Firms, Failures, and Fluctuations

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Preliminary: Handle with care!

Firm-to-Firm Linkages and Production Networks

- Modern economies organized as complex production networks between firms
  - Expenditure on intermediate goods & services in the U.S. ≈ 1 GDP.

(1) High levels of persistence in firm-to-firm relationships:

- Chile: median firm retains 41% and 46% of its domestic suppliers and customers between two average years (Huneeus, 2018)
- U.S.: 70% of link destructions due to one party's exit (Taschereau-Dumouchel, 2018)

(2) Firm-to-firm linkages can result in cascading failures:

- bankruptcies due to spillovers over credit linkages (Jacobson and Von Schedvin, 2015)
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Firm-to-Firm Linkages and Production Networks

- Existence of firm-specific relationships indicates:
  (a) relationship-specific surplus
  (b) non-competitive division of surplus and existence of non-trivial markups

- Both features are absent from most models in the literature, which are typically better approximations for industry-level linkages
  - competitive
  - monopolistically competitive + CES (constant markups)

- Important to model explicitly and understand these features for two reasons:
  (1) how shocks change relationship-specific surpluses and markups endogenously
  (2) propagation of shocks, not just through competitive prices but also failures

What We Do

- A firm-level model of production networks
  - firm-specific relationships
  - market power and endogenous markups
  - endogenous bankruptcies

- Cascading failures are an important channel for the propagation and amplification of shocks.

- Today:
  - existence and uniqueness results
  - comparative statics
  - macroeconomic implications

Related Literature

- Production networks:
  - Long and Plosser (1983); Horvath (1998, 2000); Carvalho (2010); Acemoglu et al. (2012, 2017); Atalay (2017); Baqaee (2018), and many more...
- Endogenous production networks:
  - Carvalho and Voigtländer (2014); Oberfield (2018); Acemoglu and Azar (2018)
- Misallocation and markups:
  - Jones (2013), Bigio and La'O (2018), Baqaee and Farhi (2019), Liu (2018)
- Models of firm-level interactions
  - Taschereau-Dumouchel (2018); Tintelnot et al. (2018); Kikkawaa et al. (2018)

Roadmap

1. Model
2. Solution concept
3. Existence and uniqueness
4. Comparative statics
5. Macroeconomic implications
   - industry-level aggregation
   - aggregate comparative statics

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Model

- An economy with $n+1$ industries.
  - industries $\{1, \ldots, n\}$ produce intermediate goods
  - industry 0 produces the final good.

- Each industry consists of two types of firms:
  - competitive fringe producing a generic variant of the good
  - collection of firms producing customized variants

- A unit mass of households
  - log utilities over the final good
  - one unit of labor supplied inelastically

Timing

- $t = 0$:
  - customized firms decide whether to operate their technologies by paying a fixed cost.
- $t = 1$:
  - active firms enter into pairwise contracts that determine price
  - commitments to deliver as many units as demanded by their customers
- $t = 2$:
  - production and consumption take place.

Generic Producers

- A competitive fringe of firms i°
- constant returns to scale technology:

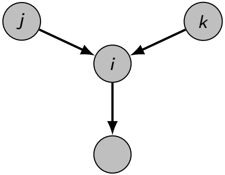
$$y_i^\circ = F_i(\ell_i^\circ, B_{i1} q_{i1}^\circ, \ldots, B_{in} q_{in}^\circ),$$

  - ℓ_i°: labor input
  - q_{ij}°: quantity of generic variants used as inputs
  - B_{ij}: productivity shock

- All inputs are gross complements (elasticity of substitution ≤ 1).

