Internet Appendix

The Double-Edged Sword of Global Integration: Robustness, Fragility & Contagion in the International Firm Network

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A Data Summary Statistics

Table A.1: Summary Statistics

	Monthly					Quarterly					Annual				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Common Stock Log Return	305231	0.01	0.13	-7.07	14.95	101533	0.03	0.24	-7.19	27.45	24336	0.11	0.52	-7.72	12.27
Lowest 10% Log Return Indicator	305231	0.1	0.3	0	1	101533	0.1	0.3	0	1	24336	0.1	0.3	0	1
Avg TED Spread	507078	0.73	0.64	0.12	3.81	169026	0.73	0.62	0.14	3.31	41370	0.74	0.59	0.19	2.76
ln(Avg TED Spread)	507078	-0.6	0.75	-2.14	1.34	169026	-0.59	0.74	-1.94	1.2	41370	-0.56	0.71	-1.66	1.01
Highest 10% TED Spread Indicator	507078	0.1	0.3	0	1	169026	0.1	0.3	0	1	41370	0.09	0.28	0	1
Highest 25% TED Spread Indicator	507078	0.25	0.43	0	1	169026	0.24	0.43	0	1	41370	0.26	0.44	0	1
Avg VIX	436158	20.65	8.09	10.61	62.64	145386	20.64	7.72	11.04	58.6	35460	20.74	6.13	12.64	32.64
Highest 10% VIX Indicator	436158	0.1	0.3	0	1	145386	0.1	0.3	0	1	35460	0.1	0.3	0	1
SP500 Log Return	505896	0.01	0.04	-0.24	0.13	167844	0.03	0.08	-0.26	0.19	40188	0.11	0.16	-0.46	0.32
Lowest 10% SP500 Log Return Indicator	505896	0.1	0.3	0	1	167844	0.11	0.31	0	1	40188	0.12	0.32	0	1
EBITDA Log Change						55950	0.02	0.45	-6.38	6.68					
Revenue Log Change						74565	0.02	0.25	-7.34	8					
Return on equity (RoE)											17003	13.98	54.32	-1874.34	701.92
YoY Difference in RoE											15842	-0.02	37.16	-1518.82	1930.47

Notes: RoE = (Trailing 12-month Net Income Available for Common Shareholders / Average Total Common Equity) * 100. Sources: Bloomberg L.P., Markit, and Global Financial Database. We queried the list of the top 1% of global firms by equity market capitalization on December 31st every year from 1992-2016 with all market values converted to U.S. dollars at market exchange rates, removed exchange traded funds and took the remaining 1,182 equity securities in the union of these annual sets as our sample. If there were multiple tickers for a single firm then we first filtered by keeping only the securities marked as primary, and if there was still more than one ticker we took the one with the best data coverage. The ticker search begins in 1992 because of Bloomberg data limitations on extending it further back in time. Our focus is on these large firms in order to ensure that they all have actively traded, liquid equity securities that are highly researched and followed, providing them with accurate price discovery.

B Global Inter-firm Network

B.1 Network Estimation Procedure

This section provides the details of how we estimate the inter-firm networks. These networks capture co-movements in the firms' equity prices, reflecting similarities in the firms themselves, regardless of the source of any underlying shock(s).

1. Standardize daily equity log return series to have mean zero and a standard deviation of one for each firm's return series over the full sample period, so that the GIRFs are comparable across firms and over time.

2. Estimate VAR models of the daily equity log returns on lags of themselves and of the returns of other firms.

   - Remove the initial observations from each dependent variable series that do not have enough lags in the data.
   - Run OLS estimation of the VAR and save the coefficient estimates, $\{\tilde{\beta}_{il}^{j}\}$.
   - Estimate the VAR model using the adaptive elastic-net (AEN) estimator from Zou and Zhang (2009). This shrinkage method allows us to overcome the curse of dimensionality. The AEN estimation combines the L_1 and L_2 penalties of the LASSO and ridge methods, with the adaptive label in the name referring to the manner in which weights are selected to further penalize coefficients that are smaller in magnitude to aid in the shrinkage. The AEN estimation procedure solves the following problem for dependent firms $j \in \{1, 2, ..., I\}$:

   $$\hat{\boldsymbol{\beta}}_{\boldsymbol{j}} = \underset{\{\beta_{il}^{j}\}}{\arg\min} \sum_{t=L+1}^{T} \left(x_{j,t} - \beta_{00}^{j} - \sum_{i=1}^{I} \sum_{l=1}^{L} \beta_{il}^{j} x_{i,t-l} \right)^2 + \rho_j \sum_{i=1}^{I} \sum_{l=1}^{L} w_{il}^{j} (\alpha_j |\beta_{il}^{j}| + \frac{(1-\alpha_j)}{2} {\beta_{il}^{j}}^2)$$

   with $\tilde{\beta}_{il}^{j}$ being the standard OLS coefficient estimates, $w_{il}^{j} \equiv \frac{1}{|\tilde{\beta}_{il}^{j}|}$, β_{00}^{j} is a constant term, $\{\beta_{il}^{j}\}$ is the set of elements of the coefficient matrix $\boldsymbol{\beta_j}$, $\{x_{it}\}$ are the standardized log returns, and L the maximum lag considered. Note that α_j is defined slightly differently here than in the main text because this is how it is implemented in the estimation package we use.

   - We use the R package glmnet to calculate this: https://cran.r-project.org/web/packages/glmnet/glmnet.pdf.
   - There are a number of parameters that we set for the estimation:
     - The maximum lag order to consider, L.
     - We use standard OLS coefficient estimates to determine the w_{il}^{j}; however, to avoid infinite weights in the case of zero OLS coefficients we add $1e^{-8}$ to their absolute values before inverting them for the weights.
     - We set $\alpha_j = \frac{\beta_{avg}}{2+\beta_{avg}}$ where β_{avg} is the average of the absolute values of the non-constant term OLS coefficients for firm j, so that the LASSO and ridge penalty terms are on average the same size. If there are no non-zero coefficients in the AEN results, then we rerun up to 50 times with lower weights on the LASSO penalty until there are. Specifically, we divide the previous iteration's α_j value by ten each time until this is satisfied.

- To choose the values of the $\{\rho_j\}$ we use 10 fold cross validation to find the best pseudo out-of-sample fit. The steps are:
  - Break the sample into 10 equal sized time periods. This is done randomly within the glmnet function.
  - Across a range of $\{\rho_j\}$, run AEN estimation on the other 90% of the data for all 10 samples.
  - Fit the "out-of-sample" 10% of the data using all ten of these estimates.
  - Select the $\{\rho_j\}$ that provide the best fit by mean-squared error.
  - Rerun the estimation on the full sample using these best fit parameters.
- Note that the dependent variables are standardized within each sub-sample being looked at so that their coefficients are comparable in the penalty terms, and the returned coefficients are scaled back to the original levels.
- Other parameters that must be set for the estimation procedure are:
  - family="gaussian"
  - nlambda= 10^3
  - maxit= 10^9
  - thresh= 10^{-7}
  - lambda.min.ratio= 0
  - nfolds= 10
  - type.measure="mse"
  - There is also a parameter to parallelize the code. See the glmnet documentation for details and an example.

3. Calculate absolute values of generalized impulse response functions (GIRFs) between all firms.

   - Pick GIRF forecast horizon, h.
   - Take the coefficient estimates and residuals from the estimated VAR and calculate all bilateral GIRFs. The precise definition of the GIRF is the effect of a shock to variable i in the VAR at time t (ϵ_{it}) on the vector of dependent variables at a horizon h (X_{t+h}), which is given by:

   $$GIRF(h, i, \Omega_{t-1}) = \mathbb{E}(X_{t+h}|\epsilon_{it} = \sigma_i, \Omega_{t-1}) - \mathbb{E}(X_{t+h}|\Omega_{t-1})$$

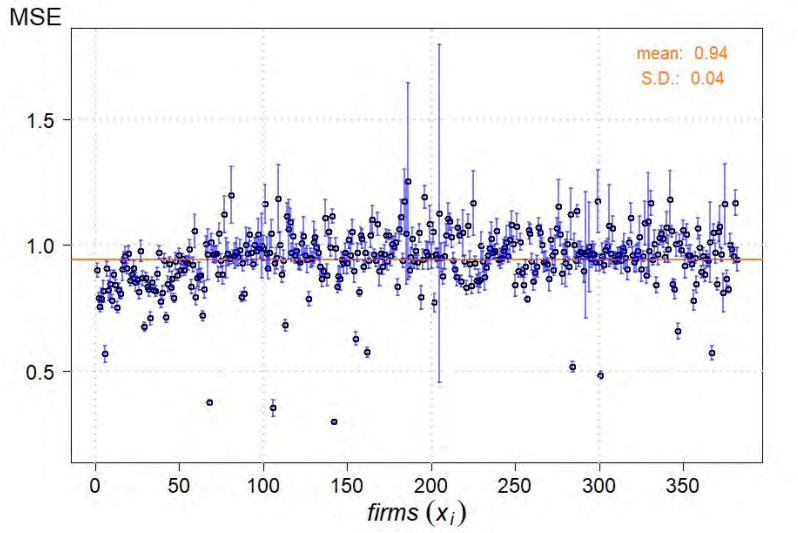
   where Ω_{t-1} is the non-decreasing information set known at time $t-1$, and σ_i is the standard deviation of the error term ϵ_i. The specific form of the GIRF that we use is the Pesaran and Shin (1998) scaled generalized impulse response function.

4. Collect these responses into matrix form, with the columns representing source firms and the rows the responding ones.

5. Take the absolute values of these responses. Together, the matrix of these bilateral responses is the adjacency matrix defining the inter-firm network.

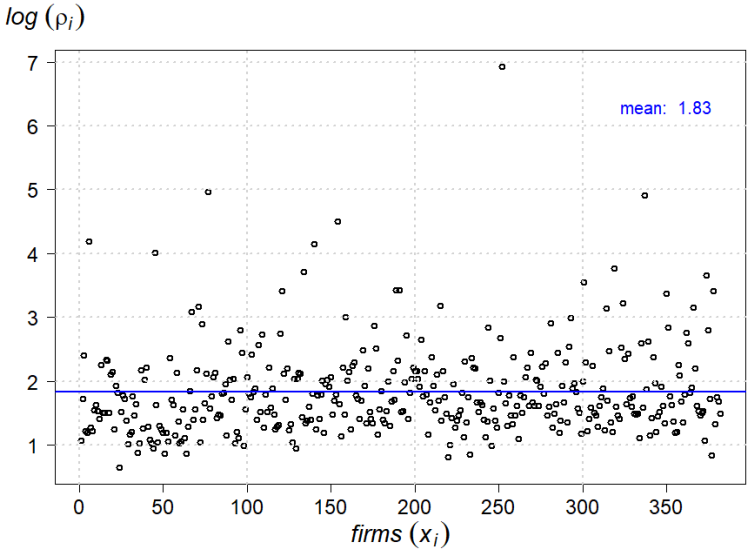
B.2 Goodness-of-Fit Statistics

Figure B.1: Diagnostics: Cross Validated Mean Squared Error (MSE)



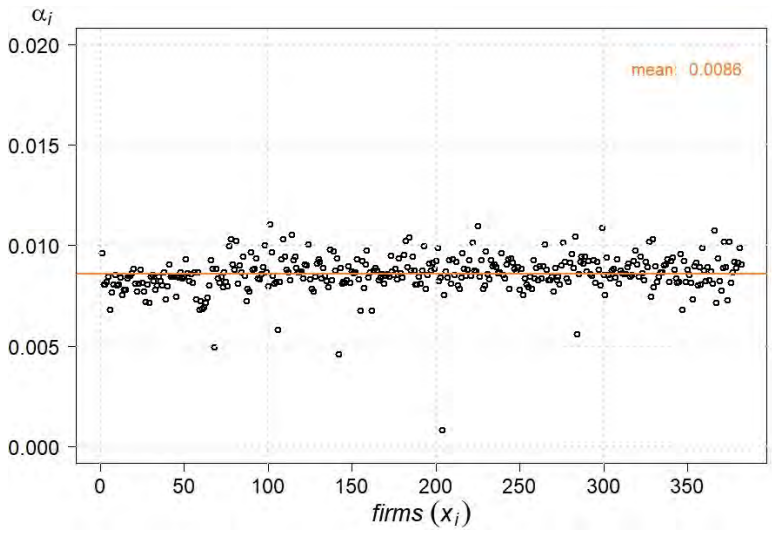
Notes: Every circle represents the lowest cross validated MSE for every firm in the sample, with standard error bars in blue. The orange line represents the average across all firms.

