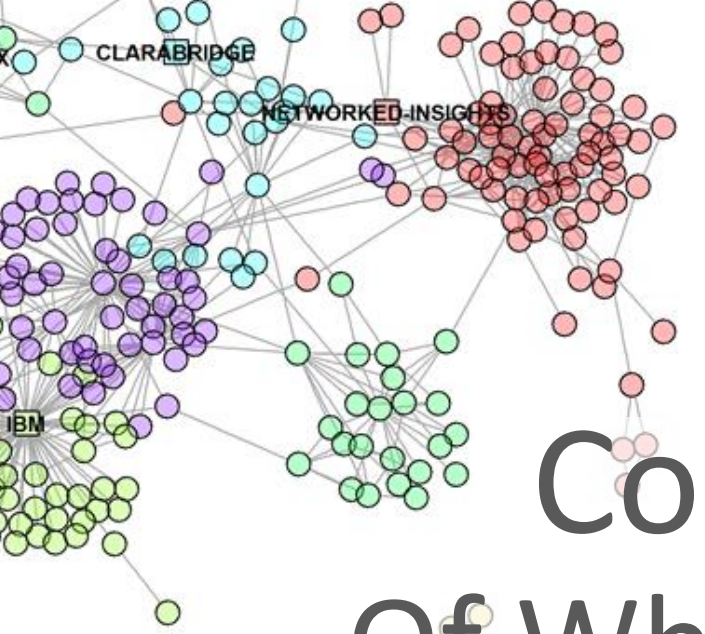

Competitive Dynamics: Of Whom Should You Be Aware?

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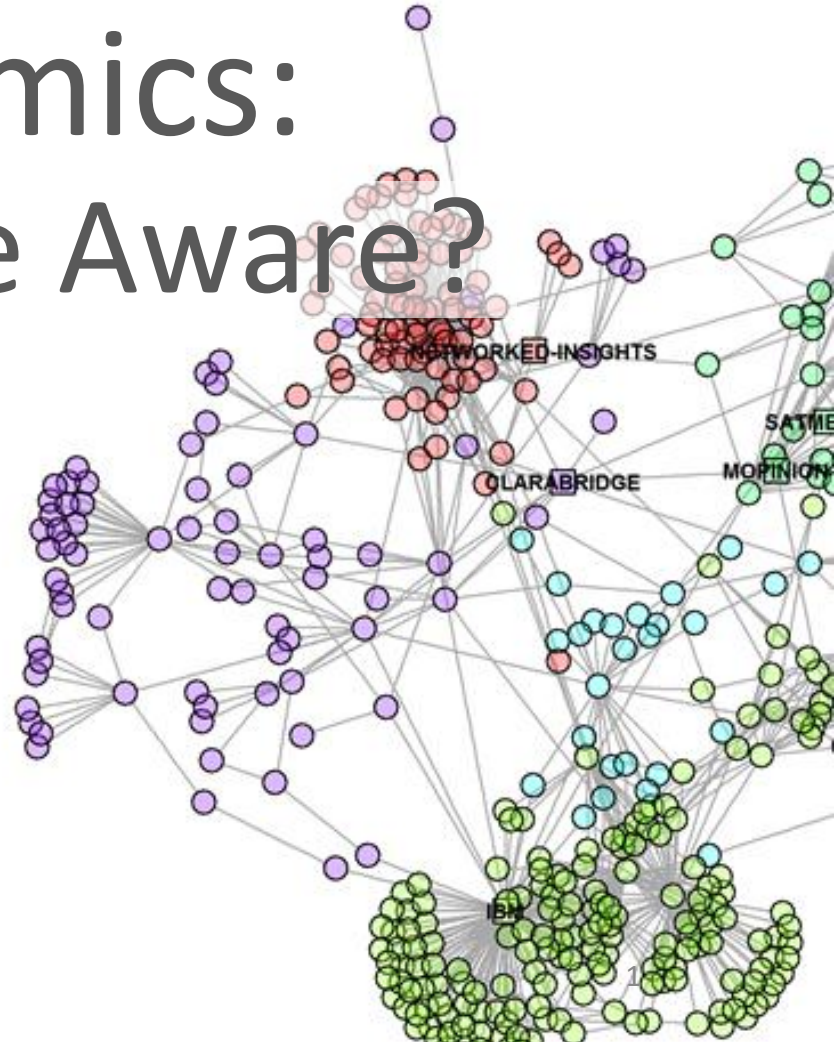
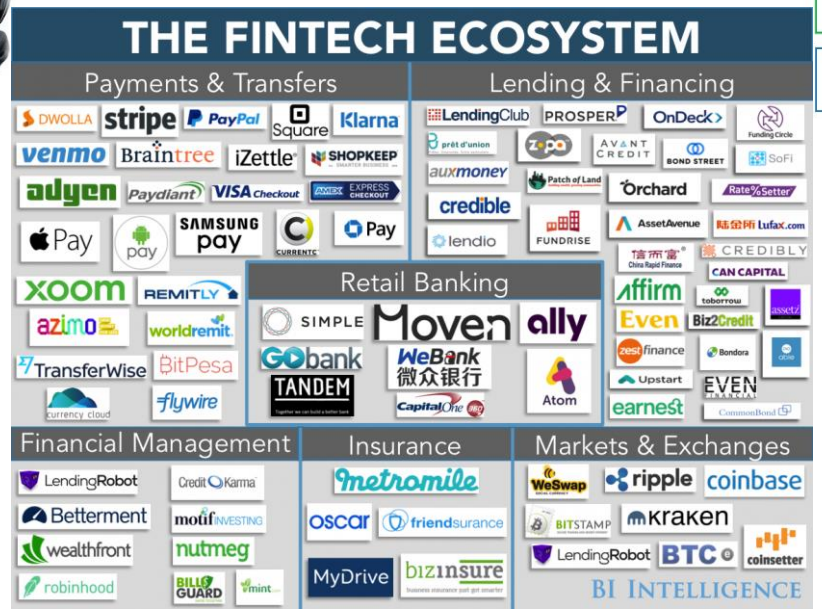
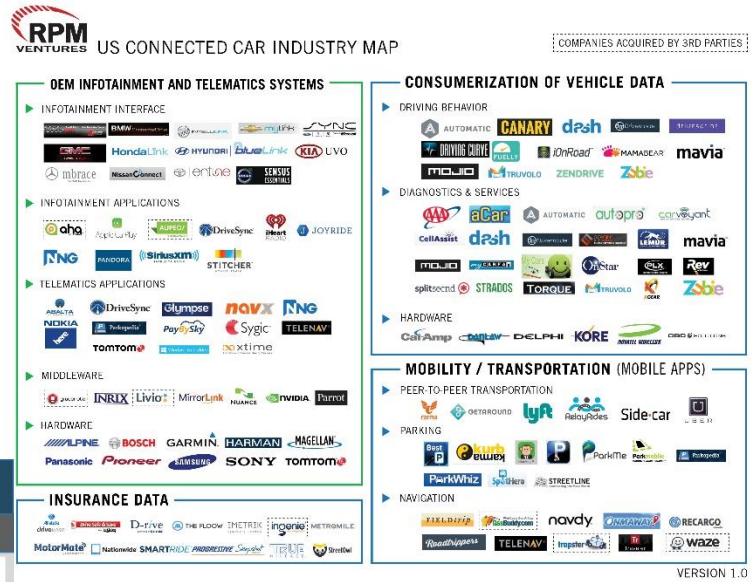


