Ownership Networks and Aggregate Volatility

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The views expressed do not reflect those of the Bank of Italy.

THE ORIGINS OF AGGREGATE FLUCTUATIONS

Question 1: Business cycles from macro or micro shocks?

- Law of large numbers and diversification
- Jovanovich (1987, QJE)

Question 2: Granular or network mechanism?

- Gabaix (2011, Econ.trica)
- Acemoglu et al. (2012, Econ.trica)
- di Giovanni et al. (2012, WP)

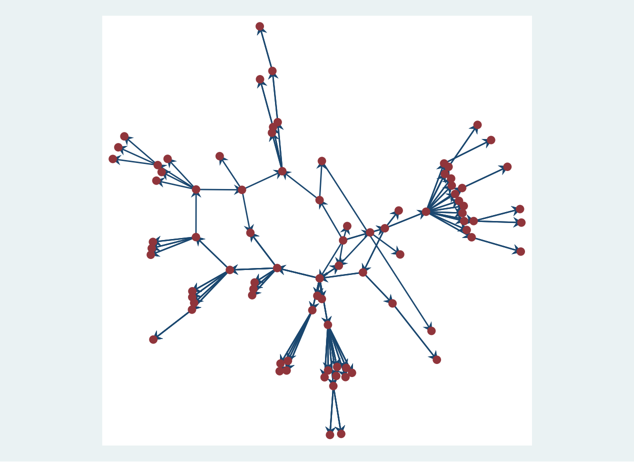
Question 3: Which network?

- Input-Output: Foerster et al. (2012, JPE)
- Financial liabilities: Acemoglu et al. (2013, WP)
- Ownership: Elliott Gollub Jackson (2013, WP)

NETWORK THEORY OF OWNERSHIP RELATIONS

Properties of ownership networks:

- Directed, weighted, acyclic, incomplete.
- Pyramids with ultimate owner and subsidiaries.



ECONOMICS OF OWNERSHIP RELATIONS

- Vertical propagation: Tunneling and Propping.

  Riyanto and Toolsema (2008, JBan&Fin), Dow and McGuire (2009, JBan&Fin).

- Horizontal propagation: Cross-subsidization and Winner-Picking.

  Bulow, Geanakoplos, Klemperer (1985, JPE), Cestone and Fumagalli (2005, RAND).

- Complex propagation: Internal capital market(s).

  Gertner, Scharfstein, Stein (1994, QJE), Lamont (1997, JFin), Samphantharak (2006, WP), Almeida & Kim (2012, WP).

OWNERSHIP DATA: SUMMARY

The Infocamere data (Chambers of Commerce): census of Italian firms with information on distribution of equity and economic performance.

Wave	Year	Links	Firms	Owners
1	2006	2,169,832	718,886	1,561,796
2	2007	2,310,296	773,287	1,653,329
3	2008	2,337,989	797,703	1,682,723
4	2009	2,440,988	842,807	1,747,105
5	2010	2,647,335	926,578	1,875,085
Overall		11,906,440	1,166,624	2,463,274

Table: Details for each wave: Date, Number of ownership links, Number of firms, Number of owners.

SALES

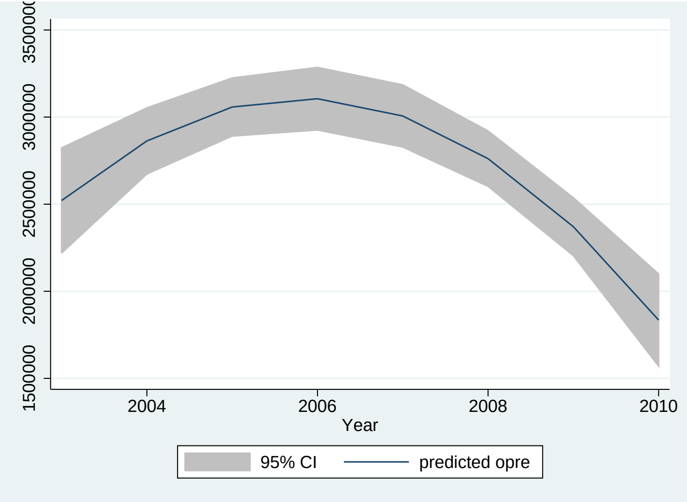


Figure: Operating revenue from 2003 to 2010. Fractional polynomial regression with 95% confidence interval.