Figure B.2: Diagnostics: Cross Validated Penalty Estimates



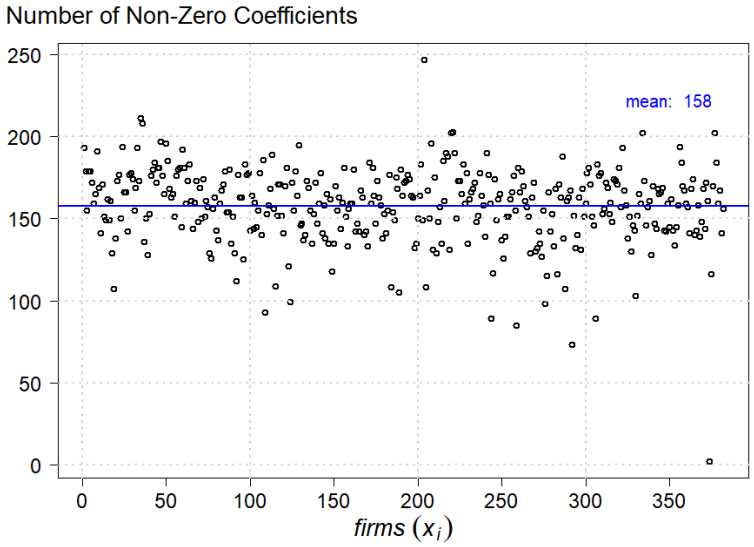
Notes: Every circle represents the log penalty term (ρ) that minimizes the cross validated mean squared error for every firm in the sample. The blue line represents the average across all firms.

Figure B.3: Diagnostics: LASSO-vs-Ridge Penalty Term (α_i)



Notes: Every circle represents the α value for every firm in the sample, estimated as $\alpha_i = \frac{\beta_{avg}}{2+\beta_{avg}}$ where β_{avg} is the average of the absolute values of the non-constant term OLS coefficients for firm i. When $\alpha_j = 1$ only the LASSO penalty is included, and when $\alpha_j = 0$ only the ridge penalty is applied, otherwise the two are mixed in standard elastic-net. The orange line represents the average across all firms.

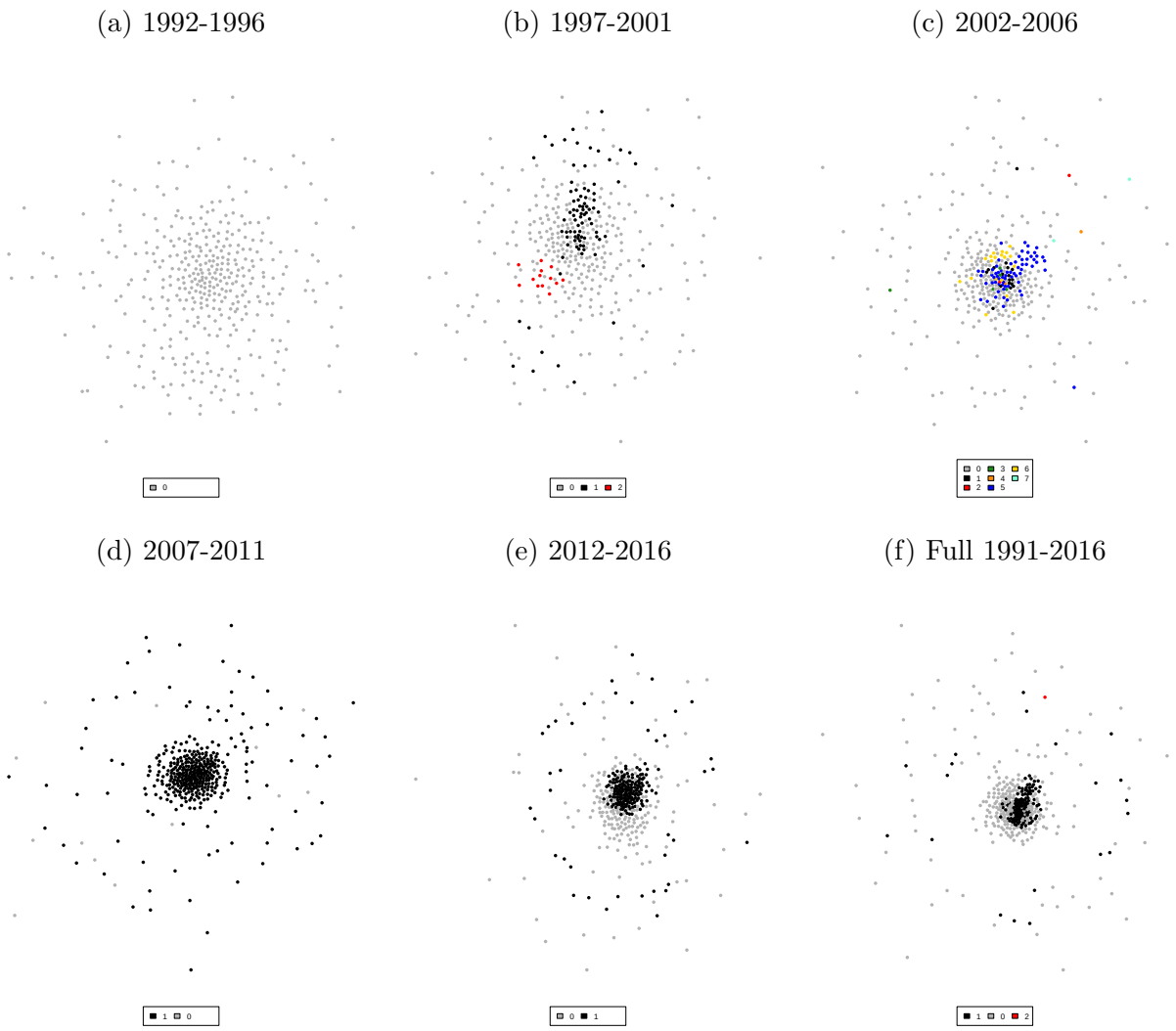
Figure B.4: Diagnostics: Non-Zero Coefficient Estimates



Notes: Every circle represents the number of non-zero coefficients for every firm equation. The blue line represents the average across all firms.

B.3 DBSCAN Clustering

Figure B.5: Global Network in Different Periods by DBSCAN Cluster



Notes: Daily equity return based networks for the balanced panel of 382 firms that were continuously traded from January 1991 through September 2016 estimated during different sub-periods. Each node represents a firm colored by its cluster using DBSCAN. The grey 0 cluster indicates no cluster assigned. The minimum number of firms required to form a cluster was 10, and the epsilon neighborhood for forming the core of a cluster was set at the top 1% of connections. Proximity of nodes is based on a network estimated from the one-period ahead GIRFs of a VAR(1) system of the firms' daily equity returns.

Table B.1: DBSCAN Cluster Membership Distributions

Period	No Cluster	1	2	3	4	5	6	7
Long 1992-1996	382							
Long 1997-2001	282	87	13					
Long 2002-2006	269	66	19	17	5	2	2	2
Long 2007-2011	13	369						
Long 2012-2016	179	203						
Long 1991-2016	236	145	1					

Notes: DBSCAN cluster results for daily equity return based networks for the balanced panel of 382 firms that were continuously traded from January 1991 through September 2016 estimated during different sub-periods. The 0 cluster indicates no cluster assigned. The minimum number of firms required to form a cluster was 10, and the epsilon neighborhood for forming the core of a cluster was set at the top 1% of connections. Proximity of nodes is based on a network estimated from the one-period ahead GIRFs of a VAR(1) system of the firms' daily equity returns.

B.4 The Role of Size and Performance

Table B.2: Summary Statistics of Variables Representing Size and Performance

Variable	Obs	Mean	St.Dev.	P5	P25	Median	P75	P95	Min	Max
Total Equity	11,207	17,304	25,951	858.5	4,400	9,164	18,894	63.9K	-90,520	287,425
Ent. Value	10,002	50,440	163,200	3,228	13,418	24,961	46,023	154K	-98,363	8.02M
Book Value	9,988	14,389	21,199	718.9	3,833	7,892	16,074	51.5K	-82,928	268,493
Employees	10,537	63,257	104,774	1,903	12,082	32,150	75,903	232K	11.25	2.3M
Revenue	11,194	7,862	11,455	389.0	1,662	3,765	9,303	29K	-16,381	121,151
EBITDA	9,248	1,410	2,324	39.89	339.6	732.08	1,505	5.62K	-23,402	23,657
ROE	10,202	15.32	51.15	-12.4	7.71	14.33	21.93	46.7	-1,874	701.9
Eq Ret (A)	10,787	0.068	0.405	-0.59	-0.09	0.11	0.27	0.58	-7.72	2.93

Notes: Summary statistics for variables matching rolling 5-year sub-samples from 2002-2016. Monetary values are annual averages of the quarterly levels in USD, converted at contemporaneous exchange rates. Source: Bloomberg.

Table B.3: Firm Performance and Size Vs. Inward & Outward Connectedness

Panel A: Inward Connectedness by Firm

Explanatory Variable:	Total Equity	Ent. Value	Book Value	Employees	Revenue	EBITDA	ROE	Annual Eq. Ret.
Coefficient	0.0001***	7.43e-07	0.0001***	6.34e-06	0.0003***	0.0011***	-0.0137	-3.34***
S.E.	(3.3e-05)	(2.6e-06)	(4.19e-05)	(9.5e-06)	(7e-05)	(0.0004)	(0.011)	(0.964)
Beta	0.103	0.00431	0.0888	0.0228	0.0990	0.0949	-0.024	-0.0469
Obs.	11,207	10,002	9,988	10,537	11,194	9,248	10,202	10,787
R-squared	0.208	0.175	0.182	0.203	0.209	0.179	0.210	0.203

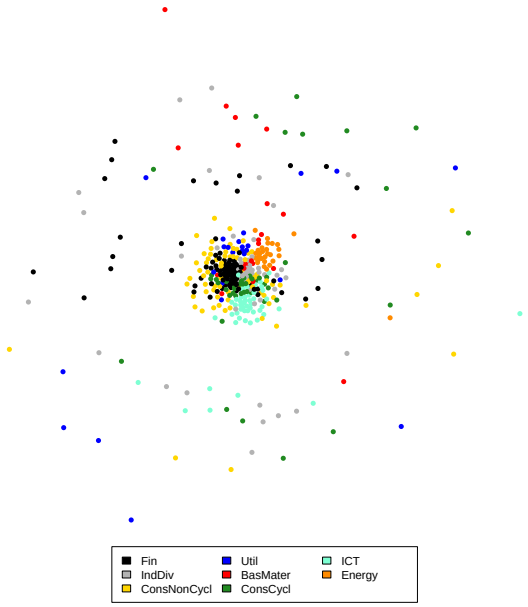
Panel B: Outward Connectedness by Firm

Explanatory Variable:	Total Equity	Ent. Value	Book Value	Employees	Revenue	EBITDA	ROE	Annual Eq. Ret.
Coefficient	3.9e-05**	9.78e-07	3.65e-05*	6.65e-06**	-1.7e-05	0.00016	0.0069	0.117
S.E.	(1.7e-05)	(2.6e-06)	(2e-05)	(3.3e-06)	(3.5e-05)	(0.0002)	(0.0065)	(0.494)
Beta	0.0594	0.00922	0.0447	0.0405	-0.0111	0.0210	0.0202	0.0027
Obs.	11,207	10,002	9,988	10,537	11,194	9,248	10,202	10,787
R-squared	0.317	0.331	0.332	0.318	0.314	0.323	0.321	0.323