Increasing Convergence…

Handhelds

Finance





Automotive …

…Requires Rethinking Awareness

Competitive Dynamics:

- *the study of inter-firm rivalry based on specific competitive actions and reactions, their strategic and organizational contexts, and their drivers and consequences* (Baum & Korn, 1996; Smith et al., 1992)

Awareness-Motivation-Capability (AMC):

(Chen, 1996)

- Awareness from market-domain overlap (Baum & Korn, 1996), strategic similarity (Gimeno, 1999)
- useful for predicting competitive actions
- applications in marketing (e.g. Gielens et al., 2008), management information systems (e.g. Chi, Ravichandran, & Andrevski, 2010), etc.
- extensions to psychological rivalry (Kilduff et al., 2010), rivalry engagement with MMC (Upson et al., 2012), etc.

Limitations:

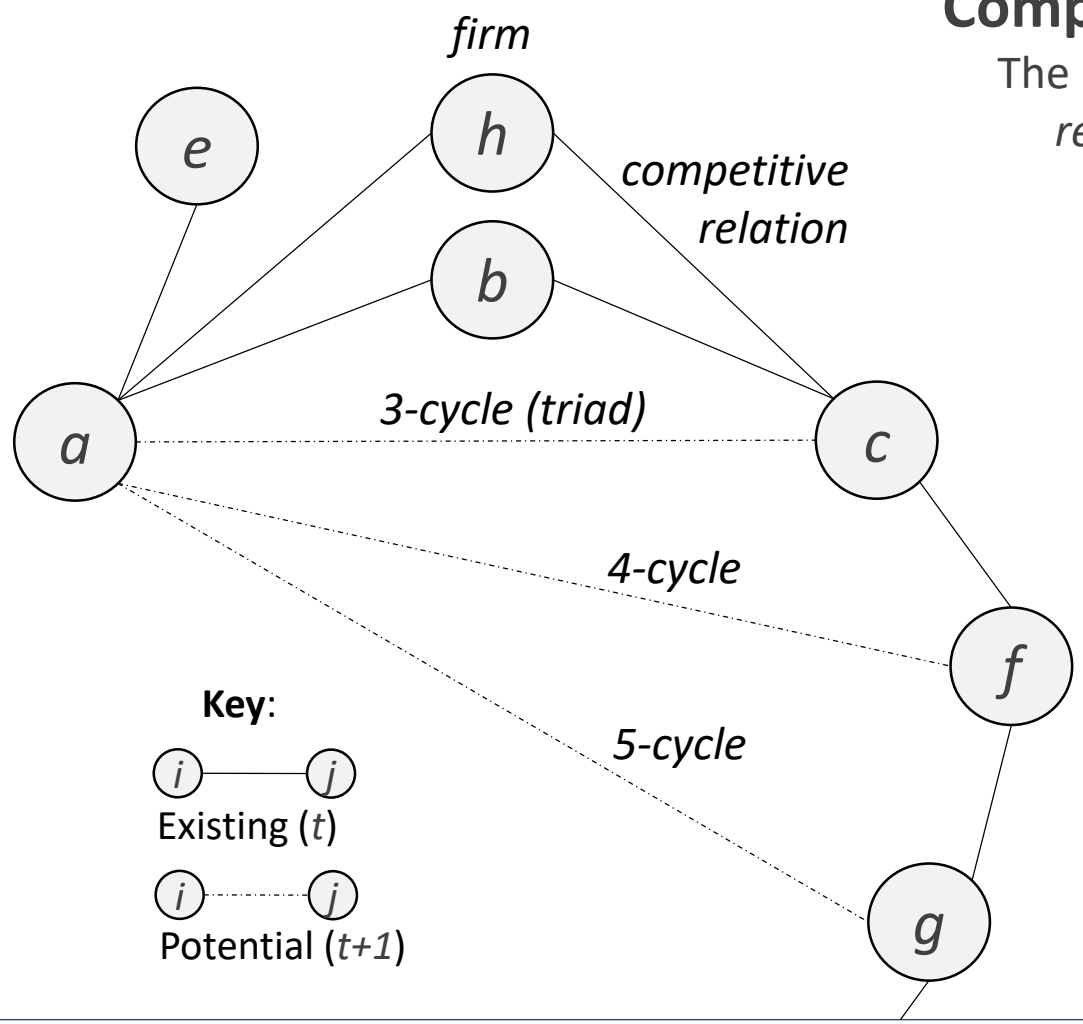
- market convergence and shifting industry boundaries
- emerging rivalry
- requires new information outside traditional awareness scope