SALES PER WORKER

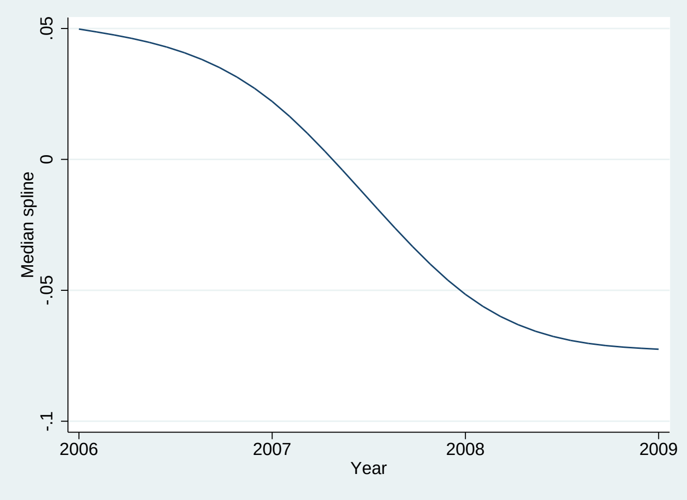


Figure: Year-on-year growth rate of sales per worker from 2006 to 2009. Median spline with 10 points between knots.

CORRELATION AMONG FIRMS

Two facts:

1. There is correlation between firms that share an ownership link.
2. The correlation seems to increase during the credit crunch.

CORRELATION AMONG FIRMS: SALES PER WORKER

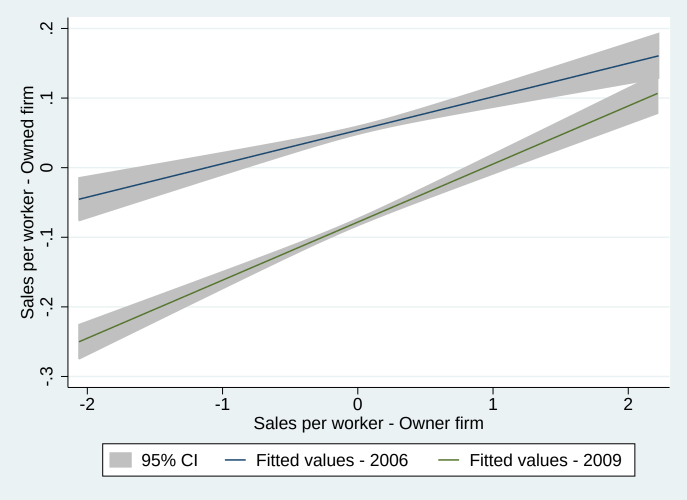


Figure: Growth of sales per worker, owner firm vs. owned firm. Linear prediction with 95% confidence interval, 2006 and 2009.

CORRELATION AMONG FIRMS: SALES

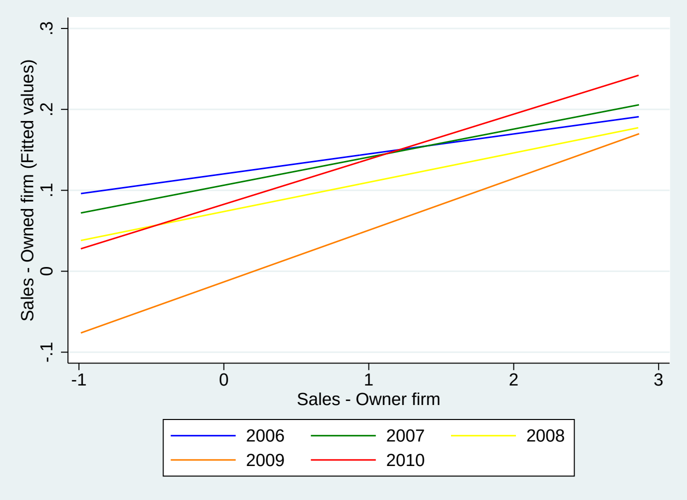
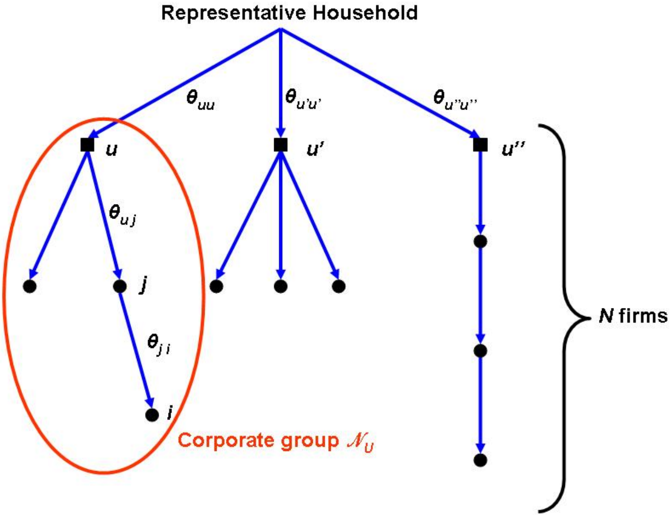


Figure: Growth of sales, owner firm vs. owned firm. Linear prediction, All years.