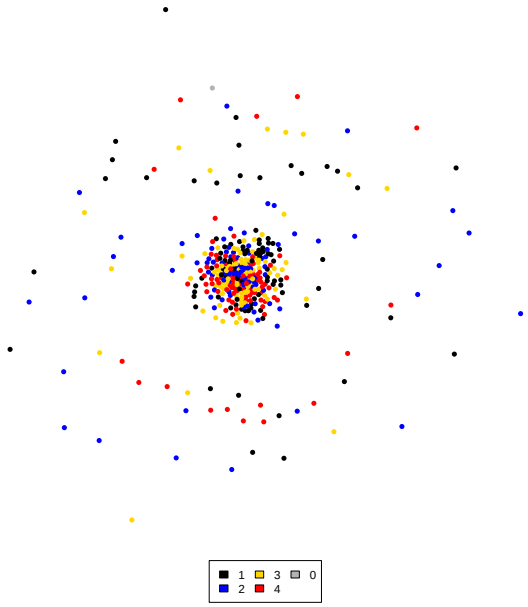
Notes: Rolling 5-year estimated firm network weights for sub-periods ending in 2002 through 2016. Each network is based on the one-period GIRFs from a VAR(1) system of daily equity log returns for all firms available continuously within each 5-year sub-period. These are matched with the average values of the weight and performance measures over the final year of each network (e.g., the network weights calculated for the 1998-2002 network are matched with the 2002 firm measures). The weights are summed at the firm level to get the inward and outward connectedness. Regressions include year-industry fixed effects. Robust standard errors clustered at the firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Figure B.6: Global Network by Different Firm Attributes (1991-2016)

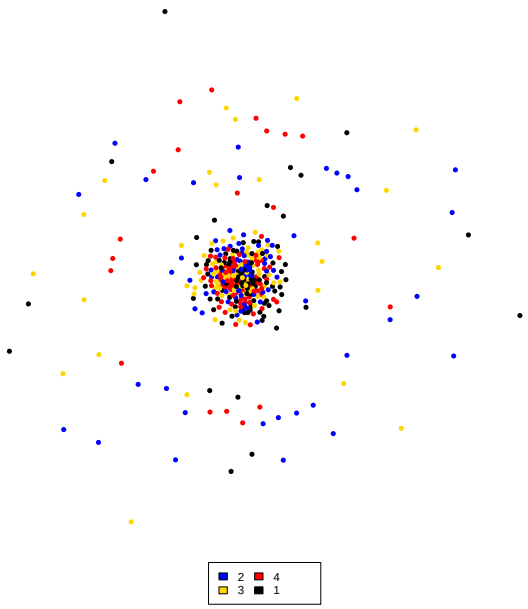
(a) Industry



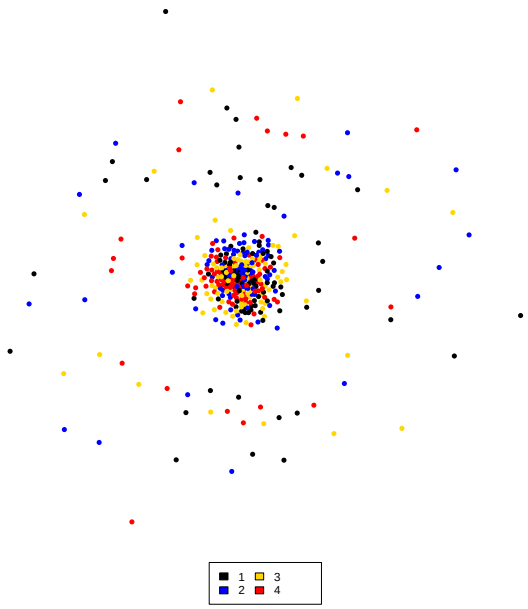
(b) Number of Employees



(c) Total Equity



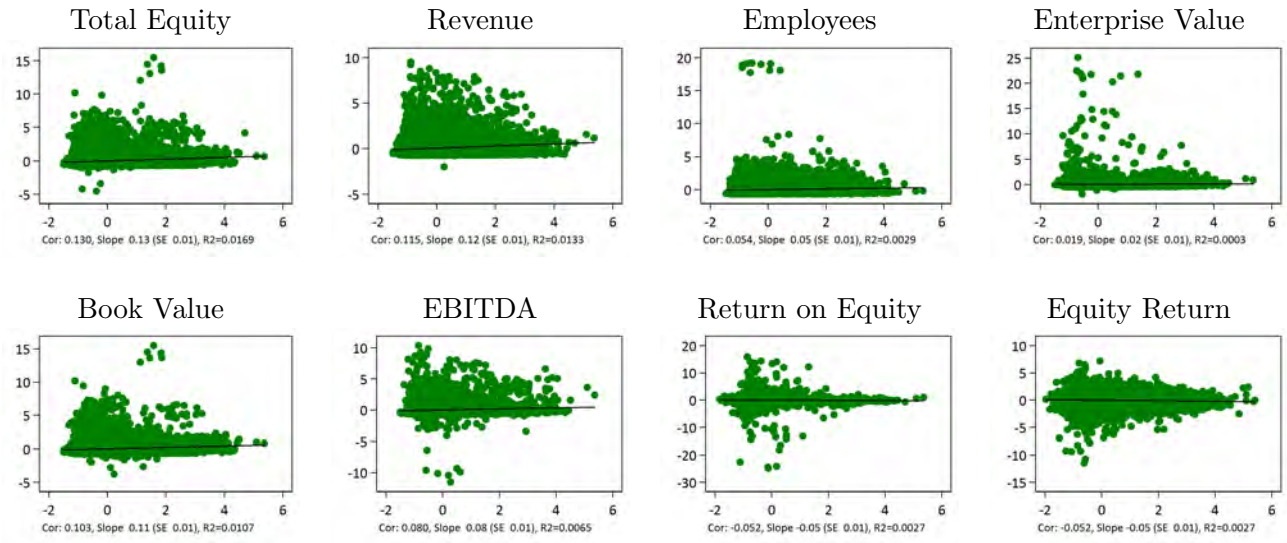
(d) Revenue



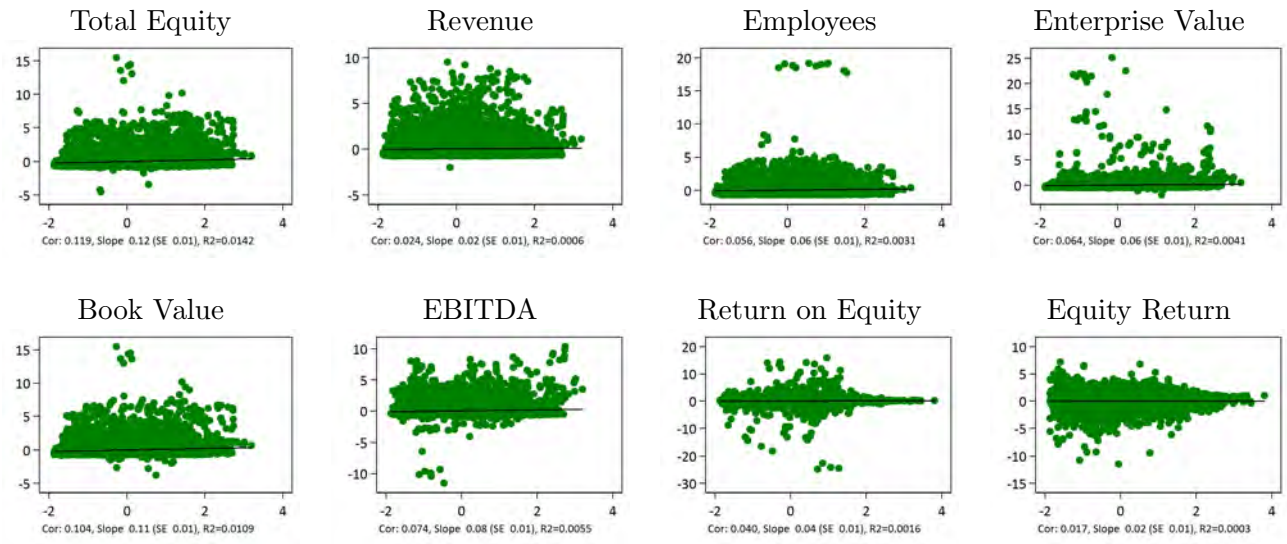
Notes: Daily equity return based network for 382 firms across 18 countries, with equities issued in 13 currencies, available continuously from January 1991 through September 2016. Each node represents a firm, colored by (a) industry, (b) number of employees, (c) total equity, or (d) total revenue. Proximity of nodes to one another is determined by the one-period GIRFs, estimated from the VAR(1) system. The clustering for total equity, revenue and employees are defined by quartiles of each measure's distribution, where higher quartile numbers correspond with greater size and the zero categories indicate missing data.

Figure B.7: Firm Performance and Size Vs. Network Connectedness

Panel A: Inward Connectedness by Firm



Panel B: Outward Connectedness by Firm



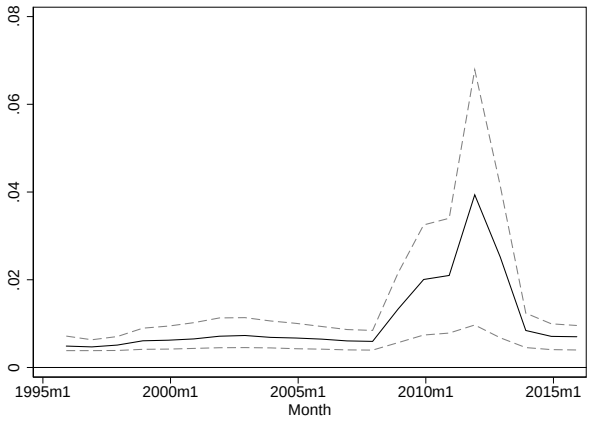
Notes: Rolling 5-year estimated firm network weights for sub-periods ending in 2002 through 2016. Each network is based on the one-period GIRFs from a VAR(1) system of daily equity log returns for all firms available continuously within each 5-year sub-period. These are matched with the average values of the size and performance measures over the final year of each network (e.g., the network weights calculated for the 1998-2002 network are matched with the 2002 firm measures). The edge weights are summed at the firm level to get the inward and outward connectedness, with these measures along the x-axis. Data are standardized to have mean zero and a standard deviation of one to make them comparable across measures and over time.

C Robustness and Fragility: Further Analysis

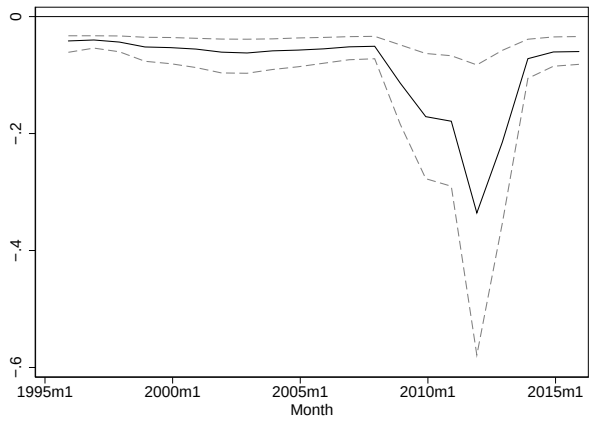
C.1 Spatial Auto-Regression Model

Figure C.1: RyF Properties Over Time in a Spatial Auto-regression Model

(a) Robustness ($\alpha_\tau \mathbf{1}_I \beta$)



(b) Fragility ($\alpha_\tau \mathbf{1}_I \lambda$)



Notes: Robustness (a) and Fragility (b) terms are obtained from a spatial auto-regression model in which the dependent variable is the firm's monthly equity return, the weight adjacency matrices are normalized so the average weights for every firm sum to one across each sample examined, and the network state variable is an indicator for the average monthly TED spread being in the top 10% of its sample distribution. The average network parameter estimates are γ=0.630, β=0.0034 and λ=-0.0291. The solid black lines are the within period averages, and the dashed lines represent the minimum and maximum values.

Figure C.2: Global Network Spatial Model Robustness Terms Vs. Sum of Weights In

Note: The dependent variables in the estimated model are the monthly firm equity returns, the weight adjacency matrices are normalized so the average weights for each firm observation sum to one across each sample examined, and the network state variable is an indicator for the average monthly TED spread being in the top 10% of its sample distribution. This sample includes 382 firms across 18 countries, with equities issued in 13 currencies.

