	0.153

◂ shocks summary

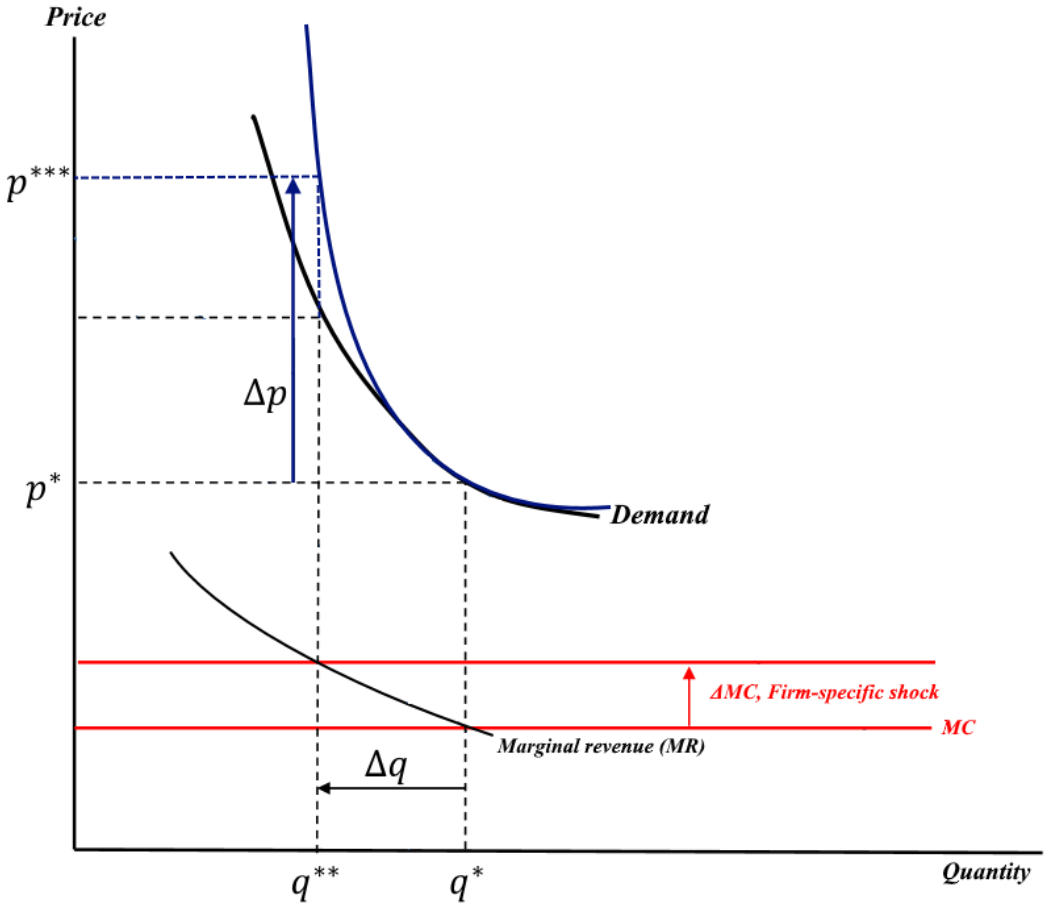
Simple economic intuition when firms are monopolies



After firm-specific supply shock:

- MC shifts up
- Adjust quantity ΔQ according to MR elasticity
- Adjust price ΔP according to demand elasticity
- Pass shock to customers via markups
  - Example. Seagate, Inc. following supply shock: "pass through (shock's) impact to customers via price changes"

Simple economic intuition when firms are monopolies



After firm-specific supply shock:

- ΔP crucially depend demand elasticity (DE)
- If demand is sufficiently inelastic $\Rightarrow \Delta P >> \Delta MC$!
  - Seagate: Scarcity of hard drives as a crucial component could lead to large cost increases for computer makers
- ΔP translates to ΔMC shock for the downstream customer $\rightarrow$ impact could be higher
  - Dell and HP: 50% of revenue decline attributable to large hard drive price increases
- Weyl & Fabringer (2013)

A deeper model with vertically connected monopoly firms:

- e.g. Supplier $\rightarrow$ Customer $\rightarrow$ Final consumer

1. Supplier ΔP higher if its DE is lower
2. In addition, if $DE^{customer} > DE^{supplier}$:
   - Supplier passes the shock to the customer
   - Customer cannot pass the shock to the final customer
   - Dual price-quantity effect: larger percolation
     - HP & Dell: Disclosed to be in more competitive environment than their suppliers $\rightarrow$ inability to pass on shocks
3. DE can be crudely proxied using market power

Are my shocks well-identified?