Customized Producers

- a (finite or infinite) collection of firms
- customized variants can only be used by specific firms as intermediate inputs
- formalized as an exogenous network **G**



Assumption

The firm-level production network **G** satisfies the following:

(i) each firm in **G** has at most one customer;

(ii) each firm in **G** has at most one customized supplier in any given industry;

Customized Producers

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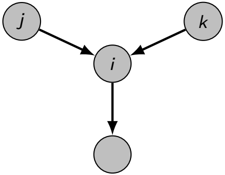

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Customized Producers: Technology

- Same production function as the generics.
- Can always use generic variants as inputs

$$y_i = F_i\left(\ell_i, \{A_{ij}x_{ij} + B_{ij}x_{ij}^{\circ}\}_{(j,i)\in\mathbf{G}}, \{B_{ij}x_{ij}^{\circ}\}_{(j,i)\notin\mathbf{G}}\right).$$

Assumption

Customized variants result in higher productivities:

$$A_{ij} \geq B_{ij}$$

- **For today:** Leontief production tehcnologies:

$$y_i = \min\left\{l_i, \{A_{ij}x_{ij} + B_{ij}x_{ij}^{\circ}\}_{(j,i)\in\mathbf{G}^*}, \{B_{ij}x_{ij}^{\circ}\}_{(j,i)\notin\mathbf{G}^*}\right\}.$$

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Customized Producers: Fixed Operational Costs

- Operating active technology requires a fixed cost z_i in the units of labor at $t = 0$
- cost is sunk by the contracting stage at $t = 1$

- Induces an endogenous subnetwork of active firms

$$\mathbf{G}^* \subseteq \mathbf{G}$$

Consumption Good Sector

- Firms transforming various inputs into industrial aggregates:

$$x_{0i} = F_{0i}\left((x_{0i} + x_{0i}^{\circ})_{(i,0)\in \mathbf{G}} \right),$$

- Outputs then aggregated to a single consumption good:

$$y_0 = F_0(x_{01}, \ldots, x_{0n})$$

- Different from customized producers:
  - no productivity difference between generic and customized inputs
  - no entry costs
  - no market power

Contracts and Terms of Trade

- Active firms can enter into pairwise contracts at $t = 1$
- Contract between $(j, i) \in \mathbf{G}^*$ specifies a price p_{ij}
- A commitment by the supplier to deliver as many units as demanded by the customer at fixed price p_{ij}.

Contracts and Terms of Trade

- Generic producers:
  - price at marginal cost irrespective of customers' identity: $p_i^\circ = c_i^\circ$

- Customized producers:
  - Rubinstein bargaining with random offers over infinitely many subperiods.
  - supplier and customer make offers with probabilities δ_{ij} and $1 - \delta_{ij}$.
  - if rejected, proceed to the next subperiod.
  - both parties discount time at rate $\eta \uparrow 1$.
  - if no agreement, the two parties cannot trade at $t = 2$.

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Contracts and Terms of Trade

- The bargaining powers δ_{ij} will determine equilibrium markups, markups' response to shocks, and shocks' pass-through.

- The customer has access to the outside option of using the generic variant:

$$p_{ij} \leq p_{ij}^{\circ} \frac{A_{ij}}{B_{ij}}$$

- Both parties have the outside option of walking away:
  - they reach an agreement in equilibrium only if there are positive gains from trade
  - imposes endogenous restrictions on p_{ij} as a function of other prices in the economy

Summary

- $t = 0$:
  - the network of potential relationships $\mathbf{G}$ is realized
  - customized producers decide to operate their technologies by paying a fixed cost
  - network of active firms: $\mathbf{G}^* \subseteq \mathbf{G}$

- $t = 1$:
  - firms enter into pairwise fixed-price contracts
  - commitments to deliver as many units as demanded by their customers

$$\boldsymbol{p} = (p_{ij})_{(j,i)\in\mathbf{G}^*}$$
$$\boldsymbol{p}^\circ = (p_1^\circ, \ldots, p_n^\circ, w)$$

- $t = 2$:
  - all firms make input and output decisions
  - households make consumption decisions

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Solution Concept: Production Equilibrium ($t = 2$)

Definition

Take the prices and the network $\mathbf{G}^*$ as given. In a production equilibrium,

(i) firms minimize costs while meeting their output obligations to their customers;

(ii) the representative household maximizes her utility;

(iii) all markets clear.