C.2 Sub-Periods

Table C.1: Global Network Monthly Equity Return Crises, Sub-period Splits

	(1)	(2)	(3)	(4)	
	1996-2006		2007-2016		
Robustness: Diversification	-0.00413***	-0.00410***	-0.00150***	-0.00128***	-
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.000363)	(0.000369)	(0.000179)	(0.000167)	
Fragility: Direct Contagion	0.0333***	0.0332***	0.0160***	0.0171***	+
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$	(0.00142)	(0.00142)	(0.000834)	(0.000899)	
Fragility: Network Vulnerability	0.0115**	0.0198**	0.0599***	0.128***	+
λN_t	(0.00517)	(0.0100)	(0.00420)	(0.00772)	
Robustness: Network Resistance		-0.00131		-0.00341***	-
$\omega N_t \sum_{j \neq i} w_{ij\tau}$		(0.00106)		(0.000504)	
Fragility: Network Crisis Reinforced Contagion		0.00581		0.000937	+
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.00554)		(0.00101)	
Observations	50,424	50,424	44,694	44,694	

Notes: The dependent variable is the monthly equity return distress indicator for firm i, the neighboring firm health variable (D_{jt}) is the equity return distress indicator for firm j, and the network state variable (N_t) is an indicator for the average monthly TED spread being in the top 25%. This sample includes 382 firms across 18 countries, with equities issued in 13 currencies. Robust standard errors clustered at the firm level in parentheses. The marginal effects for the probit regressions are provided in place of the latent regression coefficient estimates. *** p<0.01, ** p<0.05, * p<0.1

Table C.2: Global Network Continuous Monthly Equity Returns, Sub-period Splits

	(1)	(2)	(3)	(4)	
	1996-2006		2007-2016		
Robustness: Diversification	0.00138***	0.00131***	0.000753***	0.000602***	+
$\phi \sum_{j \neq i} w_{ij\tau}$	(7.16e-05)	(7.01e-05)	(4.02e-05)	(3.16e-05)	
Fragility: Direct Contagion	-0.0172***	-0.0172***	-0.00974***	-0.00938***	-
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$	(0.000691)	(0.000693)	(0.000447)	(0.000411)	
Fragility: Network Vulnerability	0.0280***	0.0101**	-0.00794***	-0.0357***	-
λN_t	(0.00232)	(0.00395)	(0.00132)	(0.00251)	
Robustness: Network Resistance		0.00246***		0.00248***	+
$\omega N_t \sum_{j \neq i} w_{ij\tau}$		(0.000433)		(0.000173)	
Fragility: Network Crisis Reinforced Contagion		-0.00863***		-0.00362***	-
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.00251)		(0.000436)	
Observations	50,424	50,424	44,694	44,694	
R-squared	0.092	0.093	0.118	0.131	

Notes: The dependent variable is the monthly equity return for firm i, the neighboring firm health variable (D_{jt}) is the equity return distress indicator for firm j, and the network state variable (N_t) is an indicator for the average monthly TED spread being in the top 25%. This sample includes 382 firms across 18 countries, with equities issued in 13 currencies. Robust standard errors clustered at the firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table C.3: Rolling Sample Global Network Monthly Equity Return Crises, 1986-2016

Panel A: Regression Estimates

	(1)	(2)	(3)	(4)	(5)	
Robustness: Diversification	9.84e-05**		-0.00182***	-0.00169***	-0.00164***	-
$\phi \sum_{j \neq i} w_{ij\tau}$	(4.83e-05)		(9.54e-05)	(9.34e-05)	(9.23e-05)	
Fragility: Direct Contagion		0.0119***	0.0161***	0.0154***	0.0157***	+
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.000395)	(0.000452)	(0.000447)	(0.000451)	
Fragility: Network Vulnerability				0.0778***	0.166***	+
λN_t				(0.00466)	(0.00888)	
Robustness: Network Resistance					-0.00351***	-
$\omega N_t \sum_{j \neq i} w_{ij\tau}$					(0.000405)	
Fragility: Network Crisis Reinforced Contagion					0.00109	+
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$					(0.000811)	
Observations	216,159	216,159	216,159	216,159	216,159	

Panel B: Standardized Coefficients

	(4)	(5)	
Robustness: Diversification	-4.0%	-3.9%	-
Fragility: Direct Contagion	5.9%	6.0%	+
Fragility: Network Vulnerability	7.8%	16.6%	+
Robustness: Network Resistance		-8.4%	-
Fragility: Network Crisis Reinforced Contagion		0.4%	+

Table C.4: Rolling Sample Global Network Continuous Monthly Equity Returns, 1986-2016

Panel A: Regression Estimates

	(1)	(2)	(3)	(4)	(5)	
Robustness: Diversification	-1.73e-05**		0.000604***	0.000567***	0.000549***	+
$\phi \sum_{j \neq i} w_{ij\tau}$	(8.74e-06)		(1.98e-05)	(1.87e-05)	(1.82e-05)	
Fragility: Direct Contagion		-0.00673***	-0.00844***	-0.00813***	-0.00820***	-
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.000191)	(0.000234)	(0.000229)	(0.000230)	
Fragility: Network Vulnerability				-0.0358***	-0.0634***	-
λN_t				(0.00212)	(0.00360)	
Robustness: Network Resistance					0.00223***	+
$\omega N_t \sum_{j \neq i} w_{ij\tau}$					(0.000175)	
Fragility: Network Crisis Reinforced Contagion					-0.00212***	-
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$					(0.000381)	
Observations	216,159	216,159	216,159	216,159	216,159	
R-squared	0.000	0.066	0.082	0.086	0.088	

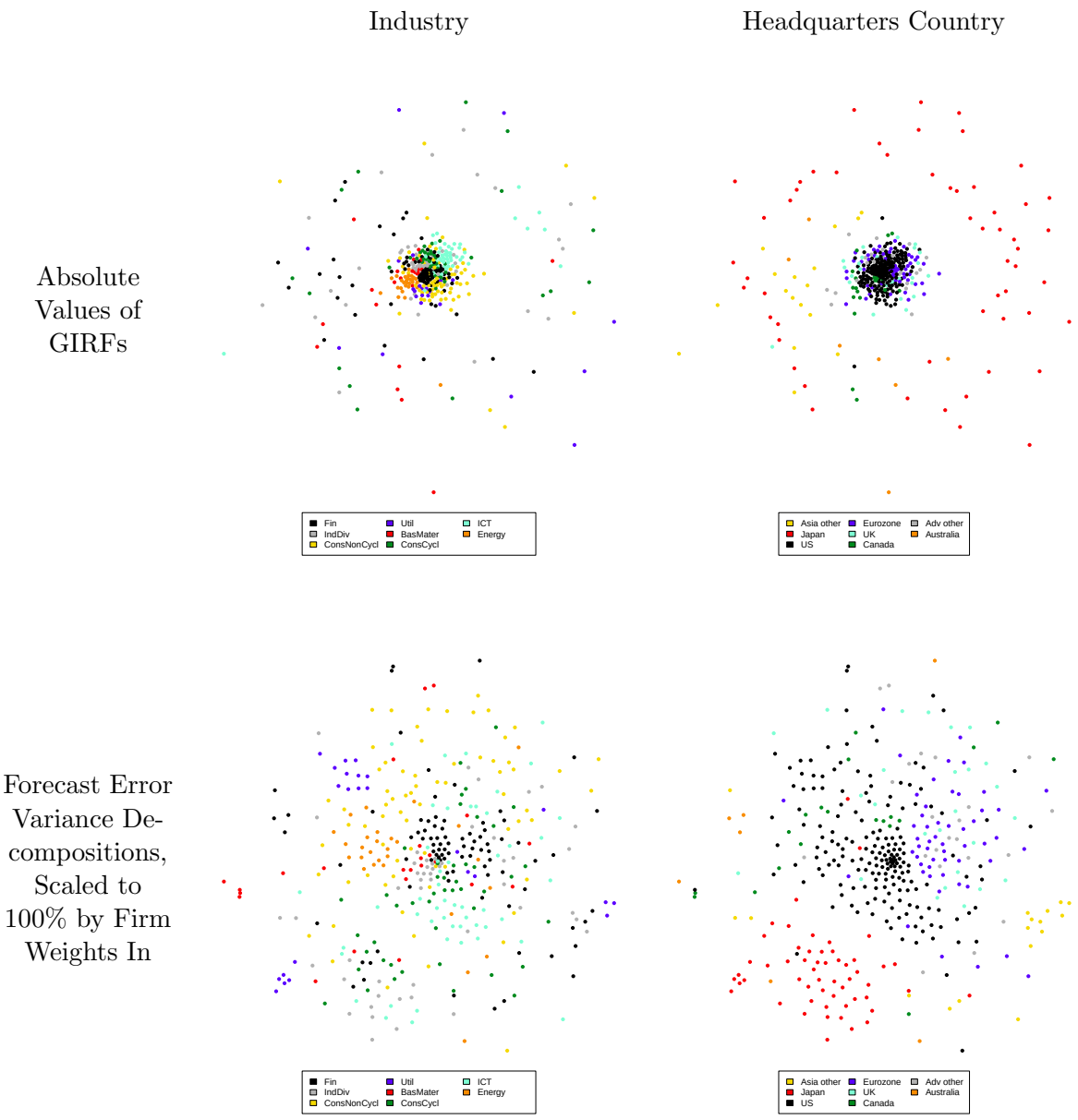
Panel B: Standardized Coefficients

	(4)	(5)	
Robustness: Diversification	13.5%	13.1%	+
Fragility: Direct Contagion	-31.3%	-31.6%	-
Fragility: Network Vulnerability	-35.8%	-63.4%	-
Robustness: Network Resistance		53.3%	+
Fragility: Network Crisis Reinforced Contagion		-8.2%	-

Notes: The neighboring firm health variable (D_{jt}) is the equity return distress indicator for firm j, and the network state variable (N_t) is an indicator for the average monthly TED spread being in the top 10%. Effects of a network crisis state indicate the effect of the indicator variable going from zero to one, and the interactions with the weight ($w_{ij\tau}$) and crisis sums are this times the standard deviation of the interacted sum term. This sample includes 1,053 firms across 49 countries, with equities issued in 35 currencies. The dependent variable is the monthly equity return distress indicator for firm i in Table C.3, where the marginal effects for the probit regressions are provided. The dependent variable is the monthly equity return for firm i in Table C.4. Robust standard errors clustered at the firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

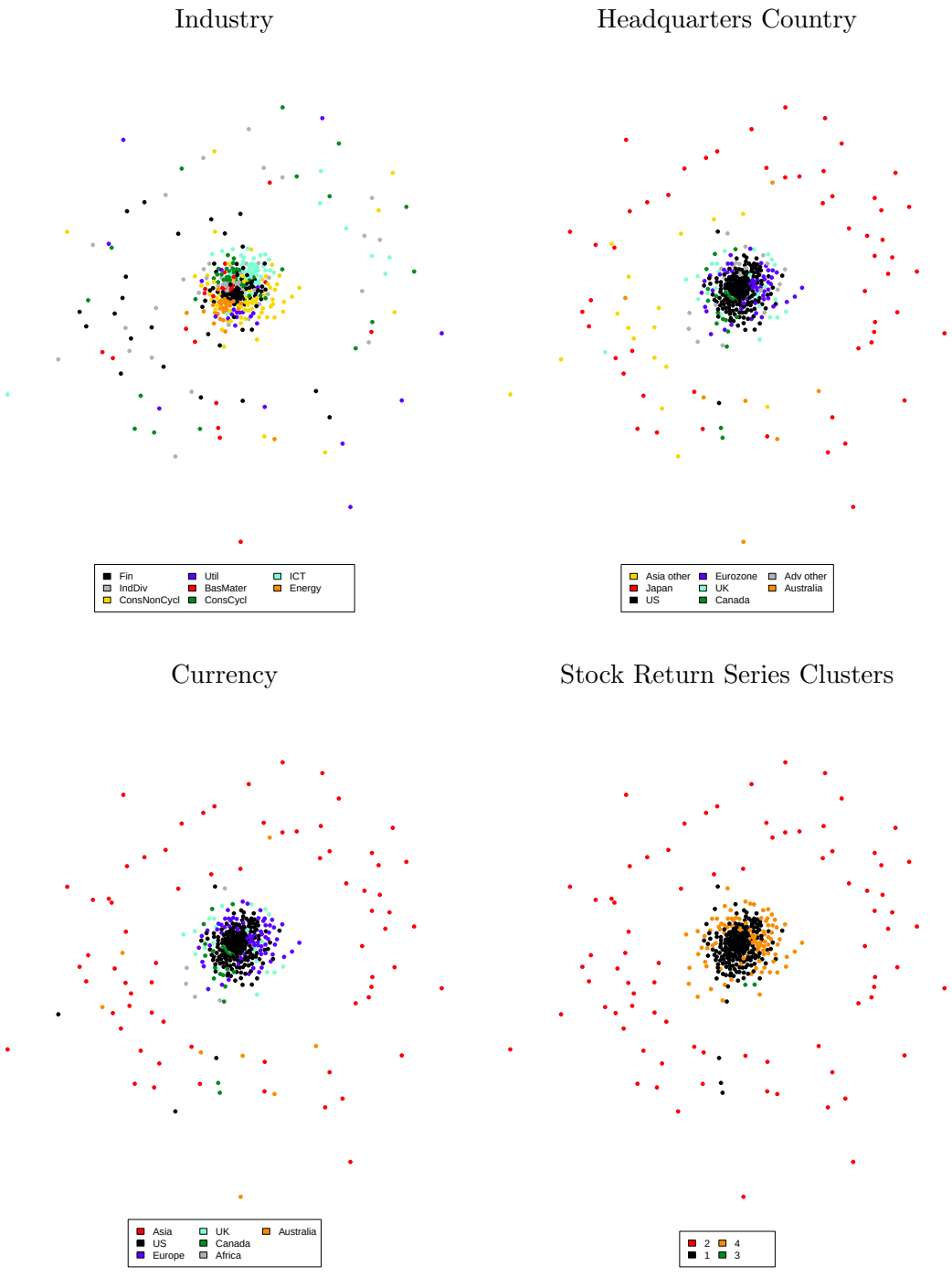
C.3 GFEVD, Lags, Horizons, and Frequency