FRAMEWORK

- Small open economy.
- International credit market: infinite supply at rate R_t.
- Continuum of identical households $\rightarrow$ Representative household.
- N firms partitioned into corporate groups, with ultimate owner firms at the top.
- General equilibrium: Equity market, Labor market.

THE PYRAMIDAL STRUCTURE OF THE ECONOMY



HOUSEHOLD SIDE

- No access to credit markets.
- Works, trades equities, consumes.

Solves

$$\max \mathbb{E} \sum_{\tau=0}^{+\infty} \beta^{\tau} \frac{\left(C_{\tau} - \psi L_{\tau}\right)^{1-\sigma} - 1}{1-\sigma},$$

subject to

$$\sum_{u \in \mathscr{U}} \theta_{uu\tau+1} P_{u\tau} + C_{\tau} \leq W_{\tau} L_{\tau} + \sum_{u \in \mathscr{U}} \theta_{uu\tau} \left(D_{u\tau} + P_{u\tau}\right).$$

FIRM SIDE

Flow-of-funds constraint of firm j:

$$D_{jt} + W_t L_{jt} + R_t B_{jt} + I_{jt} = Y_{jt} + \sum_{i \in \mathcal{N}_j^{in}} \theta_{ji} D_{it} + B_{jt+1}.$$

Dividends of ultimate owner u:

$$D_{ut} = \sum_{j \in \mathcal{N}_u} m_{uj} \left[Y_{jt} + B_{jt+1} - R_t B_{jt} - W_t L_{jt} - I_{jt} \right],$$

where

$$m_{uj} = \sum_{k=0}^{+\infty} \theta_{uj}{}^{[k]} = \theta_{uj} + \sum_i \theta_{ui}\theta_{ij} + \sum_l \sum_i \theta_{ul}\theta_{li}\theta_{ij} + \cdots .$$

$\longrightarrow$ Weighted Bonacich centrality with the net cash flows as weights.

FIRM SIDE: THE PROBLEM

Ultimate owner u chooses $\{L_{jt}, K_{jt+1}, B_{jt+1}\}_{t\geq\tau}^{j\in\mathcal{N}_u}$ to

$$\max\ \mathbb{E}_\tau\left[\sum_{t=\tau}^{+\infty}\beta^{t-\tau}\left(\frac{C_t-\psi L_t}{C_\tau-\psi L_\tau}\right)^{-\sigma}D_{ut}\right],$$

subject to

$$D_{ut}=\sum_{j\in\mathcal{N}_u}m_{uj}\left[Y_{jt}+B_{jt+1}-R_tB_{jt}-W_tL_{jt}-K_{jt+1}+(1-\delta)K_{jt}\right],$$

$$Y_{jt}=A_{jt}{}^{1-\epsilon}\left(K_{jt}^{\alpha_j}L_{jt}^{1-\alpha_j}\right)^{\epsilon},$$

and

$$B_{jt+1}\leq\kappa_{jt}K_{jt+1}.$$

DYNAMICS AROUND THE STEADY STATE

Proposition

If $R < 1/\beta$, then the loglinearized equilibrium around the deterministic steady state is such that

$$\hat{Y}_{jt} = \hat{A}_{jt} + C_{Yj}\kappa_j(1-\beta R)\hat{\kappa}_{jt-1} - C_{Yj}\kappa_j\beta R\hat{R}_t + C_{Yj}(1-\kappa_j)\hat{\beta}_t$$

and

$$\hat{\beta}_t = \pi_R(\mathbf{L})\hat{R}_t - \boldsymbol{\pi}_A(\mathbf{L})\hat{\mathbf{A}}_t - \boldsymbol{\pi}_\kappa(\mathbf{L})\hat{\boldsymbol{\kappa}}_{t-1},$$

where

$$C_{Yj} = \frac{\epsilon\alpha_j}{1-\epsilon}\frac{1}{1-\beta(1-\delta)-\kappa_j(1-\beta R)},$$

$\pi_R(\mathbf{L})$ is a polynomial of the lead operator $\mathbf{L}$, $\boldsymbol{\pi}_A(\mathbf{L})$ and $\boldsymbol{\pi}_\kappa(\mathbf{L})$ are $1 \times N$ vectors of polynomials of the lead operator $\mathbf{L}$, and $\hat{\mathbf{A}}_t$ and $\hat{\boldsymbol{\kappa}}_{t-1}$ are $N \times 1$ vectors of firm-specific shocks.