Solution Concept: Pricing Equilibrium ($t = 1$)

Definition

For given $\mathbf{G}^*$, a pricing equilibrium is collection of prices $(\boldsymbol{p}, \boldsymbol{p}^\circ)$ and quantities

(i) the quantities in any ensuing subgame correspond to a production equilibrium;

(ii) no generic producer i° can earn higher profits by offering a different price;

(iii) there is no $(j, i) \in \mathbf{G}^*$ such that one party can earn higher profits by

- renegotiating with an existing partner
- negotiating with a new partner
- terminating an already existing agreement

Solution Concept: Full Equilibrium ($t = 0$)

Definition

A full equilibrium is network $\mathbf{G}^*$ and collections of prices & quantities such that

(i) the quantities form production equilibria in the subgames at $t = 2$;

(ii) the prices correspond to a pricing equilibrium in the subgames at $t = 1$;

(iii) no customized firm has an incentive to change its decision to operate at $t = 0$:

$$\pi_i(\mathbf{G}^*) - z_i w \geq 0 \qquad \forall i \in \mathbf{G}^*$$
$$\pi_i(\mathbf{G}^* \cup \{i\}) - z_i w < 0 \qquad \forall i \notin \mathbf{G}^*.$$

- Endogenizes the production network $\mathbf{G}^* \subseteq \mathbf{G}$
- Firms account for how their decision shapes the outcomes of the various pairwise bargaining processes, input and output prices, quantities, and household wealth.

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Production Equilibrium ($t = 2$)

Theorem

For any $(\mathbf{G}^*, \boldsymbol{p}, \boldsymbol{p}^\circ)$, a production equilibrium exists and is unique.

Pricing Equilibrium ($t = 1$)

Theorem

For any feasible network of active firms $\mathbf{G}^*$,

(a) *a pricing equilibrium* $(\boldsymbol{p}, \boldsymbol{p}^\circ)$ *always exists and is unique;*

(b) *all pairs of firms* $(j, i) \in \mathbf{G}^*$ *reach an agreement;*

(c) *vector of generic prices* $\boldsymbol{p}^\circ = (p_1^\circ, \ldots, p_n^\circ, w)$ *is the solution to system of equations:*

$$p_i^\circ = c_i(w, p_1^\circ / B_{i1}, \ldots, p_n^\circ / B_{in});$$

(d) *vector of customized prices* $\boldsymbol{p} = (p_{ij})_{(j,i)\in\mathbf{G}^*}$ *is solution to the system of equations*

$$p_{ij} = \min\left\{\widehat{p}_{ij}, p_j^\circ A_{ij} / B_{ij}\right\},$$

where $\widehat{p}_{ij}$ *is the unique solution to the equation*

$$f_{ij}(\widehat{p}_{ij}) = \delta_{ij}\pi_i \frac{\partial \pi_j}{\partial p_{ij}} + (1 - \delta_{ij})\pi_j \frac{\partial \pi_i}{\partial p_{ij}} = 0.$$

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Endogenizing Production Networks: Full Equilibrium ($t = 0$)

Theorem

Suppose all production functions are Leontief. Then,

(a) *a full equilibrium exists;*

(b) *set of full equilibria has a greatest element with respect to the set inclusion order;*

(c) *aggregate output in the greatest equilibrium is higher than all other equilibria.*

- All failures in the greatest full equilibrium are "fundamental"
- Strategic complementarities only in PE but not in GE:
  - operation of a firm that makes negative net profits may reduce the profits of others.
  - cannot use lattice theoretic results like Tarski's or Milgrom and Roberts (1994).
  - monotonicity for the set of firms that make positive profits

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Exogenous Production Networks: Bargaining Power

Theorem

An increase in a supplier's bargaining power vis-à-vis the customer

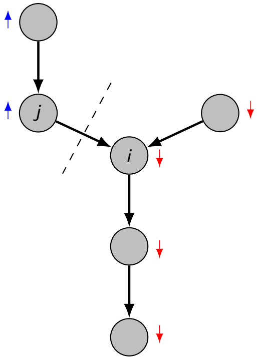
(a) *increases all upstream* ***markups*** *and decreases downstream and horizontal* ***markups****;*

(b) *increases all upstream* ***profits*** *and decreases downstream and horizontal* ***profits****;*

(c) *increases all upstream and downstream* ***prices*** *and decreases all horizontal* ***prices****.*

Exogenous Production Networks: Bargaining Power

- Changes in markups and profits in response to increase in δ_{ij}:



Exogenous Production Networks: Production Network

Theorem

Let $\underline{\mathbf{G}}^* \subseteq \bar{\mathbf{G}}^*$ denote two feasible production networks. Then, for all $i \in \underline{\mathbf{G}}^*$,

(a)

$$\mu_i(\underline{\mathbf{G}}^*) \leq \mu_i(\bar{\mathbf{G}}^*);$$

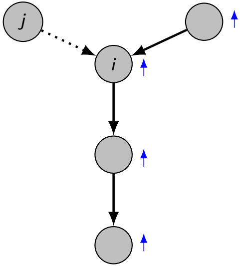
(b) *if* $\int_{\{j \in \bar{\mathbf{G}}^* \setminus \underline{\mathbf{G}}^*\}} (\pi_j(\bar{\mathbf{G}}^*) - wz_j)dj \geq 0$, *then,*

$$\pi_i(\underline{\mathbf{G}}^*) < \pi_i(\bar{\mathbf{G}}^*)$$

- Growing the set of active firms increases **profits** and **markups** of already active firms.

Exogenous Production Networks: Production Network

- Expanding the set of active firms is isomorphic to increasing the bargaining power of the already active firms.



- Strategic complementarities only in PE but not in GE:
  - holding aggregate demand constant, expanding the set of active firms increases profits (PE)
  - but operation of a firm that makes negative net profits may reduce aggregate demand (GE).

Exogenous Production Networks: Productivity Shocks

Theorem

For any $(j, i) \in \mathbf{G}^*$, an increase in productivity A_{ij}

(a) *increases all **markups** in the economy;*

(b) *increases the **profits** of all firms that are downstream and horizontal to j;*

(c) *increases the **price** of firms that are upstream and horizontal to j and decreases the **price** of downstream firms.*

Comparative Statics: Endogenous Production Networks

Theorem

An increase in the vector of fixed costs z

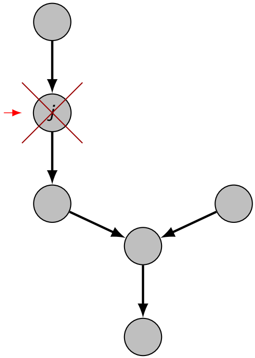
(a) *shrinks the **set of active firms** in the greatest full equilibrium;*

(b) *lowers **aggregate output** in the greatest full equilibrium;*

(c) *reduces **markups** and **profits** of all remaining firms.*

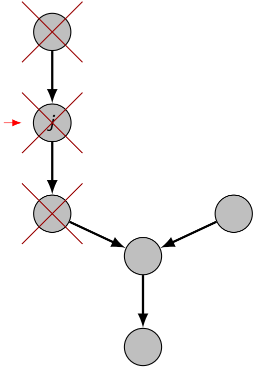
- There are complementarities in production $\rightarrow$ failure cascades
  - PE effect: direct propagation of failures over the network
  - GE effect: reduction in aggregate demand, thus lower profits for all firms

Cascading Failures



- Negative shock to j can result in upstream, downstream, and horizontal failures.
- both PE and GE effects.

Cascading Failures



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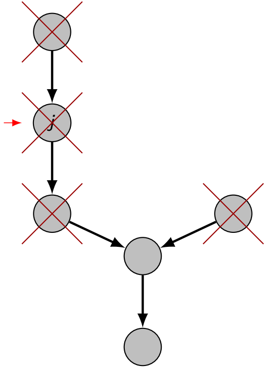

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Industry-Level Aggregation

- Can the model be aggregated to the industry level?
- Baqaee and Farhi (2019):

$$\Delta \log \text{GDP} = \tilde{\lambda}' \underbrace{\Delta \log A}_{\text{change in productivity}} - \lambda' \underbrace{\Delta \log \mu}_{\text{change in markups}} - \tilde{\Lambda} \underbrace{\Delta \log \Lambda}_{\text{change in labor income share}}$$

- Implication: changes in labor income share and industry-level markups are sufficient statistics for measuring productivity shocks' aggregate effects.

- Question: can we use industry-level aggregates to obtain for shocks' macro effects, ignoring firm-level networks and failures?