Prior trends in revenue growth

Outcomes in quarters prior to the shock should not be significantly different

$$Y_{it-k,t} = a + \sum_{n=0}^{4} b_n D_{i,t}^{n} + cX_{i,t-1} + F_t + \epsilon_{i,t}, \ (k = 1, 2, 4, 8)$$

Revenue growth	Distance from Shock Origin				
	Origin(0)	(1)	(2)	(3)	(4)
t-1→t	0.0012	-0.0004	-0.0004	-0.0013	0.0003
	(0.72)	(-0.54)	(-0.83)	(-0.61)	(0.49)
t-2→t	-0.0030	-0.0033	0.0009	-0.0016	-0.0019
	(-1.25)	(-0.89)	(1.43)	(-1.31)	(-0.62)
t-4→t	-0.0036*	0.0076	0.0039	0.0008	-0.0026
	(-1.67)	(1.53)	(1.22)	(0.69)	(-1.08)
t-8→t	0.0106	-0.0056	0.0097	0.0103	-0.0034
	(0.75)	(-0.71)	(1.19)	(0.58)	(-0.87)

◂ sb ◂ se ◂ sp ▸▸ next ▸▸ skip all ◂ return

Check for random shocks with systematic effects

Some shocks might have random causes but systematic effects

- E.g. Large earthquakes that devastate entire supply chains
- Subsample analysis 1: Check each type's impact on unconnected customers in the same industry
  - For the natural disaster group, further check by each shock keyword
  - Remove from sample if significant relations found
  - "Earthquakes" eliminated
- Subsample analysis 2: Compare overall results w/ subsample of shocks that are definitively localized
  - Factory fires
  - Results very similar

Removing individual shock types

Check for for abnormally large effects in each individual category:

- Replicate spillover regressions, removing one type at a time

	Category Removed					
	(0) None	(1) Disaster	(2) Manmade	(3) Disruption	(4) IT	(5) Upgrade
D^0	-0.0261***	-0.0253***	-0.0237***	-0.0222***	-0.0280***	-0.0288***
	(-3.33)	(-3.18)	(-3.80)	(-3.19)	(-3.94)	(-3.90)
D^1	-0.0225**	-0.0241**	-0.0210**	-0.0204**	-0.0251**	-0.0224**
	(-2.68)	(-2.96)	(-2.60)	(-2.62)	(-3.03)	(-2.71)
Control	✓	✓	✓	✓	✓	✓
FX	✓	✓	✓	✓	✓	✓

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Are my shocks well-identified?

Overstatement of effects through selective reporting

Data might over-capture impactful shocks

- Firm might disclose shocks only if they impact revenue very significantly

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Reporting standards exogenously changed on August 29, 2004

- SEC began enforcing Section 209 of the SOX Act
- Requires firms to disclose all operations-related issues
- If they previously only disclose very big shocks, after the enforcement date, they should disclose both big and smaller shocks
- $\Rightarrow$ Are shock effects weaker after the enforcement date?

Are my shocks well-identified?

Overstatement of effects through selective reporting

$$Y_{it,t+k} = b_0 + \sum_{n=0}^{4} b_n D_{i,t}^{n} + cX_{i,t-1} + F_t + \epsilon_{i,t}$$

- Cut sample in two, before and after August 29, 2004

Sample	Distance from Shock Origin				
	Origin(0)	(1)	(2)	(3)	(4)
Full	-0.0261***	-0.0225**	-0.0386***	-0.0334***	-0.0128**
	(-3.33)	(-2.68)	(-4.19)	(-3.90)	(-2.45)
Pre-Enforcement	-0.0204***	-0.0248**	-0.0352***	-0.0337***	-0.0120**
	(-3.27)	(-2.50)	(-4.24)	(-3.52)	(-2.41)
Post-Enforcement	-0.0270***	-0.0216**	-0.0393***	-0.0322***	-0.0129**
	(-3.33)	(-2.79)	(-4.15)	(-3.90)	(-2.69)

◂ sb ◂ se ◂ sp ▸▸ next ▸▸ skip all ◂ return

Are my shocks well-identified?

Reverse causality

Firms facing bad outcomes might blame them on suppliers

Are my shocks well-identified?

Reverse causality

Firms facing bad outcomes might blame them on suppliers

Separate shock sample into own shocks vs. supplier shocks

- Replicate analysis on shocks disclosed by suppliers only

Coefficient for shock dummy using different subsamples

	Distance from Shock Origin (in # of Connections)				
	Origin	n=1	n=2	n=3	n=4
Full Sample	-0.0258***	-0.0229**	-0.0377***	-0.0325***	-0.0125**
	(-3.32)	(-2.67)	(-4.22)	(-3.86)	(-2.44)
Supplier disclosure only	-0.0279***	-0.0268**	-0.0372***	-0.0339***	-0.0117**
	(-3.44)	(-2.95)	(-4.07)	(-3.91)	(-2.36)

- Similar results!

◂ sb ◂ se ◂ sp ▸▸ next ▸▸ skip all ◂ return

Are shocks correctly mapped to the network?

1. Some captured small shocks might be direct aftermath of big shocks
2. Network data might contain measurement errors and false values

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2. Network data might contain measurement errors and false values

Exact date of shock known $\Rightarrow$ can perform falsification test

1. $\forall$ shock date, randomly assign fake shocks to firms
   - Replicate spillover analysis on fake origins
2. $\forall$ shocked firm, randomly assign fake links to firms
   - Replicate spillover analysis on fake followers

◂ sb ◂ se ◂ n ◂ sp

Are shocks correctly mapped to the network?