WHAT TO DO WITH THE MODEL

1. Simulate economies with different network structures.
2. Simulate stochastically a stylized economy calibrated to aggregate moments of the Italian data.

   Some examples:

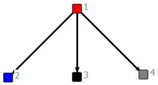
   - size distribution of corporate groups,
   - average structure of corporate groups,
   - ...
3. Use the model to filter the data and obtain idiosyncratic shocks. Perform counterfactual exercises.
4. Policy experiments.

STOCHASTIC SIMULATION

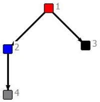
A stylized economy with 4 firms:

- one ultimate owner,
- three controlled firms,
- homogeneous capital intensities.

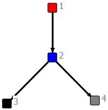
Look at 5 network structures:



Star

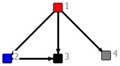


“High” tree



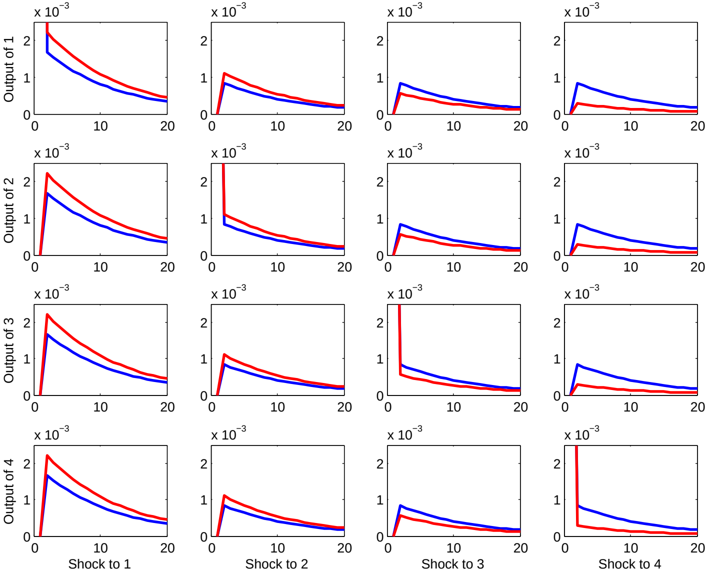
“Low” tree

Line

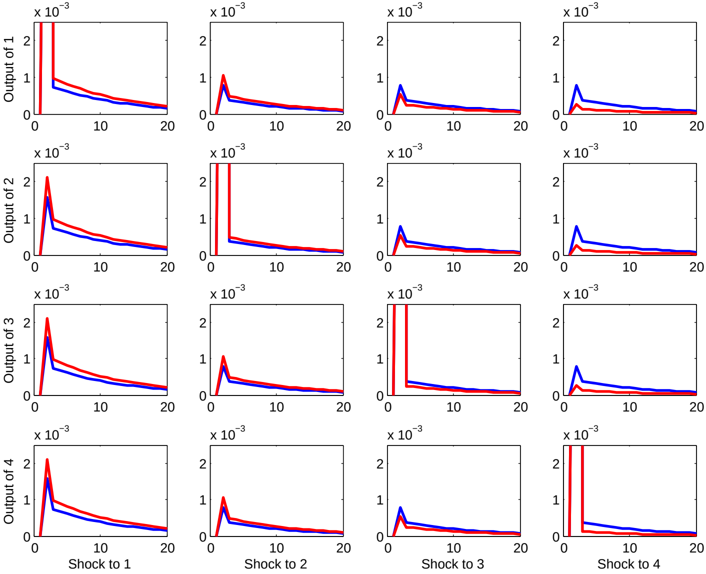


DAG with cluster

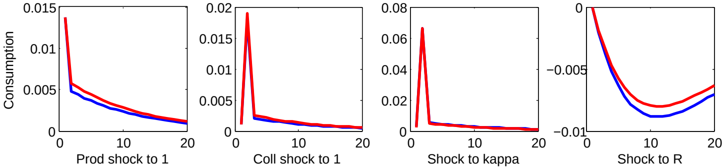
IRFs: Shocks to productivity, star vs line



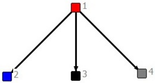
IRFs: Shocks to collateral, star vs line



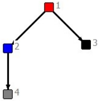
IRFs: Consumption, Star vs Line



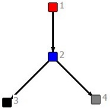
IMPLIED MOMENTS



Star

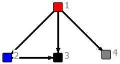


"High" tree



"Low" tree

Line



DAG with cluster

Moment	Star	Tree 1	Tree 2	Line	Cluster
σ_C	0.0890	0.0877	0.0872	0.0869	0.0896
μ_C	3.3070	3.1988	3.0924	3.0387	3.4109
σ_C/μ_C	0.0269	0.0274	0.0282	0.0286	0.0263

Table: Standard deviation, mean, and coefficient of variation implied by different network structures.

