MAPPING AND MEASURING EXTENDED SUPPLY CHAIN STRUCTURES

Jury Gualandris, Ivey Business School (Canada) Annachiara Longoni, ESADE Business School (Spain) Davide Luzzini, EADA Business School (Spain)

Agenda

(i) Data source: Bloomberg SPLC.

(ii) Supply chain mapping procedure: An illustrated application.

(iii) Things to be careful with.

(iv) Possible novel research opportunities.

DATA SOURCE

Data source: Bloomberg SPLC

- Multiple data sources;.
- Cogs, capex, sga and R&D;
- Data checked and quantified;
- > 1 mln contracts and over 123,000 firms globally (10x Compustat)
- Used in reputable management Journals (AMJ, MS).

However...

In 2016, average explained Revenue% is 28% In 2017, about 34% In 2018, about 40%.



SUPPLY CHAIN MAPPING PROCEDURE An illustrated application

Observational unit. The multi-tier supply chain of a focal firm.



Step 1

Identify focal firms in the 2015 Forbes2000 list.

Step 2

Apply a disproportionate stratified random sampling with industry-country strata.

Step 3

- (a) Identify customers, suppliers and sub-suppliers from the Bloomberg SPLC database;
- (b) Search and match redundant tickers (e.g., ABB Ltd appears as 'ABB SS Equity' on the Stockholm Stock Exchange and as 'ABBN VX Equity' on Swiss Stock Exchange).
- (c) Remove supply chain members that are not involved in COGS relationships, so to approximate 'physical' multi-tier supply chains;

Step 4

(a) Isolate 245 multi-tier supply chains from a large network(b) Remove outliers that could distort empirical results:

List of 617 focal firms.

- Representative list of 280 focal firms.
 - 245 focal firms;
- 4803 supply chain members;
 - 20504 contractual relationships.

Final sample of 189multi-tier supply chains.

Bloomberg SPLC data

Bloomberg SPLC data

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11) Faurocta SA		EOFP	1.111	23.02%	3.501	23.02B COG5	0.96%	Estimator	03/08/2010
H) Lear Corp	115	LEA US	1.411	5,48%	3,46%	21.50B C065	0.94%	Estimate	06/13/201
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36) Alphabet Inc	US	GOOGL US	89.65T	2.41*	0,10%	3.488 568A	0.91%	Estimate	05/22/2011
11) FANELC Corp	OP.	0994 IP	4.371	1:49%	0.75%	960.89H CAPEX	PE8.0	Estimato	06/08/2013
M) Clarion Co Ltd	DP.	6796 JP	85.398	1.21%	37,30%	18.17B COG5	0.77%	*2017A CF	06/26/2013
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Bloomberg SPLC data

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2	0 TMO US Equity	THC US Equity	DIRECTED	9.126744	0.22135099	8 5.215282917	CAPEX	Estimate (TMO US)
3	1 MDT US Equity	THC US Equity	DIRECTED	87.995688	1.20972895	6 2.025682926	COGS	Estimate (MDT US)
4	2 MDRX US Equity	THC US Equity	DIRECTED	9.028845	2.61251306	5 0.188572004	SGA	Estimate (MDRX US)
5	3 STJ US Equity	THC US Equity	DIRECTED	55.7182	3.95164489	7 1.256896019	COGS	Estimate (THC US)
6	4 CERN US Equity	THC US Equity	DIRECTED	57.43622	4.72352123	3 1.240254998	SGA	Estimate (CERN US)
7	5 BSX US Equity	THC US Equity	DIRECTED	42.326728	2.24188208	6 0.954810023	COGS	Estimate (THC US)
8	6 CTSH US Equity	THC US Equity	DIRECTED	5.725864	0.16991199	6 0.123641998	COGS	Estimate (CTSH US)
9	7 GNRC US Equity	THC US Equity	DIRECTED	0.753911	0.20521500	7 0.367760986	CAPEX	Estimate (GNRC US)
10	8 HRC US Equity	THC US Equity	DIRECTED	13.077735	2.27874803	5 0.295008987	COGS	Estimate (HRC US)
11	9 SN/LN Equity	THC US Equity	DIRECTED	11.275834	0.99259102	3 0.254361004	COGS	Estimate (SN/LN)
12	10 PLCM US Equity	THC US Equity	DIRECTED	0.068376	0.02357	2 0.032873001	CAPEX	Estimate (PLCM US)
13	11 PEGA US Equity	THC US Equity	DIRECTED	1.264138	0.66886997	2 0.027296999	SGA	Estimate (PEGA US)
14	12 ZBRA US Equity	THC US Equity	DIRECTED	0.223433	0.02541900	1 0.004825	COGS	Estimate (ZBRA US)
15	13 VRSN US Equity	THC US Equity	DIRECTED	0.507933	0.17663900	6 0.011171	SGA	Estimate (VRSN US)
16	14 CRVW US Equity	THC US Equity	DIRECTED	0.19273125	1	5 0.004355	COGS	2015A CF (CRVW US)
17	15 FDX US Equity	TMO US Equity	DIRECTED	33.9628	0.26167	5 1.382455945	COGS	Estimate (FDX US)
18	16 GLW US Equity	TMO US Equity	DIRECTED	9.797281	0.39079698	9 0.42098999	COGS	Estimate (GLW US)
19	17 7731 JP Equity	TMO US Equity	DIRECTED	0.802780476	0.04817099	9 0.659162998	CAPEX	Estimate (7731 JP)