A Network Perspective on Competition

Competition Network:
A group of firms connected by *competitive relations,* which may span market and industry boundaries
(Skilton & Bernardes, 2014)

Competitive Relation:
Co-occurrence in a product market (or factor market); represented by edges in the *competition network*

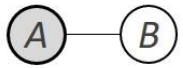
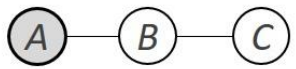
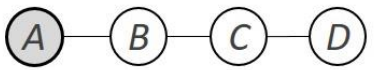
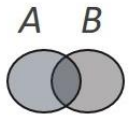
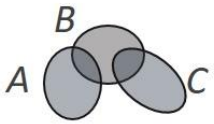
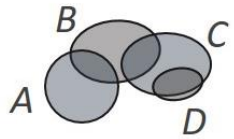
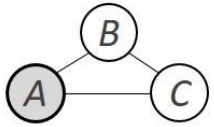
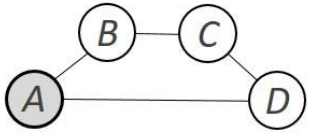
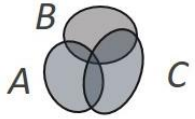
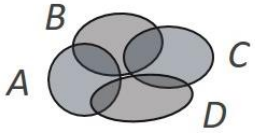
Indirect Competitors:
A firm dyad with *competitive distance* greater than 1



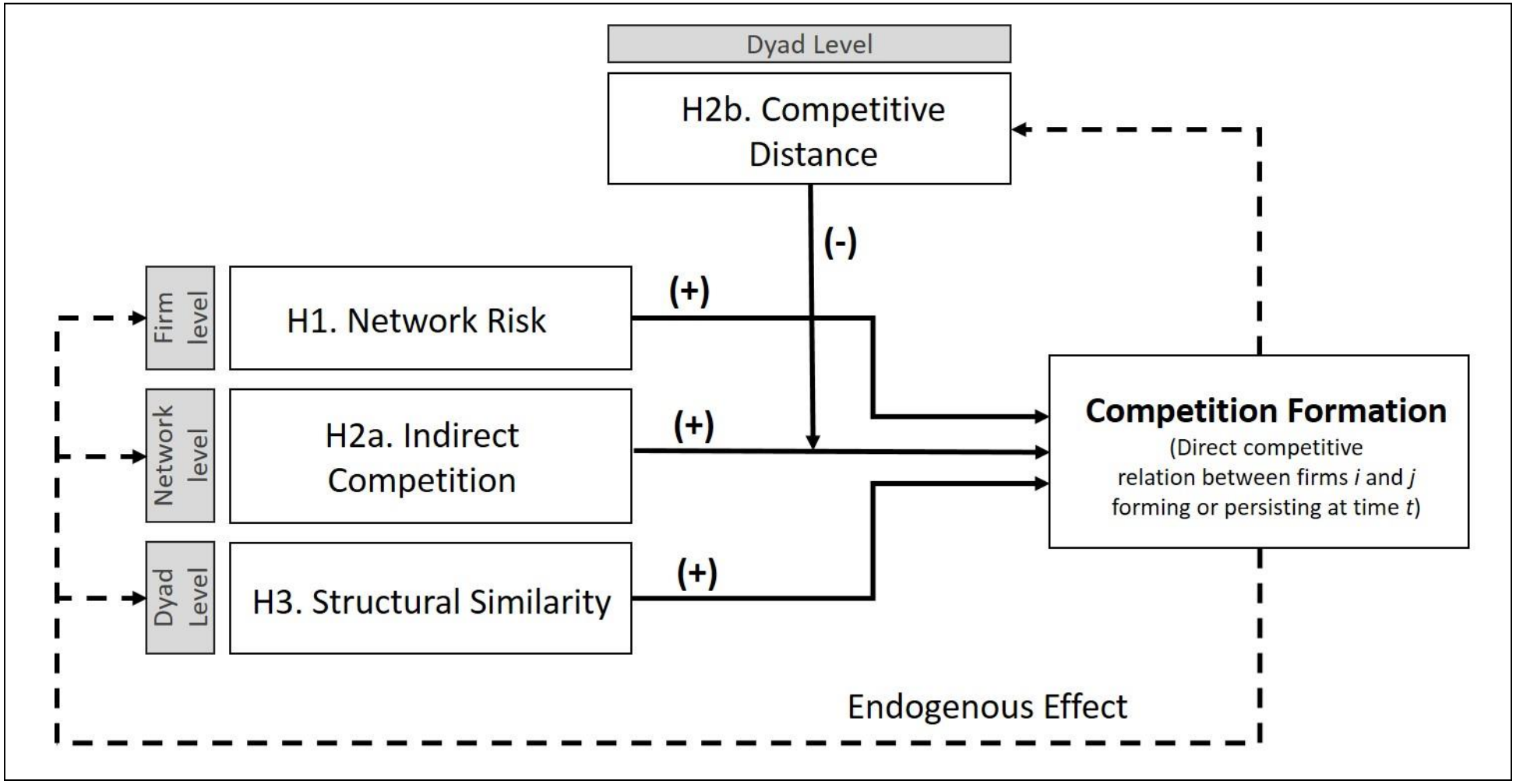
Competitive Distance:
The number of *competitive relations* separating two firms in the *competition network,* or the length of their *competition path* (*a-b-c-f-g* = 4)

***k*-cycles:**
Competitive relations (edges) that form a complete loop of length *k* within the *competition network*

Perceptions of Competition Formation

Scenarios:			I *Current*	II *Expected*	III *Unexpected*
Panel (a) Paths	Competition Network				
	Firm Product Market Scope				
	d^{th} order competitors	1st (Rivals)	A-B	A-B, B-C	A-B, B-C, C-D
		2nd (Indirect)		A-B-C	A-B-C, B-C-D
		3rd (Indirect)			A-B-C-D
Panel (b) Cycles	Competition Network				
	Firm Product Market Scope				
	Competition k - cycles	3-cycle		(A,B,C)	
		4-cycle			(A,B,C,D)