WHAT TO DO WITH THE MODEL

1. Simulate economies with different network structures.

2. Simulate stochastically a stylized economy calibrated to aggregate moments of the Italian data.

   Some examples:

   - size distribution of corporate groups,
   - average structure of corporate groups,
   - ...

3. Use the model to filter the data and obtain idiosyncratic shocks. Perform counterfactual exercises.

4. Policy experiments.

CONCLUSION

- There exists correlation among firms that share an ownership link.
- The dynamics of the economy depend on the network structure of ownership links.
- Horizontal diversification decreases more aggregate volatility the closer to the ultimate owners it occurs.

HOUSEHOLD SIDE: FOC

FOCs of the household's problem:

$$W_\tau = \psi,$$

and

$$P_{u\tau} = \beta \mathbb{E}_\tau \left[\left(\frac{C_{\tau+1} - \psi L_{\tau+1}}{C_\tau - \psi L_\tau} \right)^{-\sigma} (D_{u\tau} + P_{u\tau+1}) \right],$$

for every u.

If we iterate forward (with no bubbles):

$$P_{u\tau} = \mathbb{E}_\tau \left[\sum_{t=\tau}^{+\infty} \beta^{t-\tau} \left(\frac{C_t - \psi L_t}{C_\tau - \psi L_\tau} \right)^{-\sigma} D_{ut} \right].$$

FIRM SIDE

Firm j:

- accesses credit market under collateral constraint

$$B_{jt+1} \leq \kappa_{jt} K_{jt+1},$$

- realizes production $Y_{jt} = {A_{jt}}^{1-\epsilon} \left(K_{jt}^{\alpha_j} L_{jt}^{1-\alpha_j} \right)^{\epsilon}$,
- accumulates capital $K_{jt+1} = I_{jt} + (1-\delta) K_{jt}$,
- distributes dividends D_{jt} to its owners.

Flow-of-funds constraint:

$$D_{jt} + W_t L_{jt} + R_t B_{jt} + I_{jt} = Y_{jt} + \sum_{i \in \mathcal{N}_j^{in}} \theta_{ji} D_{it} + B_{jt+1}.$$

FIRM SIDE: ULTIMATE OWNERS

- Corporate group $\mathscr{N}_u$:

$$\mathscr{N}_u \equiv \{j \in \mathscr{N} | \forall i \in \mathscr{N}, m_{uj} \geq m_{ij}\},$$

where

$$m_{uj} = \sum_{k=0}^{+\infty} {\theta_{uj}}^{[k]} = \theta_{uj} + \sum_i \theta_{ui}\theta_{ij} + \sum_l \sum_i \theta_{ul}\theta_{li}\theta_{ij} + \cdots .$$

- Ultimate owner u at time τ maximizes value:

$$\max \; P_{u\tau} = \mathbb{E}_\tau \left[\sum_{t=\tau}^{+\infty} \beta^{t-\tau} \left(\frac{C_t - \psi L_t}{C_\tau - \psi L_\tau} \right)^{-\sigma} D_{ut} \right].$$

What is D_{ut}?

EQUILIBRIUM

Definition

An intertemporal competitive general equilibrium is a sequence

$$\{C_\tau, L_\tau, W_\tau, \theta_{uu\tau+1}, P_{u\tau}, K_{jt+1}, L_{jt}, B_{jt+1}\}_{\tau\geq 0, t\geq\tau}^{u\in\mathscr{U}, j\in\mathscr{N}}$$

such that

- $\{C_\tau, L_\tau, \{\theta_{uu\tau+1}\}_{u\in\mathscr{U}}\}_{\tau\geq 0}$ solves the representative household problem given $\{W_t, \{P_{u\tau}\}_{u\in\mathscr{U}}\}_{\tau\geq 0}$,
- $\{\{K_{jt+1}, L_{jt}, B_{jt+1}\}_{j\in\mathscr{N}}\}_{t\geq\tau}$ solves ultimate owner u's problem at time τ given $\{C_t, L_t, W_t, R_t, \{A_{jt}, \kappa_{jt}\}_{j\in\mathscr{N}}\}_{t\geq\tau}$ for every $u\in\mathscr{U}$ and for every $\tau\geq 0$,
- the market clearing conditions hold for every $\tau\geq 0$, and
- $\{R_\tau, \{A_{j\tau}, \kappa_{j\tau}\}_{j\in\mathscr{N}}\}_{\tau\geq 0}$ follow their stochastic processes.