Fake difference in revenue growth

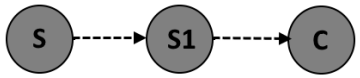
$$Y_{it,t+4} = b_0 + \sum_{n=0}^{4} b_n \; FAKED_{i,t}^{n} + cX_{i,t-1} + F_{i,t} + \epsilon_{i,t}$$

		Distance from Shock Origin				
		Origin(0)	(1)	(2)	(3)	(4)
Y	Real D	-0.0261***	-0.0225**	-0.0386***	-0.0334***	-0.0128**
		(-3.33)	(-2.68)	(-4.19)	(-3.90)	(-2.45)
	Fake D	0.0057	0.0102	0.0024	-0.0058	0.0035
		(1.02)	(0.79)	(1.23)	(-0.55)	(0.64)

◂ sb ◂ se ◂ n ◂ sp ▸▸ next ▸▸ skip all ◂ return

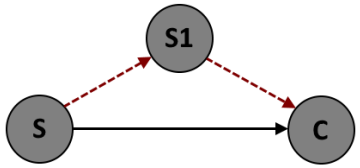
Think about missing links

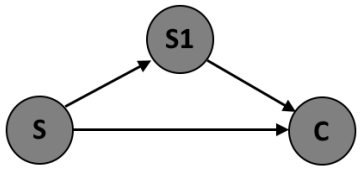
Case 1. Some links missing on the path of shock

- 

- $\Rightarrow$ Percolation effect understated

Case 2. Some links missing off the path of shock

- 

- Effect might be overstated if S1 has very high market power
- Take subsample where the S1$\rightarrow$C link is known: 

- No significant difference in results

◂ sb ◂ se ◂ n ◂ sp ▸▸ next ▸▸ skip all ◂ return

Endogenous formation of network links

Possibility 1. Network is already ex-ante optimal

- Best available mitigation achieved
- Observed effect is the smallest possible

Possibility 2. Network is not ex-ante optimal

- Problem if bad firms choose to link with bad firms
  1. Check effects with natural disaster-only shocks
  2. See if reported shocks spike during bad economic times

	Category Used					
	(1) Fire Only	(2) Disaster	(3) Manmade	(4) Breakdown	(5) IT	(6) Adjustment
Origin Firms	-0.0174**	-0.0247***	-0.0275**	-0.0288***	-0.0191*	-0.0199**
	(-2.87)	(-3.66)	(-2.73)	(-3.96)	(-2.03)	(-2.84)
Firm Controls	✓	✓	✓	✓	✓	✓
Fixed Effects	✓	✓	✓	✓	✓	✓
No. Obs	335337	335337	335337	335337	335337	335337
AR2	0.109	0.134	0.138	0.145	0.120	0.117

◂ sb

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Do shocks change the network structure?

Do shocks lead to changes in linkages?

- Probably takes a long time
- Average link persistence in sample = 6 years
- Increase in CAPEX takes place in 2-year horizon

Do shocks change market power?

- If so, power reduced for hit firm & increased for competitors
- $\Rightarrow$ ability to pass shocks mitigated
- Also unlikely to happen unless shock is severe
- Regress ex-post market power on shocks

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External validity

1. Most shocks are negative

Do positive shocks also spill over significantly to remote connections?

- Firms do not usually disclose positive news as "shocks"
  - Some discussions in 10-K/Qs
  - Hard to pin down exact timing
  - Planned work: use competitor's bad shocks
- Chu et al. (2015): Evidence of innovation spillover from large customers to immediate suppliers
  - No evidence on supplier→customer links and remote spillovers
- New plant-level data from Census allows for estimation of granular productivity innovations
  - Needs some structure

◂ id1 ◂ id2 ◂ id3 ◂ n ◂ sp ▸▸ next ▸▸ skip all ◂ return

External validity

2. No private firms

Is the lack of private firms a significant concern?

1. Network data valid w/o private firms?
2. Omitting private firms introduces biases?

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Solutions:

1. BEA "replication" exercise
   - Aggregate Vs from my network data at the BEA-defined sectoral level
   - Construct similar "input-output" tables
   - Resulting "aggregated sectoral" network similar to BEA in both links and weights

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1. BEA "replication" exercise
   - Aggregate Vs from my network data at the BEA-defined sectoral level
   - Construct similar "input-output" tables
   - Resulting "aggregated sectoral" network similar to BEA in both links and weights
2. Private firms introduce attenuating bias in spillover estimates
   - All shocks originated from public firms
   - Missing private firms in network serve as alternative suppliers to sample firms
   - $\Rightarrow$ Overall effect mitigated

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External validity

Other directions of spillover e.g. customers → suppliers

Can shocks also travel upstream?

- Probably. Customer's production shocks transmit upstream as lowered demand
- Harder to isolate using LDA

Can shocks spillover horizonally?

- Probably. Supplier's bad shock is its competitor's good shock
- However: Can also propagate from supplier A→customer→supplier B
- Analysis more nuanced

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