Early Awareness Model of Competition Formation

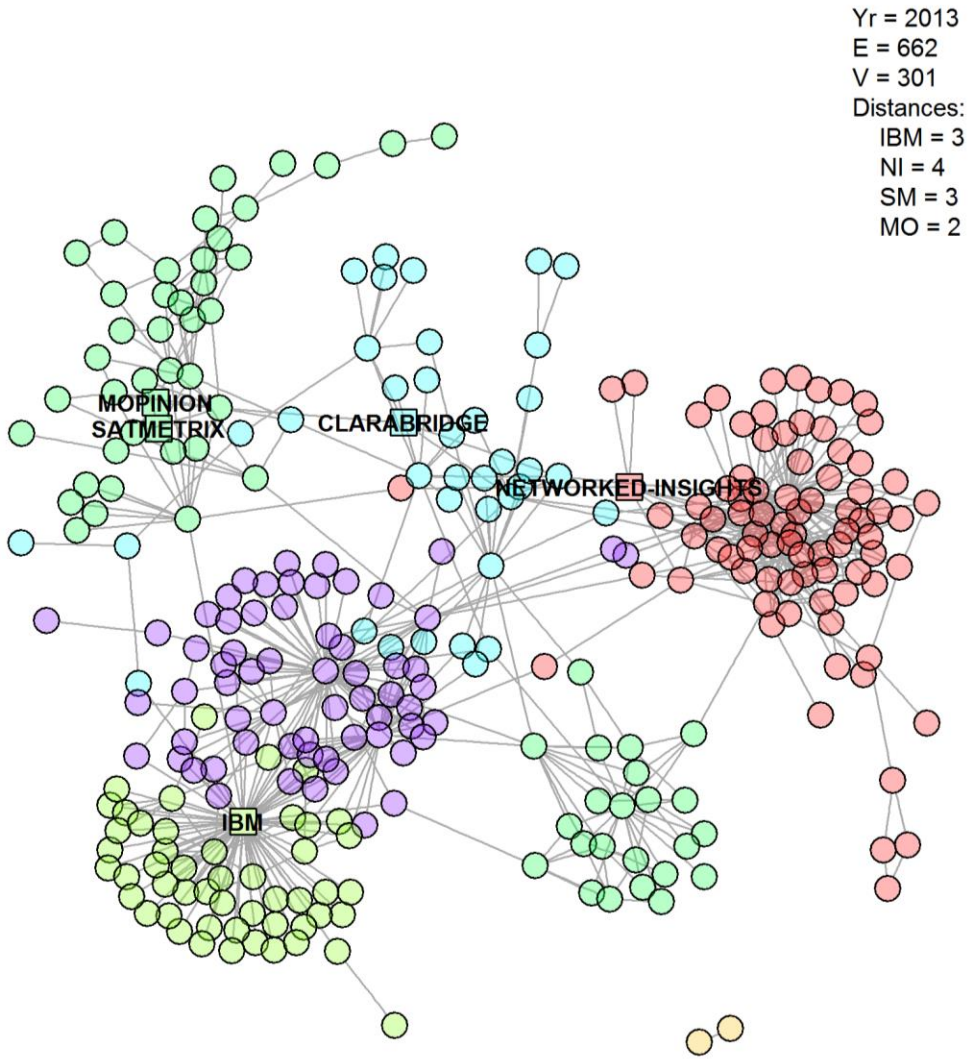


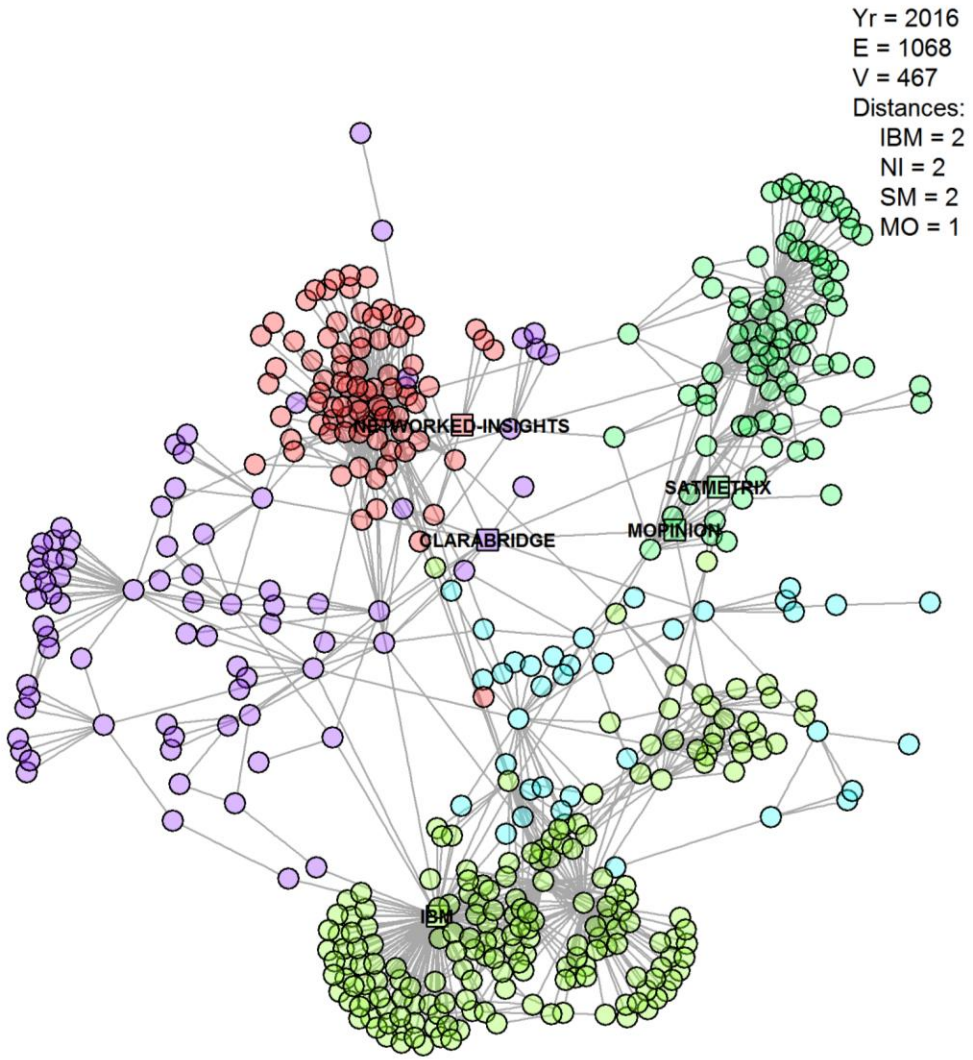
Industry Profile

- Business software and services industry (2011 – 2016)
  - Customer Experience Management (CEM) *"the practice of designing and reacting to customer interactions to meet or exceed customer expectations and, thus, increase customer satisfaction, loyalty and advocacy."* -- Gartner
  - Enterprise social listening (ESL), enterprise social networks (ESN), enterprise feedback management (EFM), digital experience platforms, and customer analytics
- In 2015, IDC estimated the ESN/ESL market would grow to reach US$ 3.5 billion by 2019, at a CAGR of 19.1% (Thompson, 2015).
- Low diversification (specialists): Clarabridge, Networked Insights, Brandwatch, NetBase, etc.
- High diversification (generalists): IBM, SAP, Oracle, Adobe, etc.

Network Cluster Key:
(g) Enterprise Feedback Mgmt
(r) Enterprise Social Listening
(p) Machine Learning / AI
(y) Customer Analytics & Digital Exp.
(b) BI & Business Statistics

Converged CEM Software Industry





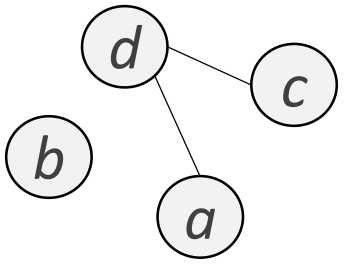
Sample & Dependent Variable

- Sample
  - competitive ties, firm-level covariates, controls from CrunchBase (latest academic API access on October 26, 2016)
  - 475 firms, 6 periods of 1 yr (324,586 period-dyadic observations)

- Dependent Variable
  - entire competition network $\underline{\mathbf{Y}} \in \{0,1\}^{N \times N \times T}$