MARKET CLEARING

Equity market:

$$\theta_{uu\tau} = 1 \text{ for every } u \in \mathscr{U}.$$

Labor market:

$$\sum_{j \in \mathscr{N}} L_{j\tau} = L_{\tau}.$$

DETERMINISTIC STEADY STATE

Proposition

If $R < 1/\beta$, then there exists a unique deterministic steady state characterized by

$$Y_j = A_j C_{Kj}^{\frac{\epsilon}{1-\epsilon}\alpha_j} C_{Lj}^{\frac{\epsilon}{1-\epsilon}(1-\alpha_j)},$$

$$K_j = \frac{\beta}{1-\beta(1-\delta)-\kappa_j(1-\beta R)}\epsilon\alpha_j Y_j,\ L_j = C_{Lj} Y_j,\ B_j = k_j K_j,$$

$$L = \sum_{j\in\mathcal{N}} L_j,\ ,\ W = \psi,$$

and

$$C = \psi L + \sum_{u\in\mathcal{U}} \sum_{j\in\mathcal{N}_u} m_{uj} \left[1 - \left((R-1)\kappa_j + \delta\right) C_{Kj} - \psi C_{Lj}\right] Y_{jt},$$

where

PARAMETER VALUES

Parameter	Value	Origin
ψ	1	Bianchi (2012, NBER)
σ	1	"
ϵ	0.765	Bhattacharya, Guner, Ventura (2013, RED)
α	0.426	"
δ	0.067	"
β	0.946	"

Table: Parameter values from previous literature.

CHARACTERIZATION OF STOCHASTIC PROCESSES

Define the stochastic processes:

$$A_{jt} = \exp\left(\varepsilon^a_{jt}\right), \text{ where } \varepsilon^a_{jt} \sim \mathcal{N}(0, \sigma_a),$$

$$\kappa_{jt} = 0.5\kappa_t \exp\left(\varepsilon^\kappa_{jt}\right), \text{ where } \varepsilon^\kappa_{jt} \sim \mathcal{N}(0, \sigma_\kappa) \text{ and } \kappa_t \sim \mathcal{U}(0, 1),$$

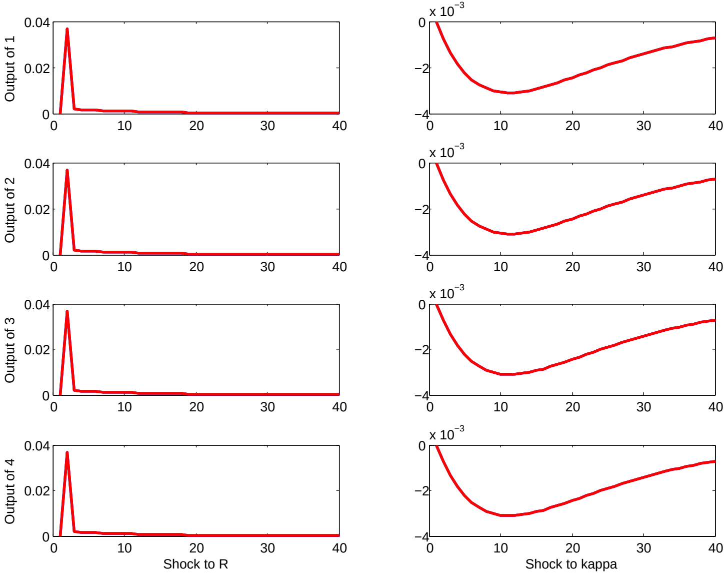
and

$$R_t = (1 - \rho_r)R_{ss} + \rho_r * R_{t-1} + \varepsilon^r_t, \text{ where } \varepsilon^r_t \sim \mathcal{N}(0, \sigma_r).$$

Parameter	Value
σ_a	0.05
σ_κ	0.05
σ_r	0.001
ρ_r	0.9
R_{ss}	0.99

Table: Parameter values for the stochastic simulation.

IRFs: Aggregate shocks, star vs line



FREQUENCY DISTRIBUTION OF OWNERSHIP

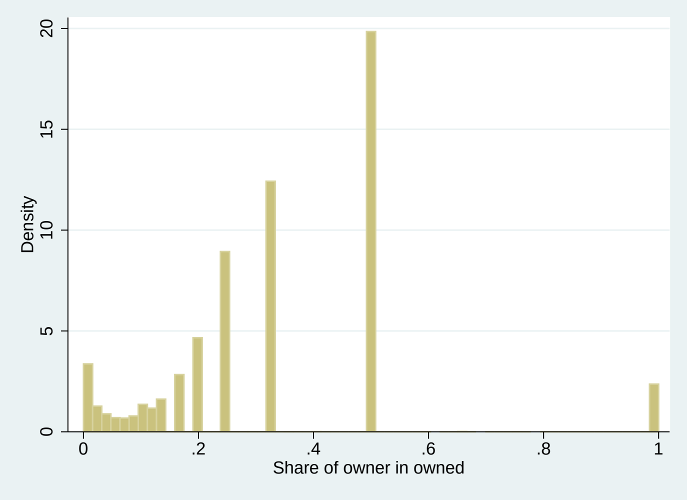


Figure: The frequency distribution of ownership links by share. Year: 2006.