Figure C.3: Global Network, 1991-2016, GIRF vs FEVD Base Networks



Notes: Daily equity return based network for all firms available continuously from January 1991 through September 2016, using our standard GIRF based networks and the approach of Demirer et al. (2018) using forecast error variance decompositions. Estimated using 1 lag in the VAR and GIRF horizon=1. This sample includes 382 firms across 18 countries, with equities issued in 13 currencies. gcor network correlation between the two matrices is 0.0071 and is statistically significant at the 1% level using the QAP network comparison test.

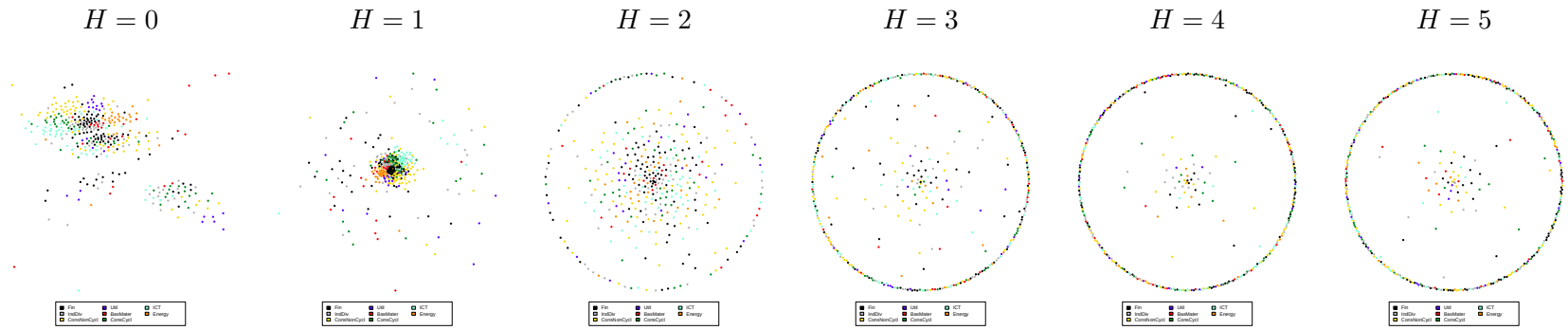
Figure C.4: Global Network, 1991-2016, by Firm Categories for 5 Lags



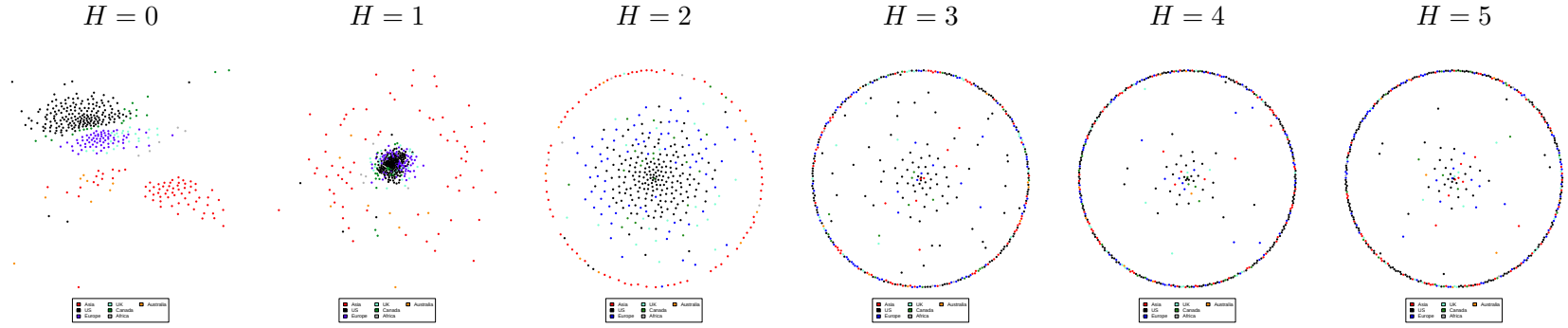
Notes: Daily equity return based network for all firms available continuously from January 1991 through September 2016. Estimated using 5 lags in the VAR and GIRF horizon=1. This sample includes 382 firms across 18 countries, with equities issued in 13 currencies.

Figure C.5: Global Network with GIRF Horizons 0 to 5 (1991-2016)

A. Colored by Industry



B. Colored by Country



Notes: Daily equity return based network for all firms continuously available during the 1991-2016 period. Each node represents a firm colored by industry in Panel A and country of equity issuance in Panel B. Proximity of nodes to one another is determined by the one- to five-day GIRFs, estimated from the VAR(1) system.

Table C.5: RyF Global Network (1996-2016): Different GIRF Horizons

Panel A: Dependent Variable: Firm Distress Indicator

	(1) H=0	(2) H=1	(3) H=2	(4) H=3	(5) H=4	(6) H=5	
Robustness: Diversification	-0.00126***	-0.00232***	-0.0122***	-0.0307***	-0.0801***	-0.145***	(–)
$\phi \sum_{j \neq i} w_{ij\tau}$	(6.12e-05)	(0.000200)	(0.000659)	(0.00247)	(0.00596)	(0.0104)	
Fragility: Direct Contagion	0.00899***	0.0210***	0.0842***	0.222***	0.563***	0.919***	(+)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$	(0.000268)	(0.000927)	(0.00321)	(0.0103)	(0.0251)	(0.0399)	
Fragility: Network Vulnerability	0.0214***	0.0811***	0.0844***	0.104***	0.121***	0.139***	(+)
λN_t	(0.00509)	(0.00684)	(0.00654)	(0.00807)	(0.00797)	(0.00771)	
Observations	95,118	95,118	95,118	95,118	95,118	95,118	

Panel B: Dependent Variable: Equity Returns

	(1) H=0	(2) H=1	(3) H=2	(4) H=3	(5) H=4	(6) H=5	
Robustness: Diversification	0.000298***	0.000771***	0.00340***	0.00895***	0.0224***	0.0483***	(+)
$\phi \sum_{j \neq i} w_{ij\tau}$	(9.98e-06)	(3.89e-05)	(0.000166)	(0.000502)	(0.00112)	(0.00239)	
Fragility: Direct Contagion	-0.00538***	-0.0111***	-0.0456***	-0.120***	-0.299***	-0.503***	(–)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$	(0.000120)	(0.000492)	(0.00184)	(0.00609)	(0.0124)	(0.0224)	
Fragility: Network Vulnerability	-0.0219***	-0.0388***	-0.0436***	-0.0485***	-0.0538***	-0.0567***	(–)
λN_t	(0.00243)	(0.00266)	(0.00254)	(0.00269)	(0.00262)	(0.00259)	
Observations	95,118	95,118	95,118	95,118	95,118	95,118	
R-squared	0.157	0.099	0.100	0.093	0.084	0.071	

Notes: Network links from firm j to firm i ($w_{ij\tau}$) are obtained from the global inter-firm network estimated the previous 5-years under different GIRF horizons; D_{jt} is the equity return distress indicator for firm j; and N_t is an indicator for the average monthly TED spread being in the top 10% of the distribution. In Panel A, the marginal effects for the probit regressions are reported, where the dependent variable is the monthly equity return distress indicator for firm i defined as being in the worst 10% tail of the overall sample distribution. In Panel B, OLS coefficients are reported, where the dependent variable is the monthly equity return for firm i. In both panels, the last column reports whether the variable is expected to relate to robustness (+) or fragility (−). *** p<0.01, ** p<0.05, * p<0.1

Table C.6: RyF Global Network (1996-2016) - Weekly Network Estimation

Dependent Variable: Firm Equity Return Distress Indicator

	(1)	(2)	(3)	(4)	(5)	
Robustness: Diversification	0.479360***		-0.630066***	-0.610128***	-0.596796***	(−)
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.053600)		(0.081417)	(0.081562)	(0.081157)	
Fragility: Direct Contagion		7.600774***	8.457715***	8.321011***	8.417694***	(+)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.391176)	(0.393411)	(0.396819)	(0.414828)	
Fragility: Network Vulnerability				0.204991***	0.439967***	(+)
λN_t				(0.032436)	(0.062351)	
Robustness: Network Resistance					-0.428526***	(−)
$\omega N_t \sum_{j \neq i} w_{ij\tau}$					(0.179944)	
Fragility: N Crisis Reinforced Contagion					-0.876147	(+)
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$					(0.424249)	
Observations	95,118	95,118	95,118	95,118	95,118	
Pseudo R-squared	0.007	0.143	0.150	0.150	0.151	

Notes: Network links from firm j to firm i ($w_{ij\tau}$) are obtained from the global inter-firm network estimated the previous 5-years with weekly, instead of daily data. D_{jt} is the equity return distress indicator for firm j; and N_t is an indicator for the average monthly TED spread being in the top 10% of its sample distribution. The marginal effects for the probit regressions are reported, where the dependent variable is the monthly equity return distress indicator for firm i defined as being in the worst 10% tail of the overall sample distribution, along with McFadden's pseudo R-squared. The last column reports whether the variable is expected to relate to robustness (+) or fragility (−). Robust standard errors clustered at the firm level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

C.4 First Differences and Alternative Measures of Network Crisis

Table C.7: Global Network Continuous Monthly Equity Returns, 1996-2016 in First Differences

Panel A: Regression Estimates

	(1)	(2)	(3)	(4)	(5)	
Robustness: Diversification	-0.000627**		0.00257***	0.00230***	0.00223***	+
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.000305)		(0.000320)	(0.000317)	(0.000322)	
Fragility: Direct Contagion		-0.0133***	-0.0134***	-0.0134***	-0.0134***	-
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.000634)	(0.000639)	(0.000639)	(0.000645)	
Fragility: Network Vulnerability				-0.0154***	-0.00498	-
λN_t				(0.00237)	(0.00395)	
Robustness: Network Resistance					-0.000712***	+
$\omega N_t \sum_{j \neq i} w_{ij\tau}$					(0.000226)	
Fragility: Network Crisis Reinforced Contagion					-0.000799	-
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$					(0.000757)	
Observations	94,736	94,736	94,736	94,736	94,736	
R-squared	0.000	0.081	0.082	0.082	0.082	

Panel B: Standardized Coefficients

	Standardized coefficients for regression:		
	(4)	(5)	
Robustness: Diversification	36.8%	35.7%	+
Fragility: Direct Contagion	-37.4%	-37.4%	-
Fragility: Network Vulnerability	-15.4%	-5.0%	-
Robustness: Network Resistance		-11.4%	+
Fragility: Network Crisis Reinforced Contagion		-2.2%	-