  - $y_{ij}^{t} = \begin{cases} 1, & \text{firms } i,j \text{ same product market at } t \\ 0, & \text{firms } i,j \textbf{ not} \text{ same market at } t \end{cases}$
  - N = 475 firms in 2016
  - $T = 6$ (1-yr periods)

year t

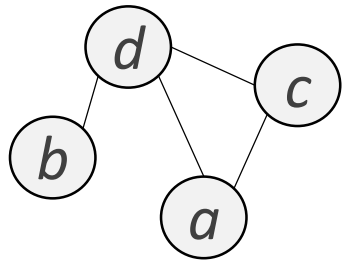
$$\mathbf{y}^{t} = \begin{array}{c} \begin{matrix} a & b & c & d \end{matrix} \\ \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 \end{bmatrix} \end{array} \begin{matrix} a \\ b \\ c \\ d \end{matrix}$$



time

year $t+1$

$$\mathbf{y}^{t+1} = \begin{array}{c} \begin{matrix} a & b & c & d \end{matrix} \\ \begin{bmatrix} 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix} \end{array} \begin{matrix} a \\ b \\ c \\ d \end{matrix}$$



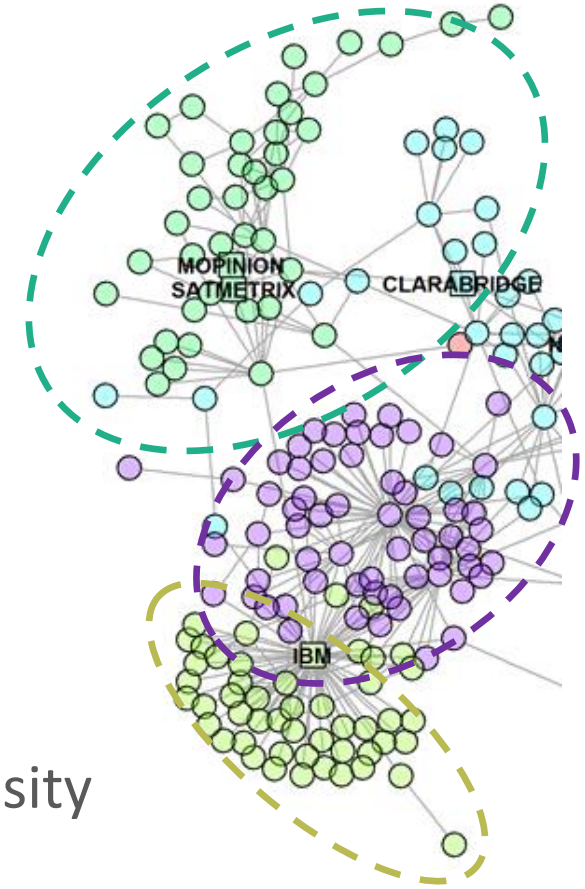
Independent Variables

Distance & Density:

- Network Risk (H1)
  - $R_i^t = \left(\frac{n-1}{\sum_{j=1}^{n} w_{ij}^t}\right), \quad \forall j \neq i$: Network Risk of firm *i* at *t*
  - $w_{ij}^t = \begin{cases} d_{ij}^t \left(2 - D\left(G_i^t\right)\right), & G_i^t = G_j^t \\ d_{ij}^t \left(2 - D\left(G_i^t, G_j^t\right)\right), & G_i^t \neq G_j^t \end{cases}$

    density-weighted distance
  - d_{ij}: competitive distance between firms i and j
  - $D\left(G_i^t\right) = \sum_{i,j \in G_i^t; i \neq j} \left\{\frac{y_{ij}^t}{|G_i^t|(|G_i^t|-1)/2}\right\}$: the CNG density
  - $D\left(G_i^t, G_j^t\right) = \sum_{i \in G_i^t} \sum_{j \in G_j^t; i \neq j} \left\{\frac{y_{ij}^t}{|G_i^t| \cdot \left|G_j^t\right|}\right\}$: the CNG cross-density