Customers/Suppliers relationships list and network:

	Population:	Final Sample	e:	Contractual relat
	Focal firms	Focal firms	Supply chain members	hadde and
	1			
Capital goods - 2010	68	38	674	the second state of the second states
Food, Beverage and Tobacco - 3020	86	32	252	and the second state of th
Technology Hardware and Equipment - 4520	66	25	504	a start was a start of the star
Automobiles and components - 2510	30	24	280	the stand when the stand when the stand the stand the stand
Materials - 1510	196	22	620	with a second in second in the back of the second
Pharma & Biotech - 3520	44	19	209	1971年,1992年中国大学学家的中国大学学校的任何。1971年1月1日,1971年1月1日,1971年1月1日,1971年1月1日,1971年1月1日,1971年1月1日,1971年1月1日,1971年1月1日,197
Consumer Durables & Apparel - 2520	20	13	175	A CARLES AND A C
Health Care Equipment - 3510	46	9	131	
Household and Personal Products - 3030	39	6	37	State
Seminconductors - 4530	22	1	254	
Others	0	0	1667	A A A A A A A A A A A A A A A A A A A
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United States	105	66	1001	E. M. S.
Japan	185	00	014	
Taiwan	21	40	914	State of the second
United Kingdom	10	11	413	
China/Hong Kong	64	9	762	and the second Rest and the second
France	10	8	85	
Germany	25	8	94	
South Korea	15	8	492	
Switzerland	16	6	43	the second stand and the second stand and the second stand and the
Sweden	12	4	51	
Brazil	11	2	36	
Finland	5	2	22	a state and state state and state and state
Mexico	7	2	31	
Others	119	8	646	1. 1. 1997. 1997. A. 1977. A. 1977. A. 1977. A. 1977. A. 1977. A.
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Total	61 7	189	4803	
				1947 - T. S.

Note: data cleaning did not introduce relevant biases (35 retailers, 56 focal firms with poor data quality)

Isolating Multi-tier SCs

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Isolating Multi-tier SCs

a) Generic sub	-matrix identifying potential supply chain members:
A B C	
A 0 X1 X2	
B X3 0 X4	
C X5 X6 0	

b) Sub-matrixes that identify legitimate sub-suppliers of a generic focal firm 'A'

A←	–B←C	$A \leftarrow B \leftrightarrow C$		$A \leftrightarrow B \leftarrow$	-С		A↔B←	→C		
	A B C	A	B C		A B	C		A	B	С
	A 0 0 0	A 0	0 0	Α	0 1	0	A	0	1	0
	B 1 0 0	B 1	0 1	В	1 0	0	B	1	0	1
	C 0 1 0	C 0	1 0	С	0 1	0	С	0	1	0

c) Sub-matrixes that identify firms to be excluded from the multi-tier supply chain of a generic focal firm 'A':

A	⇔B–	ъC			1
		A	B	С	
	A	0	1	0	I
	B	1	0	1	
	С	0	0	0	

A	←B-	→C		
		A	B	C
	A	0	0	0
	B	1	0	1
	C	0	0	0

Examples of SC structural measures

Geographical Heterogeneity: $1 - \sum_{k} p_{k}^{2}$ where p_{k} is the proportion of focal firm's suppliers that fall in category k (k=77 countries) (Jackson et al., 1991; Richard et al., 2004)

Industrial Heterogeneity: $1 - \sum_{k} p_{k}^{2}$ where p_{k} is the proportion of focal firm's suppliers that fall in category k (k=78 Industry groups) (Jackson et al., 1991; Richard et al., 2004)

Density: *E/V(V–1), where E is the number of contractual relationships and |V| is the number of suppliers (Wasserman and Faust, 1994)*

Clustering: $G^{-1} \sum_{i=1}^{G} C_i^D$, with $C_i^D = \frac{Closed triads_i^D}{Open triads_i^D}$ (Fagiolo, 2007)

THINGS TO BE CAREFUL WITH...