Note: The dependent variable is the monthly equity return for firm i, the neighboring firm health variable (D_{jt}) is the equity return distress indicator for firm j, and the network state variable (N_t) is an indicator for the average monthly TED spread being in the top 10%. Effects of a network crisis state indicate the effect of the indicator variable going from zero to one, and the interactions with the weight ($w_{ij\tau}$) and crisis sums are this times the standard deviation of the interacted sum term. This sample includes 382 firms across 18 countries, with equities issued in 13 currencies. Robust standard errors clustered at the firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table C.8: RyF Global Network (1996-2016): Various Network Crisis Measures

Panel A: Dependent Variable: Firm Equity Return Distress Indicator

	(1) Indicator TedSprd	(2) Indicator VIX	(3) Indicator RetSP500	(4) Indicator % Distressed Firms	(5) TedSprd	(6) VIX	(7) RetSP500†	(8) % Distressed Firms	
Robustness: Diversification $\phi \sum_{j \neq i} w_{ij\tau}$	-0.0023***	-0.0021***	-0.0013***	-0.0013***	-0.0020***	-0.0017***	-0.0009***	4.29e-05	(–)
	(0.000200)	(0.000193)	(0.000159)	(0.000163)	(0.000197)	(0.000181)	(0.000138)	(0.000115)	
Fragility: Direct Contagion $\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$	0.0210***	0.0187***	0.0120***	0.0112***	0.0199***	0.0156***	0.00912***	0.00245***	(+)
	(0.000927)	(0.000874)	(0.000684)	(0.000605)	(0.000933)	(0.000796)	(0.000568)	(0.000419)	
Fragility: Network Vulnerability λN_t	0.0811***	0.0607***	0.148***	0.120***	0.0406***	0.00350***	-1.079***	0.518***	(+)
	(0.00684)	(0.00369)	(0.00758)	(0.00395)	(0.00239)	(0.000133)	(0.0414)	(0.0163)	
Observations	95,118	95,118	95,118	95,118	95,118	95,118	95,118	95,118	
Pseudo R-squared	0.109	0.112	0.131	0.153	0.113	0.126	0.149	0.177	

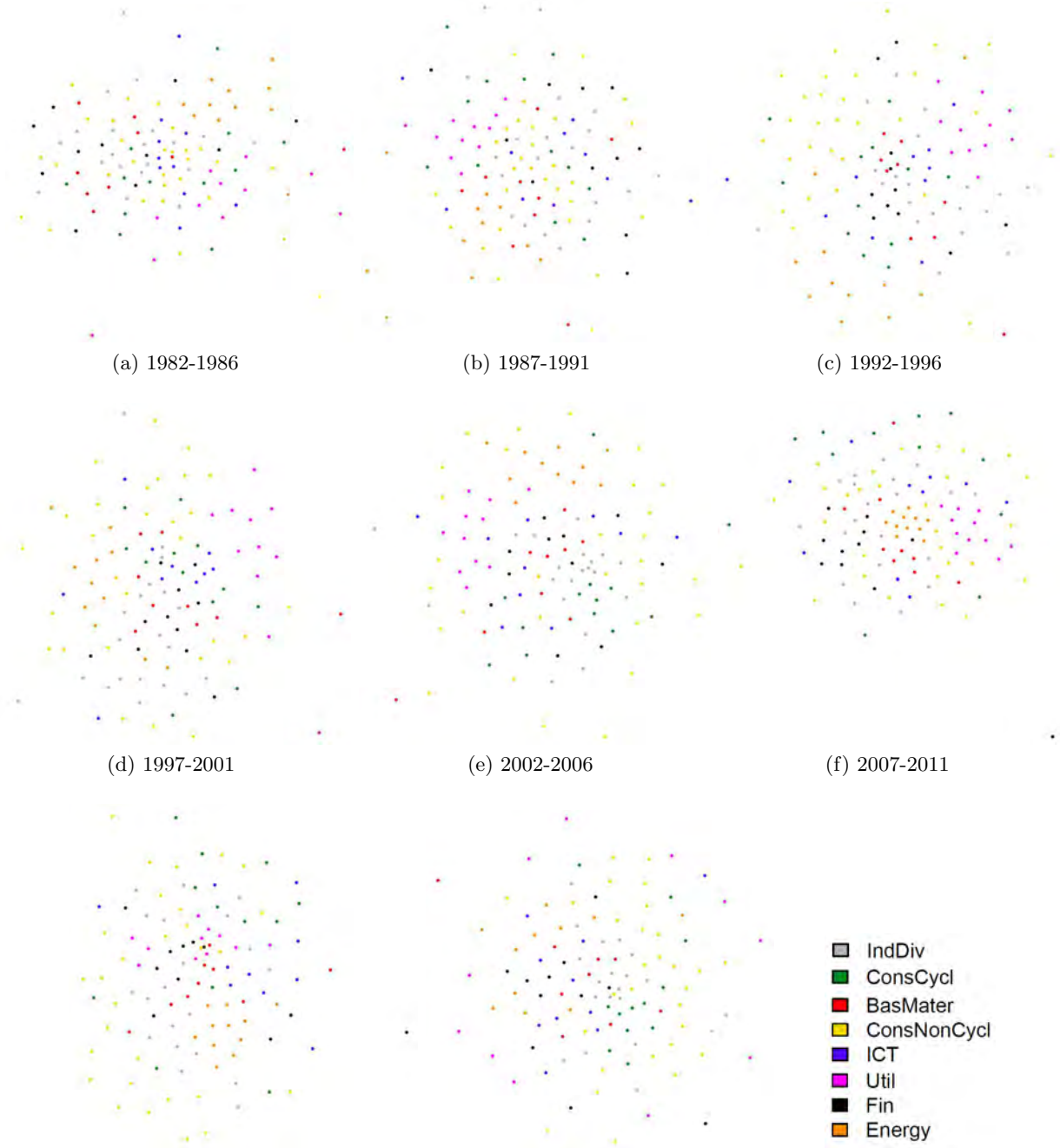
Panel B: Dependent Variable: Firm Monthly Equity Returns

	(1) Indicator TedSprd	(2) Indicator VIX	(3) Indicator RetSP500	(4) Indicator % Distressed Firms	(5) TedSprd	(6) VIX	(7) RetSP500†	(8) % Distressed Firms	
Robustness: Diversification $\phi \sum_{j \neq i} w_{ij\tau}$	0.00077***	0.00080***	0.00048***	0.00048***	0.00077***	0.00079***	0.00017***	3.35e-05	(+)
	(3.89e-05)	(4.15e-05)	(3.09e-05)	(3.16e-05)	(4.00e-05)	(4.30e-05)	(2.15e-05)	(2.34e-05)	
Fragility: Direct Contagion $\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$	-0.0111***	-0.0113***	-0.0069***	-0.0073***	-0.0113***	-0.0113***	-0.0031***	-0.0017***	(–)
	(0.000492)	(0.000513)	(0.000383)	(0.000386)	(0.000501)	(0.000533)	(0.000272)	(0.000320)	
Fragility: Network Vulnerability λN_t	-0.0388***	-0.0055***	-0.0592***	-0.0432***	-0.0075***	-0.0002***	0.823***	-0.303***	(–)
	(0.00266)	(0.00138)	(0.00274)	(0.00156)	(0.00123)	(6.47e-05)	(0.0256)	(0.00978)	
Observations	95,118	95,118	95,118	95,118	95,118	95,118	95,118	95,118	
R-squared	0.099	0.094	0.120	0.125	0.095	0.094	0.188	0.158	

Notes: Network links from firm j to firm i ($w_{ij\tau}$) are obtained from the global inter-firm network estimated the previous 5-years; D_{jt} is the equity return distress indicator for firm j; and N_t is (1) an indicator for the average monthly TED spread being in the top 10% of the distribution (benchmark); (2) an indicator for the average monthly VIX being in the top 10% of the distribution; (3) an indicator for the monthly return in the S&P 500 Index being in the worst 10% of the distribution; (4) an indicator for the within-period averages of the D_{jt} measures across all firms being in the top 10% of the distribution; (5) the average monthly TED spread; (6) the average monthly VIX; (7) the average monthly return in the S&P 500 Index; or (8) the share of firms currently in a distressed state. Robust standard errors clustered at the firm level are reported in parentheses. In Panel A, the marginal effects for the probit regressions are reported, where the dependent variable is the monthly equity return distress indicator for firm i defined as being in the worst 10% tail of the overall sample distribution, along with McFadden's pseudo R-squared. In Panel B, OLS coefficients are reported, where the dependent variable is the monthly equity return for firm i. In both panels, the last column reports whether the variable is expected to relate to robustness (+) or fragility (−). †Expected to have an opposite network vulnerability coefficient sign. *** p<0.01, ** p<0.05, * p<0.1

C.5 RyF U.S. Networks

Figure C.6: U.S. Network in Different Periods by Industry



(a) 1982-1986 (b) 1987-1991 (c) 1992-1996

(d) 1997-2001 (e) 2002-2006 (f) 2007-2011

(g) 2012-2016 (h) 1981-2016

Notes: Daily equity return based network for firms with equities issued in USD, available during different sub-periods. Each node represents a firm, colored by industry. Proximity of nodes to one another is determined by the one-period GIRFs, estimated from the VAR(1) system of firms continuously traded during every period.

Table C.9: RyF U.S. Network (1986-2016): Probability of Firm Distress

Panel A: Regression Estimates

	(1)	(2)	(3)	(4)	(5)	
Robustness: Diversification	-0.00238***		-0.0134***	-0.0129***	-0.0124***	(–)
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.000623)		(0.000958)	(0.000942)	(0.000941)	
Fragility: Direct Contagion		0.0759***	0.0920***	0.0895***	0.0893***	(+)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.00540)	(0.00570)	(0.00560)	(0.00559)	
Fragility: Network Vulnerability				0.0412***	0.0797***	(+)
λN_t				(0.00684)	(0.0177)	
Robustness: Network Resistance					-0.00977**	(–)
$\omega N_t \sum_{j \neq i} w_{ij\tau}$					(0.00390)	
Fragility: Network Crisis Reinforced Contagion					0.00623	(+)
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$					(0.00580)	
Observations	41,697	41,697	41,697	41,697	41,697	

Panel B: Standardized Coefficients

	(4)	(5)	
Robustness: Diversification	-3.7%	-3.6%	(–)
Fragility: Direct Contagion	4.9%	4.9%	(+)
Fragility: Network Vulnerability	4.1%	8.0%	(+)
Robustness: Network Resistance		-2.8%	(–)
Fragility: Network Crisis Reinforced Contagion		0.3%	(+)

Table C.10: RyF U.S. Network (1986-2016): Firm Equity Returns

Panel A: Regression Estimates

	(1)	(2)	(3)	(4)	(5)	
Robustness: Diversification	0.000609***		0.00389***	0.00378***	0.00342***	(+)
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.000124)		(0.000231)	(0.000225)	(0.000213)	
Fragility: Direct Contagion		-0.0493***	-0.0555***	-0.0540***	-0.0525***	(–)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.00249)	(0.00280)	(0.00272)	(0.00293)	
Fragility: Network Vulnerability				-0.0212***	-0.0479***	(–)
λN_t				(0.00270)	(0.00545)	
Robustness: Network Resistance					0.0102***	(+)
$\omega N_t \sum_{j \neq i} w_{ij\tau}$					(0.00123)	
Fragility: Network Crisis Reinforced Contagion					-0.0115***	(–)
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$					(0.00319)	
Observations	41,697	41,697	41,697	41,697	41,697	
R-squared	0.000	0.104	0.120	0.122	0.125	

Panel B: Standardized Coefficients

	(4)	(5)	
Robustness: Diversification	13.6%	12.3%	(+)
Fragility: Direct Contagion	-37.1%	-36.1%	(–)
Fragility: Network Vulnerability	-26.5%	-59.9%	(–)
Robustness: Network Resistance		36.6%	(+)
Fragility: Network Crisis Reinforced Contagion		-7.9%	(–)

Notes: Network links from firm j to i ($w_{ij\tau}$) are obtained from the 113 U.S. inter-firm network estimated the previous 5-years; D_{jt} is the equity return distress indicator for firm j; and N_t is an indicator for the average monthly TED spread being in the top 10% of the distribution. The marginal effects for the probit regressions are reported in Table C.9, where the dependent variable is the monthly equity return distress indicator for firm i defined as being in the worst 10% tail of the distribution. OLS coefficients are reported in Table C.10, where the dependent variable is the monthly equity return for firm i. Results are similar if including firm fixed effects. The last column reports whether the variable is expected to relate to robustness (+) or fragility (−). Robust standard errors clustered at the firm level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table C.11: RyF U.S. Network (1986-2016): Annual Frequency