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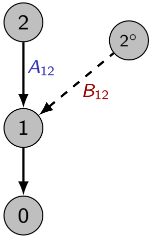
Industry-Level Aggregation: Counterexample

- $\psi_2 =$ fraction of active firms in industry 2.

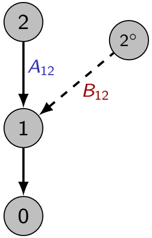


- industry-level markups depend on the composition of firms:

$$\mu_2^\circ = 1$$
$$\mu_2 = 1 - \delta_{12} + \delta_{12} A_{12} / B_{12}$$
$$\mu_1 = [(1 - \psi_2)/\mu_2^\circ + \psi_2/\mu_2]^{-1}$$

Industry-Level Aggregation: Counterexample

- A proportional increase in A_{12} and B_{12} (TFP shock to industry 1).



- Industry-level aggregation holds if and only if

$$(1-\delta_{12})\frac{d\psi_2}{dA_{12}} = 0.$$

- With endogenous failures, industry-level variables are not sufficient statistics for the impact of industry-level shocks.

Aggregate Comparative Statics: Fixed Costs

- ψ: mass of active firms

cascade effect $(-)$

partial equilibrium $(+)$

$$\frac{d \log \text{GDP}}{dz_k} = -\frac{\left.\frac{\partial \log \text{GDP}}{\partial z_k}\right|_{\psi \text{ fixed}} + \sum_r \left(\frac{\partial \psi_r}{\partial z_k}\right) \left(\frac{\partial \log \text{TFP}}{\partial \psi_r}\right)}{1 + \sum_r \left(\frac{\partial \psi_r}{\partial \log y}\right) \left(\frac{\partial \log \text{TFP}}{\partial \psi_r}\right)}.$$

aggregate demand effect $(+)$

entry effect $(-)$

- PE effect: as if $\mathbf{G}^*$ were exogenous (holding ψ constant)
- cascade effect: increase in fixed costs shrink the set of active firms
- entry/exit effect: less active firms reduces aggregate productivity
- aggregate demand: less active firms decreases final demand

Aggregate Comparative Statics: Fixed Costs

- ψ: mass of active firms

cascade effect $(-)$

partial equilibrium $(+)$

$$\frac{d\log \text{GDP}}{dz_k} = -\frac{\left.\frac{\partial \log \text{GDP}}{\partial z_k}\right|_{\psi \text{ fixed}} + \sum_r \left(\frac{\partial \psi_r}{\partial z_k}\right)\left(\frac{\partial \log \text{TFP}}{\partial \psi_r}\right)}{1 + \sum_r \left(\frac{\partial \psi_r}{\partial \log y}\right)\left(\frac{\partial \log \text{TFP}}{\partial \psi_r}\right)}.$$

aggregate demand effect $(+)$

entry effect $(-)$

- PE effect: as if $\mathbf{G}^*$ were exogenous (holding ψ constant)
- cascade effect: increase in fixed costs shrink the set of active firms
- entry/exit effect: less active firms reduces aggregate productivity
- aggregate demand: less active firms decreases final demand

Aggregate Comparative Statics: Fixed Costs

- ψ: mass of active firms

cascade effect $(-)$

partial equilibrium $(+)$

$$\frac{d\log \text{GDP}}{dz_k} = -\frac{\left.\frac{\partial \log \text{GDP}}{\partial z_k}\right|_{\psi\ \text{fixed}} + \sum_r \left(\frac{\partial \psi_r}{\partial z_k}\right)\left(\frac{\partial \log \text{TFP}}{\partial \psi_r}\right)}{1 + \sum_r \left(\frac{\partial \psi_r}{\partial \log y}\right)\left(\frac{\partial \log \text{TFP}}{\partial \psi_r}\right)}.$$

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Aggregate Comparative Statics: Fixed Costs