SC data coverage and biases related to the selection mechanism:

POSSIBLE NOVEL RESEARCH OPPORTUNITIES

Examples of novel research opportunities

Investigate how supply chain structure influences a firm's:

- Innovation capability (Bellamy et al., 2014)
- Financial performance (Lu and Shang, 2017)

Investigate how **supply chain structure influences a supply chain-level phenomenon** (Carter and Washispack, 2018):

- Evolution of structures of supply chains (Park et al., 2018)
- Supply chain innovations (Carnovale and Yeniyurt, 2015)
- Suppliers' and sub-suppliers' collective ESG disclosure

How to measure a collective SC-level phenomenon

Collective Supply Chain Disclosure: $\sum_{j=1}^{N} D_j / N_N$ where D_i is a supplier's disclosure index

Tests for reliability: ICC(2) = (MSB-MSW)/MSB Test for non-independence: ICC(1) = (MSB-MSW / (MSB+(k-1)*MSW)

MAPPING AND MEASURING EXTENDED SUPPLY CHAIN STRUCTURES

Jury Gualandris, Ivey Business School (Canada) Annachiara Longoni, ESADE Business School (Spain) Davide Luzzini, EADA Business School (Spain)

BACK-UP

Heterogeneity: a simplified illustration

Categorical Heterogeneity

- Blau / Herfindhal / Hirschman index
 - P_k is proportion of ego's alters that fall in category k

$$H = 1 - \sum_{k} p_{k}^{2}$$

- H = 0 if all alters in one category
- H = 1 1/K if all categories have equal frequency (can't reach 1.0)
- Agresti's IQV
 - Divide H by 1 1/K so that measure runs between 0 and 1
 - Gives amount of diversity given the number of categories
 - H could be seen as best measure of diversity, because it is not satisfied until the number of categories $\rightarrow \infty$, which would imply massive diversity

Bill	freq	prop	prop^2	K =	2
Male	14	0.875	0.765625	H =	0.219
Female	2	0.125	0.015625	IQV =	0.438
	16	1	0.78125		
Jane					
Male	8	0.5	0.25	H =	0.5
Female	8	0.5	0.25	IQV =	1
	16	1	0.5		

$$IQV = \frac{H}{1 - \frac{1}{K}}$$

Clustering in directed binary networks:

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Clustering in complex directed networks

Giorgio Fagiolo*

Sant'Anna School of Advanced Studies, Laboratory of Economics and Management, Piazza Martiri della Libertà 33, I-56127 Pisa, Italy (Received 6 February 2007; published 16 August 2007)

Many empirical networks display an inherent tendency to cluster, i.e., to form circles of connected nodes. This feature is typically measured by the clustering coefficient (CC). The CC, originally introduced for binary, undirected graphs, has been recently generalized to weighted, undirected networks. Here we extend the CC to the case of (binary and weighted) *directed* networks and we compute its expected value for random graphs. We distinguish between CCs that count all directed triangles in the graph (independently of the direction of their edges) and CCs that only consider particular types of directed triangles (e.g., cycles). The main concepts are illustrated by employing empirical data on world-trade flows.

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Robustness checks:

(a) Supply chain data coverage (n = 189)

(b) Supply chain independence (n = 189)

Robustness checks:

	(1) Robustn	ess: Data coverage	(2) Robustn	ess: Independence
	Coefficient	Robust Std Errors	Coefficient	Robust Std Errors
SCGeographicalH	0.603***	0.191	0.356**	0.165
SCIndustrialH	0.191	0.274	-0.568***	0.197
SCDensity	1.10***	0.264	0.502***	0.179
SCClustering	-0.440**	0.206	-0.384***	0.089
SCHorizontal	-0.014	0.092	0.080	0.081
SCVertical	-0.240**	0.106	-0.038	0.082
SCOrgSize	-0.027	0.198	0.078	0.163
IndustryClock	-0.427*	0.227	-0.209	0.226
FFDisclosure	0.153**	0.072	0.138**	0.061
IndustryRepRisk	0.071	0.098	-0.011	0.078
SCRegPressure	-0.035	0.131	0.201**	0.088
Constant	0.428**	0.198	0.312	0.216
Observations	95		95	
R-squared	0.497		0.598	

Note: *p <0.1; **p<0.05; ***p<0.01.

STEP 3b: Bloomberg ESG?

- Multiple data sources;.
- 120 ESG indicators;
- Data checked and standardized;
- Over 10,000 public firms globally;
- ESG data integrated with financials;
- History from 2007;
- Used by more than 12,600 customers;
- Widely used in reputable accounting Journals.

Strengths: higher coverage than Sustainalytics and Thomson ASSET4;

Limits: predominantly medium/large Mkt Cap. In our dataset, 34% have ESG=0 and Mkt Cap <2bln. However, randomly distributed across SCs.