Panel A: Dependent Variable: Probability of Firm Distress

	(1)	(2)	(3)	(4)	(5)	
Robustness: Diversification	-0.00976***		-0.0134***	-0.00836***	-0.0119***	(–)
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.00200)		(0.00195)	(0.00190)	(0.00181)	
Fragility: Direct Contagion		0.0840***	0.0888***	0.0309**	0.134***	(+)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.0118)	(0.0123)	(0.0136)	(0.0171)	
Fragility: Network Vulnerability				0.322***	0.748***	(+)
λN_t				(0.0728)	(0.0786)	
Robustness: Network Resistance					0.142	(–)
$\omega N_t \sum_{j \neq i} w_{ij\tau}$					(0.109)	
Fragility: Network Crisis Reinforced Contagion					-0.417**	(+)
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$					(0.190)	
Observations	3,390	3,390	3,390	3,390	3,390	

Panel B: Dependent Variable: Firm Equity Returns

	(1)	(2)	(3)	(4)	(5)	
Robustness: Diversification	0.00764***		0.0144***	0.0100***	0.0133***	(+)
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.00150)		(0.00170)	(0.00162)	(0.00166)	
Fragility: Direct Contagion		-0.269***	-0.292***	-0.172***	-0.388***	(–)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.0258)	(0.0276)	(0.0330)	(0.0354)	
Fragility: Network Vulnerability				-0.341***	-0.837***	(–)
λN_t				(0.0666)	(0.106)	
Robustness: Network Resistance					-0.313	(+)
$\omega N_t \sum_{j \neq i} w_{ij\tau}$					(0.285)	
Fragility: Network Crisis Reinforced Contagion					1.093**	(–)
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$					(0.479)	
Observations	3,390	3,390	3,390	3,390	3,390	
R-squared	0.006	0.105	0.124	0.148	0.207	

Notes: Network links from firm j to i ($w_{ij\tau}$) are obtained from the 113 U.S. inter-firm network estimated the previous 5-years; D_{jt} is the equity return distress indicator for firm j; and N_t is an indicator for the average annual TED spread being in the top 10% of the distribution. In Panel A, the marginal effects for the probit regressions are reported, where the dependent variable is the annual equity return distress indicator for firm i defined as being in the worst 10% tail of the distribution. In Panel B, OLS coefficients are reported, where the dependent variable is the annual equity return for firm i. Results are similar if including firm fixed effects. In both panels, the last column reports whether the variable is expected to relate to robustness (+) or fragility (−). Robust standard errors clustered at the firm level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table C.12: RyF U.S. Networks During Different Periods

Panel A: Dependent Variable: Probability of Firm Distress

	(1)	(2)	(3)	(4)	(5)	(6)	
	1986-1995		1996-2006		2007-2016		
Robustness: Diversification	-0.00636***	-0.00627***	-0.0253***	-0.0253***	-0.0133***	-0.0116***	(–)
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.00105)	(0.00124)	(0.00329)	(0.00340)	(0.00129)	(0.00132)	
Fragility: Direct Contagion	0.0818***	0.0751***	0.176***	0.174***	0.0640***	0.0664***	(+)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$	(0.00544)	(0.00577)	(0.0135)	(0.0136)	(0.00597)	(0.00606)	
Fragility: Network Vulnerability	0.000593	-0.0107*	0.0196**	0.0149	0.0307***	0.0919***	(+)
λN_t	(0.00383)	(0.00616)	(0.00817)	(0.0176)	(0.00541)	(0.0157)	
Robustness: Network Resistance		0.000325		-0.00657		-0.0166***	(–)
$\omega N_t \sum_{j \neq i} w_{ij\tau}$		(0.00148)		(0.00939)		(0.00365)	
Fragility: Network Crisis Reinforced Contagion		0.0232***		0.0579		0.00991*	(+)
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.00777)		(0.0363)		(0.00596)	
Observations	13,560	13,560	14,916	14,916	13,221	13,221	

Panel B: Dependent Variable: Firm Equity Returns

	(1)	(2)	(3)	(4)	(5)	(6)	
	1986-1995		1996-2006		2007-2016		
Robustness: Diversification	0.00378***	0.00368***	0.00799***	0.00785***	0.00363***	0.00272***	(+)
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.000249)	(0.000284)	(0.000681)	(0.000658)	(0.000349)	(0.000267)	
Fragility: Direct Contagion	-0.0602***	-0.0560***	-0.0929***	-0.0909***	-0.0421***	-0.0412***	(–)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$	(0.00244)	(0.00279)	(0.00774)	(0.00791)	(0.00326)	(0.00341)	
Fragility: Network Vulnerability	0.00271**	0.00512**	0.0192***	0.0168**	-0.00721***	-0.0397***	(–)
λN_t	(0.00122)	(0.00221)	(0.00408)	(0.00766)	(0.00199)	(0.00507)	
Robustness: Network Resistance		-5.06e-05		0.00882**		0.0128***	(+)
$\omega N_t \sum_{j \neq i} w_{ij\tau}$		(0.000443)		(0.00384)		(0.00161)	
Fragility: Network Crisis Reinforced Contagion		-0.00762**		-0.0666***		-0.0140***	(–)
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.00368)		(0.0157)		(0.00259)	
Observations	13,560	13,560	14,916	14,916	13,221	13,221	
R-squared	0.197	0.197	0.097	0.098	0.112	0.126	

Notes: Network links from firm j to i ($w_{ij\tau}$) are obtained from the 113 U.S. inter-firm network estimated the previous 5-years; D_{jt} is the equity return distress indicator for firm j; and N_t is an indicator for the average monthly TED spread being in the top 25% of the distribution. In Panel A, the marginal effects for the probit regressions are reported, where the dependent variable is the monthly equity return distress indicator for firm i defined as being in the worst 10% tail of the distribution. In Panel B, OLS coefficients are reported, where the dependent variable is the monthly equity return for firm i. Results are similar if including firm fixed effects. In both panels, the last column reports whether the variable is expected to relate to robustness (+) or fragility (−). Robust standard errors clustered at the firm level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

C.6 Defactored Networks

Table C.13: RyF Global Network (1996-2016) - Excluding the First 3 Common Factors

Dependent Variable: Firm Equity Return Distress Indicator

	(1)	(2)	(3)	(4)	(5)	
Robustness: Diversification	0.009949**		-0.184145***	-0.181783***	-0.179645***	(–)
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.003937)		(0.017533)	(0.017421)	(0.017547)	
Fragility: Direct Contagion		0.619620***	1.552549***	1.534031***	1.539498***	(+)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.065563)	(0.136309)	(0.135274)	(0.139417)	
Fragility: Network Vulnerability				0.170497***	0.262774***	(+)
λN_t				(0.031221)	(0.041099)	
Robustness: Network Resistance					-0.104636**	(–)
$\omega N_t \sum_{j \neq i} w_{ij\tau}$					(0.050587)	
Fragility: N Crisis Reinforced Contagion					0.188894	(+)
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$					(0.245955)	
Observations	94,954	94,954	94,954	94,954	94,954	
Pseudo R-squared	0.000	0.012	0.026	0.026	0.026	

Notes: Network links from firm j to firm i ($w_{ij\tau}$) are obtained from the global inter-firm network estimated the previous 5-years, after removing the first 3 common factors. D_{jt} is the equity return distress indicator for firm j; and N_t is an indicator for the average monthly TED spread being in the top 10% of its sample distribution. The marginal effects for the probit regressions are reported, where the dependent variable is the monthly equity return distress indicator for firm i defined as being in the worst 10% tail of the overall sample distribution, along with McFadden's pseudo R-squared. The last column reports whether the variable is expected to relate to robustness (+) or fragility (−). Robust standard errors clustered at the firm level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table C.14: RyF Global Network (1996-2016) - Excluding the First 5 Common Factors

Dependent Variable: Firm Equity Return Distress Indicator

	(1)	(2)	(3)	(4)	(5)	
Robustness: Diversification	0.000473		-0.315243***	-0.309629***	-0.308874***	(–)
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.007031)		(0.024984)	(0.024747)	(0.024999)	
Fragility: Direct Contagion		1.058168***	2.687021***	2.639913***	2.688802***	(+)
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$		(0.085063)	(0.179952)	(0.177909)	(0.184202)	
Fragility: Network Vulnerability				0.160606***	0.294144***	(+)
λN_t				(0.030841)	(0.042645)	
Robustness: Network Resistance					-0.138009*	(–)
$\omega N_t \sum_{j \neq i} w_{ij\tau}$					(0.075807)	
Fragility: N Crisis Reinforced Contagion					-0.149505	(+)
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$					(0.341441)	
Observations	94,937	94,937	94,937	94,937	94,937	
Pseudo R-squared	0.000	0.010	0.023	0.024	0.024	

Notes: Network links from firm j to firm i ($w_{ij\tau}$) are obtained from the global inter-firm network estimated the previous 5-years, after removing the first 5 common factors. D_{jt} is the equity return distress indicator for firm j; and N_t is an indicator for the average monthly TED spread being in the top 10% of its sample distribution. The marginal effects for the probit regressions are reported, where the dependent variable is the monthly equity return distress indicator for firm i defined as being in the worst 10% tail of the overall sample distribution, along with McFadden's pseudo R-squared. The last column reports whether the variable is expected to relate to robustness (+) or fragility (−). Robust standard errors clustered at the firm level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