Competition Network Group (CNG)



Independent Variables

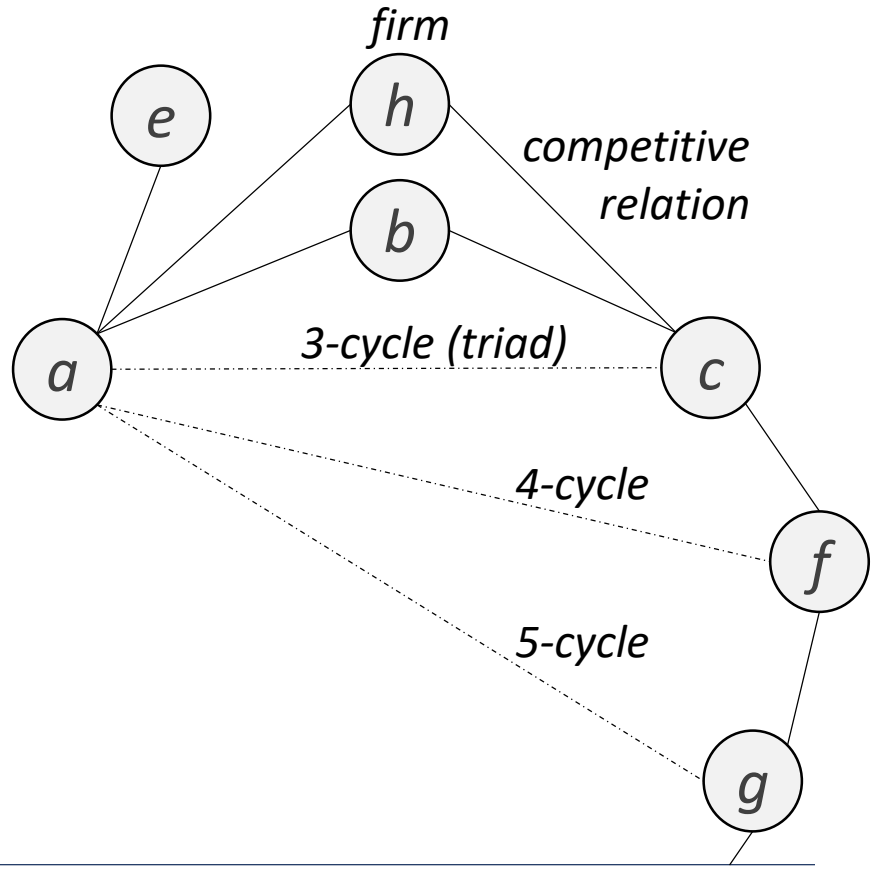
k-Cycles:

- 3-cycles
- 4-cycles and 5-cycles (H2a, H2b)

$$g_{\mathrm{C_k}}(\mathbf{y}^t) = \sum_{i=1}^{n}\sum_{j=1}^{n}\dots\sum_{k=1}^{n} y_{ij}^t \cdot y_{jl}^t \cdot \dots \cdot y_{ik}^t \,,$$

$$\forall k \neq \dots \neq j \neq i$$

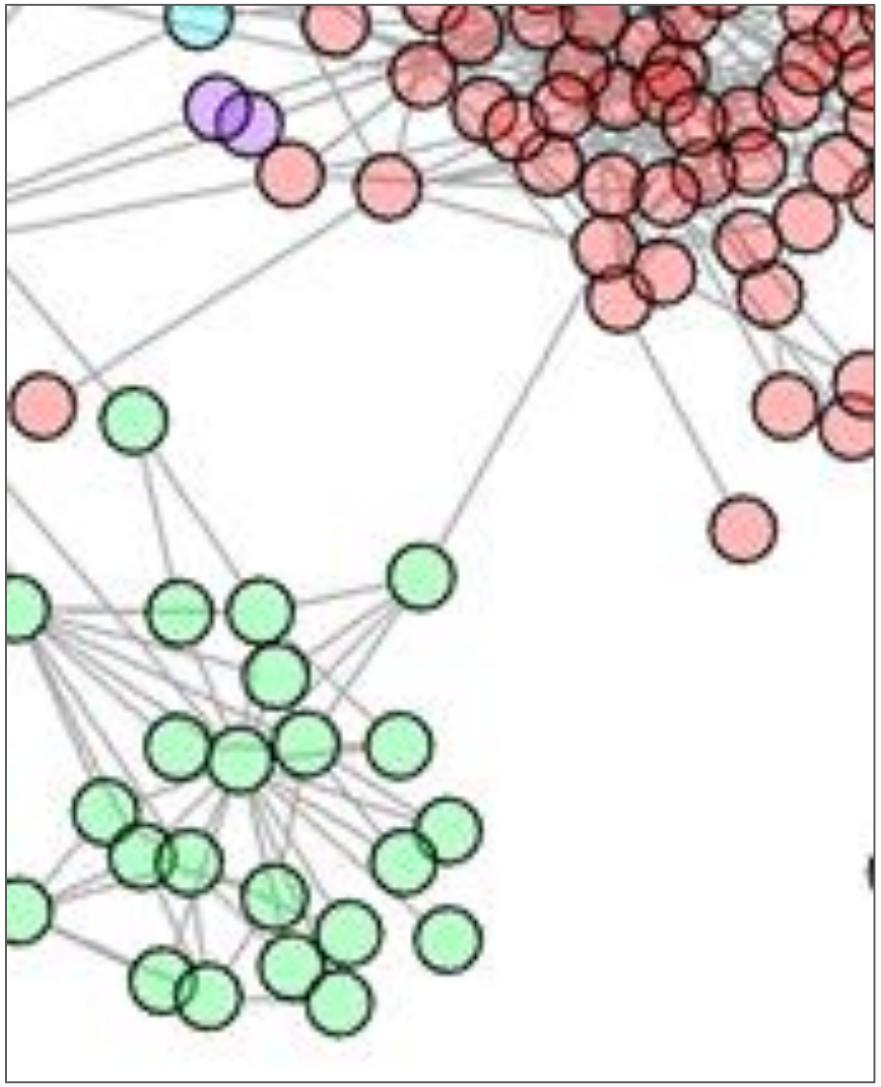
- adds one whenever all the competitive ties (y_{ij}^t,…,y_{ik}^t) are present during the same time period, forming a cycle.