FREQUENCY DISTRIBUTION OF OWNERSHIP

Year	Mean	Std. Dev.	Min.	Max.	N
2006	0.331	0.208	0.0001	1	2,169,832
2007	0.335	0.214	0.0001	1	2,310,296
2008	0.341	0.217	0.0001	1	2,337,989
2009	0.345	0.222	0.0001	1	2,440,988
2010	0.350	0.226	0.0003	1	2,647,335

Table: Summary statistics of the ownership links' strength. The second wave is for simplicity reported as 2007 although its date is December 31, 2006.

INDEGREE DISTRIBUTION

How many owners does each firm have?

Year	Mean	StDev	Max.	Skewn.	Kurtosis	N
2006	3.018	6.501	1,536	63.045	8,289.596	718,886
2007	2.988	7.427	1,415	63.192	6,895.980	773,287
2008	2.931	7.510	1,536	71.813	8,950.296	797,703
2009	2.896	7.579	1,536	68.466	7,880.459	842,807
2010	2.857	9.869	3,938	170.822	54,428.47	926,578

Table: Indegree distribution through time.

INDEGREE DISTRIBUTION

How many owners does each firm have?

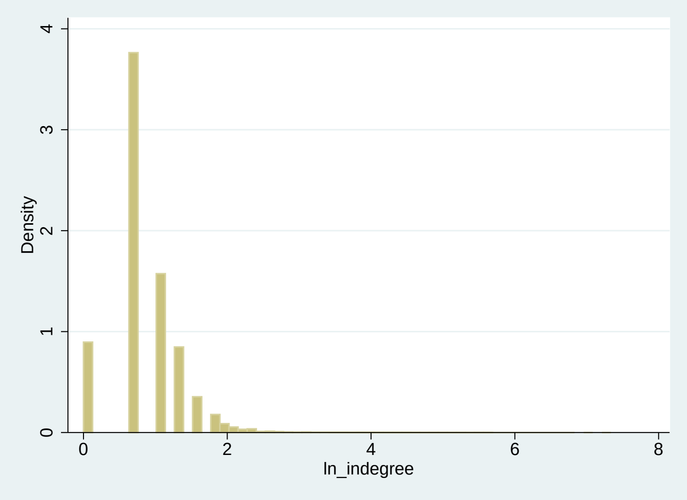


Figure: The (log) indegree distribution of ownership links. Year: 2006.

OUTDEGREE DISTRIBUTION

How many firms does each owner own?

Year	Mean	StDev	Max.	Skewn.	Kurtosis	N
2006	1.389	2.307	1,221	214.1748	80,926.77	1,561,796
2007	1.397	2.288	1,212	211.4052	80,097.64	1,653,329
2008	1.389	2.159	1,106	192.2791	68,542.86	1,682,723
2009	1.397	2.175	1,151	197.5014	73,522.13	1,747,105
2010	1.412	6.092	7,027	894.9156	974,973.8	1,875,085

Table: Outdegree distribution through time.

OUTDEGREE DISTRIBUTION

How many firms does each owner own?

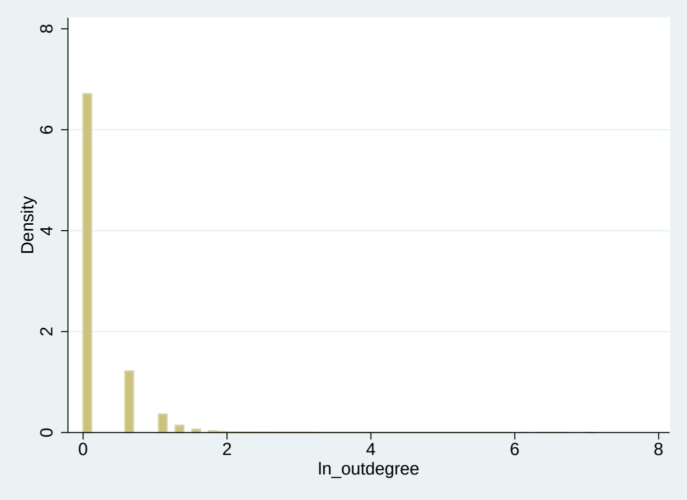


Figure: The (log) outdegree distribution of ownership links. Year: 2006.