D Simulation of Fall 2008 Global Contagion

Table D.1: Fall 2008 Crisis Source Firm Details

Name	Stock Ticker	2008 Stock Return	Company Description	2008 Key Events	Status at End of 2008
WACHOVIA CORP	1255173d	*-84.7%*	Fourth-largest bank holding company in U.S. based on total assets. Provided banking, asset & wealth mgment., and corporate and investment products and services.	**2Q**: 8.9 billion in losses. **Jun. 2**: CEO forced to retire. **Sep. 26**: Declared "Sytematically important" - Citigroup aggreeing to purchase. **Oct. 3**: Announcement of Wells Fargo acquiring. **Oct. 12**: Federal Reserve unanimously approves merger. **Dec. 31**: Acquisition completed.	12/31/2008: Aquired by Wells Fargo
AMERICAN INTERNATIONAL GROUP	aig	*-97.3%*	American multinational insurance corporation. 1) AIG Property Causalty; 2) AIG Life & Retirement; 3) United Guaranty Corporation.	**Jun. 15**: Stockholders wrote letter to Board of Directors seeking to oust CEO and changes to management. **Jun. 15**: CEO resigned. **Sept. 17**: New CEO forced by government to step down and replaced. **Sept. 16**: Federal Reserve provided $85 bn. (2-year loan).	9/16/2008: Government Bailout
DEXIA SA	dexb	*-80.3%*	Franco-Belgian financial institution active in public finance, providing retail and commercial banking services.	**Sept. 29**: Under pressure but other banks refused to provide credit. **Sept. 30**: Downgraded long term debt and deposits rating. **Oct. 7**: CEO & Chairman replaced.	9/30/2008: Government Bailout
FREDDIE MAC	fmcc	*-97.8%*	Public government-sponsored enterprise, expanding the secondary market for mortgages in the U.S.	As of 2008, Fannie Mae and Freddie Mac owned or garuanteed half of U.S. $12 tn mortgages.	9/7/2008: Government Takeover
FANNIE MAE	fnma	*-98.0%*	Public government-sponsored enterprise, expanding the secondary market for mortgages in the U.S.	**July 11**: The New York Time reported plan to take over Fannie Mae, Freddie Mac.	9/7/2008 : Government Takeover
GENERAL GROWTH PROPERTIES	ggp	*-96.7%*	American real estate investment trust, which operates and manages shopping malls throughout U.S.	**Sept. 30**: Reported debt in excess of $25 bn (mortgages). **Oct. 26**: CEO resigned. **Nov.**: Missed deadline to repay $900 m loans. Failed to reach agreement with creditors.	4/16/2009: Chapter 11 Bankruptcy
HBOS PLC	hbos	*-89.8%*	Banking and insurance company. HBOS was the U.K.'s largest mortgage lender.	**Mar.**: Shares fell 17 percent. **Sept. 18**: Announcement of Lloyds TSB offer to purchase HBOS. **Jan. 19, 2009**: Goverment assisted takeover by Lloyds TSB deal.	10/13/2008: Acquired by Lloyd TSB with U.K. backing (NOTE: not finalized until 2009)
LEHMAN BROS HLDG	lehmq	*-100.0%*	Global financial services firm, 4-largest U.S. investment bank. Investment banking, equity/fixed-income sales & trading (U.S. treasury securities), research, investment managmt., private equity & banking.	**1H**: Stock lost 73% of value. **Mar. 16**: Market analysts suggested would be next to fail. **Jun. 9**: Q-2 resulted in loses sparking major managmt. shake up. **Aug.**: Reported cutting of 6% of work force. **Aug. 22**: Talks of state-controlled Korea Development Bank purchasing Lehman. **Sept. 10**: Announced loses of 3.9 bn.	9/15/2008: Bankruptcy
MERRILL LYNCH	mer	*-77.3%*	Wealth management division of Bank of America.	**Jul.**: Q-4 losses amounting to $4.9 bn. July 2007/July 2008: Lost $19.2 bn. **Aug.**: New York attorney general threatened to sue over misrepresentation of risk on mortgage-backed securities leading to buy back $12 bn in auction-rate debt. Froze hiring and revealed $30 bn in losses to subsidiaries in U.K. **Aug. 22**: Deal with MA Secretary of State to buy back auction-rate securities. **Sept. 5**: Downgraded to "Conviciton Sell" and warned of further losses. **Sept. 14**: Agreed to be acquired by Bank of America.	9/14/2008: Bought by Bank of America (NOTE: not finalized until 2009)
NATIONAL CITY CORP	ncc	*-88.8%*	Regional bank holding company in Cleveland, Ohio. One of ten largest banks in terms of deposits, mortgages & home equity lines of credit. Areas: commercial & retail banking, consumer finance, asset mgment.	SEC investigation into matters including loan underwriting, bank regulatory matters, and the sale of sub-prime subsidiary (First Franklin Financial Corp.). **Oct. 9**: WSJ reported talks between Nation City and other banks for sale. **Oct. 24**: Announcement of PNC Bank purchase of National City Corp. **Dec. 31**: Acquisition completed.	12/31/2008: Acquired by PNC Bank
ROYAL BANK OF SCOTLAND	rbs	*-85.8%*	One of the retail banking subsidiaries of the Royal Bank of Scotland group plc. Provides mortgages and supports Scottish businesses.	**Apr.**: Announced need to raise 12 bn pounds from shareholders. **2H**: Pre-tax loss of 691 m. pounds. **Oct.**: Share price falls 50%. **Oct. 13**: Scottish government takes 58% in RBS for 15 bn pounds & CEO steps down and is replaced. **Jan. 2009**: RBS announces losses for 2008 could be up to 28 billion pounds (mostly from writedowns from ABN Amro acquisition).	October 13, 2008: Government Takeover; January 19, 2009: Government Takeover took over more shares in company
UBS GROUP AG	ubsg	*-68.2%*	Swiss global financial services company. Provides wealth & asset management, and investment banking sevices. Switzerland's largest bank.	**Apr.**: Announcement of $19 bn writedown of investments in sub-prime and other mortgage assets; total $37 bn. **Oct. 12**: Swiss government announced plan to help UBS and Credit Suisse, and take 10% stake in UBS. In response, UBS announced a CHF 15 bn rights offering. **2009**: Head of investment banking division resigned and UBS announced planned cuts of 8,700 jobs.	10/16/2008: Government Bailout (took 10% stake in company)
UBS AG-REG	ubsn	*-68.1%*	Alternate equity listing for above firm.		
WAMU INC	wamuq	*-99.8%*	Washington Mutual Inc. was a savings bank holding company and former owner of Washington Mutual Bank, which was U.S.'s largest savings and loan association.	**Apr**.: Announced 3,000 people would lose jobs and infusion of $7 bn new capital by outside investors, diluting holdings of existing shareholders. **Jun.**: Chairman stepped down. **Mid-Sept**.: Suffered massive run, customers pulled out $16.7 bn in deposits in a 10-day span. FDIC held secret auction with JP Morgan winning, taking WaMU for $1.9 bn.	9/26/2008: Chapter 11 Bankruptcy
XL GROUP LTD	xl	*-92.1%*	Now XL Catlin, global insurance company providing property, causalty, and specialty products.	**May:** Hired Mike McGavick. From $2.6 bn loss in 2008, XL swung to a profit of $1.3 bn in 2009. XL Group received no bailout.	No change
BEAR STEARNS COS	2942331q	*-89.4%*	Global investment bank, securities trading & brokerage firm. Areas: capital markets, investment banking, wealth management and global clearing services.	**Mar. 14**: FRBNY agreed to provide $25 bn but later retracted. **Jun. 29**: Former managers of hedge funds at were arrested. Merger agreement with JPMorgan, funding from FRBNY.	3/16/2008: Government sponsored buyout by JPMorgan
COUNTRYWIDE FINANCIAL	cfc	*-49.8%*	Originated, purchased, securitized, and serviced mortgages.	**Jan. 11**: Bank of America announced plans to purchase Countrywide Financial. **Jun. 5**: Announced approval by FRS. **Jun. 25**: Approval from 69% of shareholders.	7/1/2008: Acquired by Bank of America

Notes: Key events and company details were obtained from on-line sources for the purpose of illustrating these firms' state during 2008 and leading to the Global Financial Crisis.

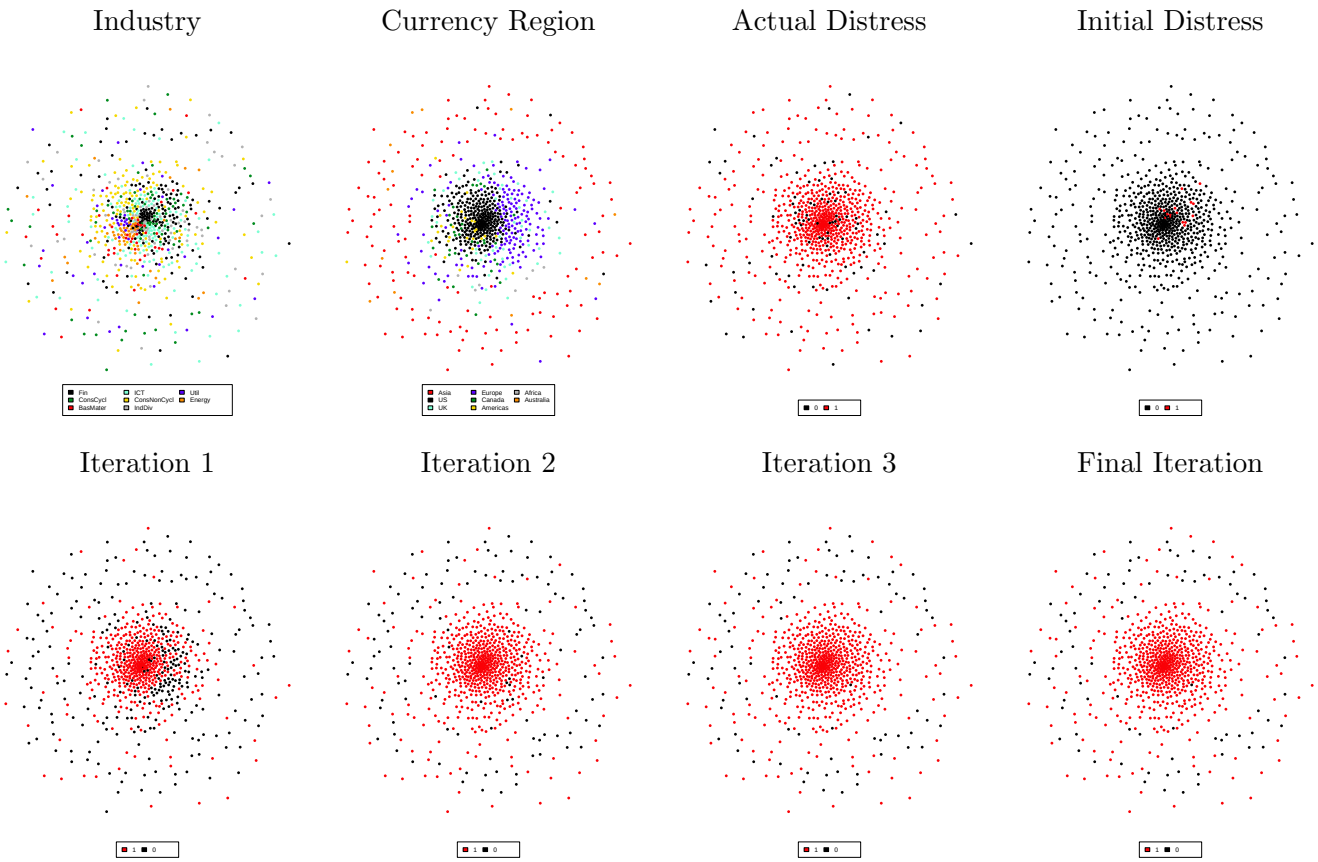
Table D.2: Quarterly Model for Fall 2008 Simulation Analysis

	Quarterly Return Crisis Indicator	
Robustness: Diversification	-0.0109***	-
$\phi \sum_{j \neq i} w_{ij\tau}$	(0.00178)	
Fragility: Direct Contagion	0.156***	+
$\gamma \sum_{j \neq i} w_{ij\tau} D_{jt}$	(0.00938)	
Fragility: Network Vulnerability	0.0508***	+
λN_t (N_t =Average VIX)	(0.00225)	
Robustness: Network Resistance	-0.00103***	-
$\omega N_t \sum_{j \neq i} w_{ij\tau}$	(0.000165)	
Fragility: Network Crisis Reinforced Contagion	-0.00294***	+
$\theta N_t \sum_{j \neq i} w_{ij\tau} D_{jt}$	(0.000259)	
Credit Tightness: Average TED Spread	0.199***	+
	(0.0294)	
Constant	-1.566***	
	(0.0297)	
Observations	31,706	

Notes: The dependent variable is the quarterly equity return distress indicator for firm i, the neighboring firm health variable (D_{jt}) is the equity return distress indicator for firm j, and the network state variable (N_t) is the average quarterly VIX level. The quarterly average TED spread is also included to control for credit spreads. This sample runs from 1996Q1-2016Q3 and includes 382 firms across 18 countries, with equities issued in 13 currencies. Robust standard errors clustered at the firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Fig. D.1 contains a series of spring plots based on the 2003-2007 global firm network that we use, which present features of the actual network and illustrate the modeled contagion. The first two panels show the industry and locality of each firm, which demonstrate distributions that are extremely similar to what we saw earlier for our main global firm sample. For example, both industry and region are important for firm connectedness, the Asian and Australian firms are on the periphery, and finance is at the center of the network. The next panel shows which firms actually experienced equity return distress over late 2008, with those affected in red. The substantial scope of the contagion across regions and industries in the fall of 2008 is evident in the plot. The final panel in the top row shows the positions of the 17 initially distressed firms in red. These are predominantly financial firms and have USD issued equities, so it is not surprising that they are all located relatively near the center of the network plot. The second row of panels then shows the modeled contagion spread over each iteration through convergence in the fourth one. As the spring plots show, the contagion quickly spread from the initially distressed firms in the first iteration, particularly to other USD and financial firms. The second iteration saw a significant increase in the spread to European firms with the U.S. market having hit a critical mass. At this point, the large number of distressed firms abroad then led to an echo effect, where the contagion spread more widely across U.S. firms that were connected to foreign ones.

Figure D.1: Fall 2008 Contagion — Actual Data vs Model Simulations



Notes: Spring plots are based on the rolling global firm sample network from 2003-2007. Simulations are based off of quarterly predictions from the main sample using the latent linear model estimates from a probit model estimated from 1996-2016, with firm distress as the dependent variable and the five robust and fragile terms from our main regressions with the level of the VIX as the network crisis variable, in addition to the TED spread as its own term. VIX and TED spread levels from the end of 2008 and the above initially distressed firms are entered into the model, which is simulated until reaching a steady state. See Internet Appendix Table D.1 for details on the initially distressed firms, and Table D.2 for the estimated latent probit model used. This sample includes 756 firms across 40 countries, with equities issued in 25 currencies. 0=not in distress and 1=distress.