Independent Variables

Structural Similarity:

- Constraint (Burt, 1992)
  - $C_i^t = \sum_{j \in V_i} \left[\left(p_{ij}^t + \sum_{l \in V_i} p_{il}^t p_{lj}^t \right)^2 \right]$, $\forall j \neq l \neq i$
- Absolute difference of constraint (H3)
  - $S_{ij}^t = \left| C_i^t - C_j^t \right|$



Network Inference: Temporal ERGM

- Exponential random graph (ERG) models (Frank and Strauss, 1986; Snijders *et al.*, 2006; Wasserman and Pattison, 1996)
- $\text{logit}\,\mathbb{P}\left(Y_{ij}=1\middle|y_{ij}^{c},\mathbf{x}\right)=\ln\frac{\mathbb{P}\left(Y_{ij}=1\middle|y_{ij}^{c},\mathbf{x}\right)}{\mathbb{P}\left(Y_{ij}=0\middle|y_{ij}^{c},\mathbf{x}\right)}=\boldsymbol{\theta}^{T}\delta\left(\boldsymbol{g}(\mathbf{y},\mathbf{x})\right)_{ij}$
  - Y_{ij} : random variable for relation between the pair (i,j), realization $y_{ij}\in\{0,1\}$, complement y_{ij}^{c}
  - $\mathbf{x}$: an array of node (firm) and/or edge (relation) covariates.
  - $\boldsymbol{g}=g_1,g_2,\ldots,g_p$: vector of functions on the space of graphs
    - each element of $g_i(\mathbf{y},\mathbf{x})$ yields a sufficient statistic for the graph represented by $\mathbf{y}$ with covariates $\mathbf{x}$
  - "change statistics", $\delta\left(\boldsymbol{g}(\mathbf{y},\mathbf{x})\right)_{ij}=\boldsymbol{g}\left(\mathbf{y}_{ij}^{+},\mathbf{x}\right)-\boldsymbol{g}\left(\mathbf{y}_{ij}^{-},\mathbf{x}\right)$: effect on those network statistics when the firm relation (i,j) is changed from $y_{ij}=0$ to $y_{ij}=1$
  - $\boldsymbol{\theta}=\theta_1,\theta_2,\ldots,\theta_p$; vector of parameters to be inferred for the network statistics
- Dynamic competition network requires an alteration to the ERGM specification, called temporal ERGM (TERM), (Hanneke, Fu, & Xing, 2010).

$$\mathbb{P}\left(\mathbf{Y}^{t}=\mathbf{y}^{t}\middle|\{\mathbf{Y}\}_{t-q}^{t-1},\{\mathbf{X}\}_{t-q}^{t},\boldsymbol{\theta}\right)=\frac{\exp\left\{\boldsymbol{\theta}'\boldsymbol{g}\left(\{\mathbf{y}\}_{t-q}^{t},\{\mathbf{x}\}_{t-q}^{t}\right)\right\}}{Z(\boldsymbol{\theta},\mathbf{Y}^{t-1})}$$, (Cranmer & Desmarais, 2012)

- Bootstrapped maximum pseudo-likelihood estimation (MPLE) (Desmarais & Cranmer, 2012)

H1: Network Risk

- Supported
- Direct competition more likely if:
  - Shorter avg. competitive distance
  - Denser CNG

		I	IV
Network Risk	H1	0.239*	0.456*
		[0.145; 0.289]	[0.343; 0.488]
3-Cycles			0.756*
			[0.542; 1.072]
4-Cycles	H2a		0.066*
			[0.052; 0.095]
5-Cycles	H2b		-0.017*
			[-0.022; -0.014]
Constraint			-6.921*
			[-7.885; -3.554]
Abs. Diff. Constraint	H3		5.158*
			[3.999; 6.442]
- - - Abridged - - -			
Num. obs.		323,045	324,586

* 0 outside the 95% bootstrapped confidence interval;

1,000 bootstrap resampled 95% confidence intervals shown in brackets

H2: Indirect Competition & Competitive Distance

H2a:

- Supported
- Direct competition more likely if:
  - More short (3-4) cycles

H2b:

- Supported
- Direct competition *less* likely if:
  - More long (5+) cycles
- firms should focus their attention among 4th order (and lower) indirect competitors

		II	IV
Network Risk	H1		0.456*
			[0.343; 0.488]
3-Cycles		1.220*	0.756*
		[0.490; 1.743]	[0.542; 1.072]
4-Cycles	H2a	0.134*	0.066*
		[0.112; 0.190]	[0.052; 0.095]
5-Cycles	H2b	-0.017*	-0.017*
		[-0.021; -0.014]	[-0.022; -0.014]
Constraint			-6.921*
			[-7.885; -3.554]
Abs. Diff. Constraint	H3		5.158*
			[3.999; 6.442]
- - - Abridged - - -			
Num. obs.		97,918	324,586

* 0 outside the 95% bootstrapped confidence interval;
1,000 bootstrap resampled 95% confidence intervals shown in brackets

H3: Structural Similarity

- Opposite of prediction
- Direct competition *less* likely if:
  - Structurally similar (same network positions)
- Possible explanations:
  1. Artifact of the data source
  2. Forbearance mechanism in the competition formation process
- Interpretation:
  - direct competition less likely for firms with more constraint on average
  - likelihood of a competitive tie with a specific potential competitor strongly depends on the difference of their local network structures.