JOINT DEGREE DISTRIBUTION - 2006

Which types of firm associate with each type of owner?

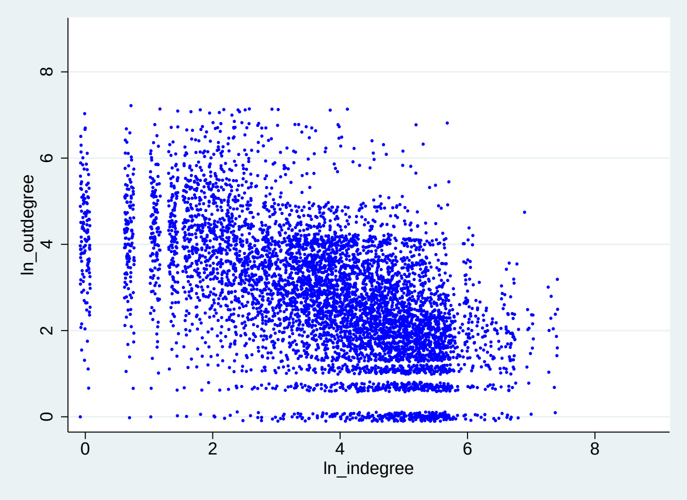


Figure: The joint distribution of (log) indegree and (log) outdegree.

JOINT DEGREE DISTRIBUTION - 2010

Which types of firm associate with each type of owner?

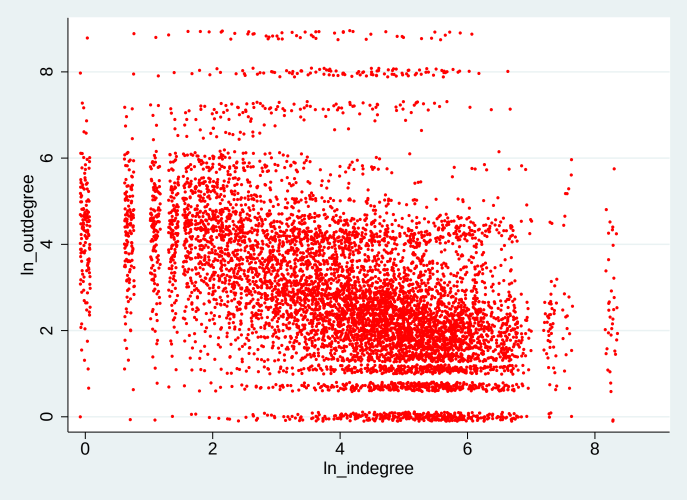


Figure: The joint distribution of (log) indegree and (log) outdegree.

PERFORMANCE DATA: REPRESENTATIVENESS

Year	Coverage	N
2003	1.071	643,367
2004	1.312	713,044
2005	1.284	759,349
2006	1.510	784,883
2007	1.426	854,240
2008	1.278	876,673
2009	1.061	885,582
2010	1.134	842,929
Total		6,360,067

Table: Representativeness of the sample: Ratio of total revenue to Italian NGDP over time and number of observations for each year.

SIZE DISTRIBUTION OF ITALIAN FIRMS

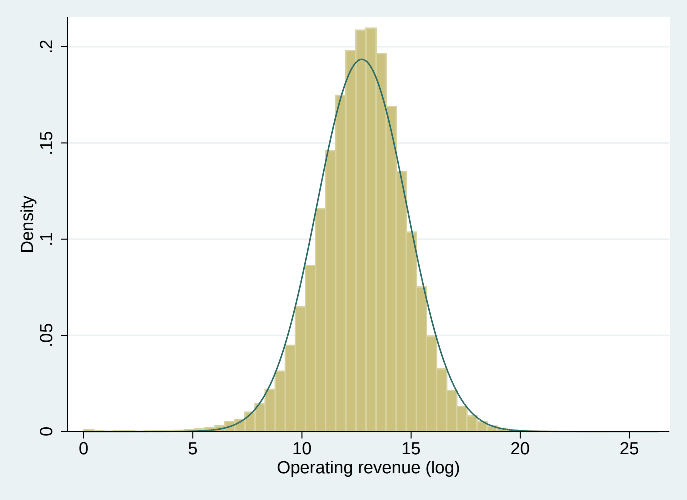


Figure: The size distribution of Italian firms. Variable: (log) operating revenue in 2006.

Year	Contemporaneous	1 lag	2 lags
2006	0.0414***	-	-
2007	0.0291***	0.0158***	-
2008	0.0392***	-0.0015	0.0045
2009	0.0717***	0.0032	0.0050
All years	0.0613***	0.0133***	0.0056

* $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table: Correlation of the (demeaned) growth rate of sales per worker of the owned firms with that of the owner firm.