- ψ: mass of active firms

cascade effect $(-)$

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$$\frac{d \log \text{GDP}}{dz_k} = -\frac{\left.\frac{\partial \log \text{GDP}}{\partial z_k}\right|_{\psi\ \text{fixed}} + \sum_r \left(\frac{\partial \psi_r}{\partial z_k}\right)\left(\frac{\partial \log \text{TFP}}{\partial \psi_r}\right)}{1 + \sum_r \left(\frac{\partial \psi_r}{\partial \log y}\right)\left(\frac{\partial \log \text{TFP}}{\partial \psi_r}\right)}.$$

aggregate demand effect $(+)$

entry effect $(-)$

- PE effect: as if $\mathbf{G}^*$ were exogenous (holding ψ constant)
- cascade effect: increase in fixed costs shrink the set of active firms
- entry/exit effect: less active firms reduces aggregate productivity
- aggregate demand: less active firms decreases final demand

Aggregate Comparative Statics: Productivities

$$\frac{d\log \mathrm{GDP}}{d\log A_{ij}} = -\frac{\underbrace{\left.\frac{\partial \log \mathrm{GDP}}{\partial \log A_{ij}}\right|_{\psi\ \text{fixed}}}_{\text{partial equilibrium }(+)} + \sum_r \underbrace{\left(\frac{\partial \psi_r}{\partial \log A_{ij}}\right)}_{\text{cascade effect }(?)} \left(\frac{\partial \log \mathrm{TFP}}{\partial \psi_r}\right)}{1 + \sum_r \underbrace{\left(\frac{\partial \psi_r}{\partial \log y}\right)}_{\text{aggregate demand effect }(+)} \underbrace{\left(\frac{\partial \log \mathrm{TFP}}{\partial \psi_r}\right)}_{\text{entry effect }(-)}}.$$

Aggregate Comparative Statics

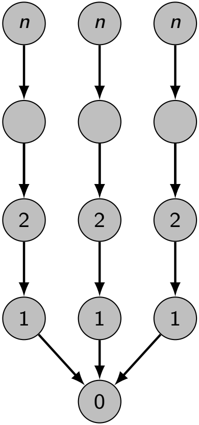
for today:

some implications of how interactions between firm-specific

relationships, markups, and failures shape aggregate output

Example 1: Failure Propagations

- Supplier has all the bargaining power $\delta_{k-1,k} = 1$.



ψ_k = fraction of active firms

Example 1: Failure Propagations

- aggregate output:

$$\text{GDP} = \frac{L - \bar{z}}{\sum_{k=1}^{n} (\psi_k - \psi_{k+1}) (A_{12} \dots A_{k-1,k} B_{k,k+1} \dots B_{n-1,n})^{-1}}$$

- failure cascades:

$$\psi_{k+1} = \psi_k \mathcal{H}_{k+1} \left(\frac{(1 - B_{k,k+1} / A_{k,k+1}) \, \text{GDP}}{A_{12} \dots A_{k-1,k} B_{k,k+1} \dots B_{n-1,n}} \right)$$

- Output in the economy with endogenous set of active firms relative to an economy with exogenous set of active firms with $\psi_k = 1$:

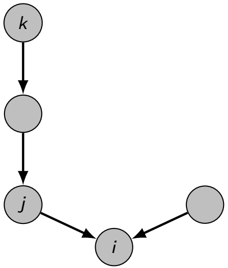
$$\lim_{A_k \to \infty} \lim_{A_1 \downarrow B_1} \frac{\text{GDP}_{\text{end}}}{\text{GDP}_{\text{exg}}} = 0.$$

Example 2: Productivity Shocks in a Non-Competitive Economy

- Leontief technologies + exogenous production network:

$$\frac{d \log \text{GDP}}{d \log A_{ij}} > 0$$

- Endogenous production network:
  positive productivity shocks may reduce aggregate outputs



  - an increase in A_{ij} increases k's markup, but may reduce its profits and lead to its failure.

Summary and Next Steps

- A firm-level model that takes relationship-specific surplus and firm failures into account.
  - how shocks change firm-specific relationships and markups endogenously
  - propagation of shocks via failures

- Aggregated industrial-level variables (Domar weights, sectoral markups) not sufficient statistics for understanding the above.
- Different implications from to standard models with competitive pricing/constant markups

- Next steps:
  - more detailed comparative statics?
  - quantitive exercise for the various forces in a more realistic economy?
  - measuring the various terms in the data?