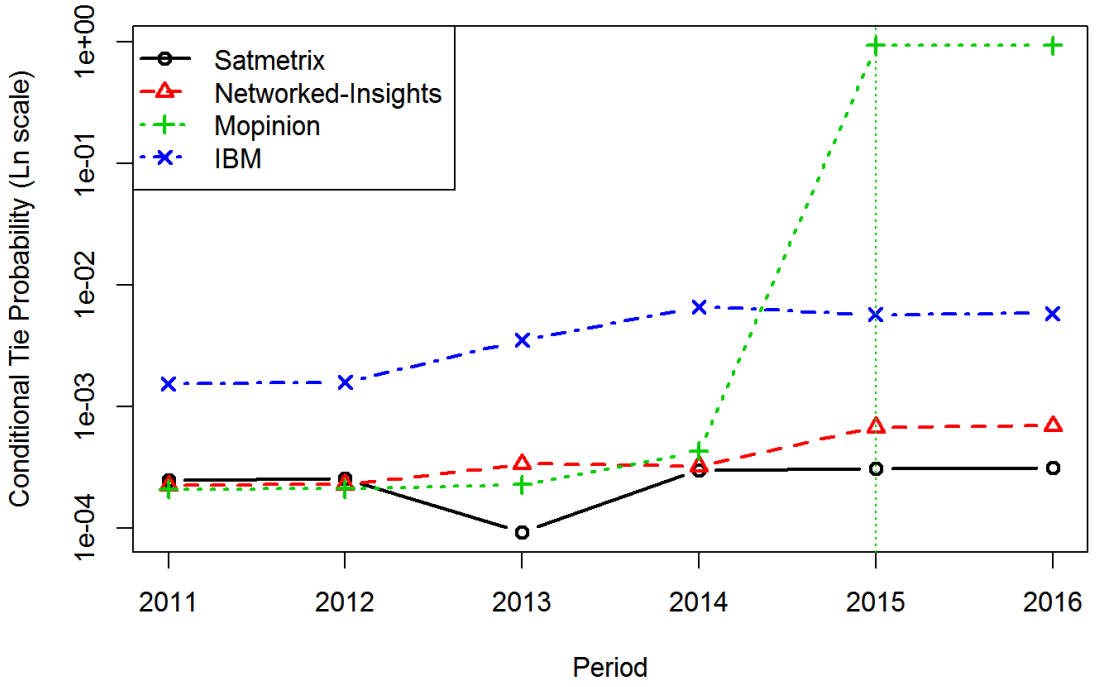
		III	IV
Network Risk	H1		0.456*
			[0.343; 0.488]
3-Cycles			0.756*
			[0.542; 1.072]
4-Cycles	H2a		0.066*
			[0.052; 0.095]
5-Cycles	H2b		-0.017*
			[-0.022; -0.014]
Constraint		-0.482	-6.921*
		[-2.731; 0.831]	[-7.885; -3.554]
Abs. Diff. Constraint	H3	3.350*	5.158*
		[2.707; 5.109]	[3.999; 6.442]
- - - Abridged - - -		- - -	
Num. obs.		97,918	324,586

* 0 outside the 95% bootstrapped confidence interval;

1,000 bootstrap resampled 95% confidence intervals shown in brackets

TERGM Micro-Interpretation

- High Diversification (IBM):
  - most prominent potential rival
- Low Diversification (Satmetrix, Mopinion, Networked Insights):
  - increasing trend, consistent with the decreased competitive distances
- Differentiate High vs Low:
  - Different market entry behavior and competitive motivations (Markman & Waldron, 2014)
  - Evaluating IBM relative to itself: relatively stabile competitive situation



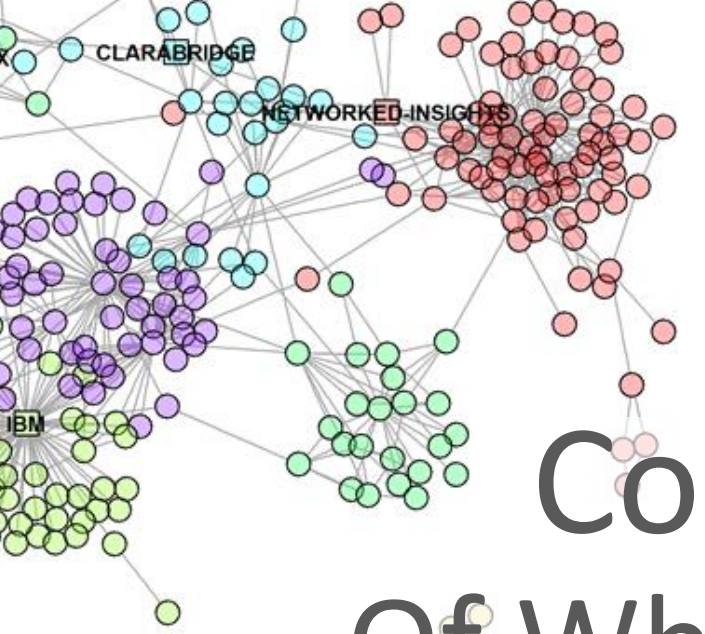
See Leifeld et al. (2016b) for explanation of computations.

Contributions & Implications

- Theoretical Contributions
  - Enhanced the concept of awareness in the AMC framework, combining logic, methods of network theory, competitive dynamics
  - Addressed the explore-exploit tradeoff for current vs future rivals
- Managerial Implications
  - Unexpected rivals and unanticipated actions can have the direst consequences
  - Leaders need to take a three-dimensional view of numerous, distant product market spaces
  - A competition network perspective can capture both current and emerging rivalry

Future Research

- Limitations:
  - Data sample completeness
  - Estimation scalability, robustness
- Research Directions:
  - Link between competition formation and competition intensity (frequency, speed)
    - How long before an indirect competitor becomes a direct competitor?
    - Influence of competitive embeddedness upon competitive (re)actions?
  - Interaction of cooperative relations within competition network
    - Use of AMC framework for awareness/prediction of *cooperative* actions?



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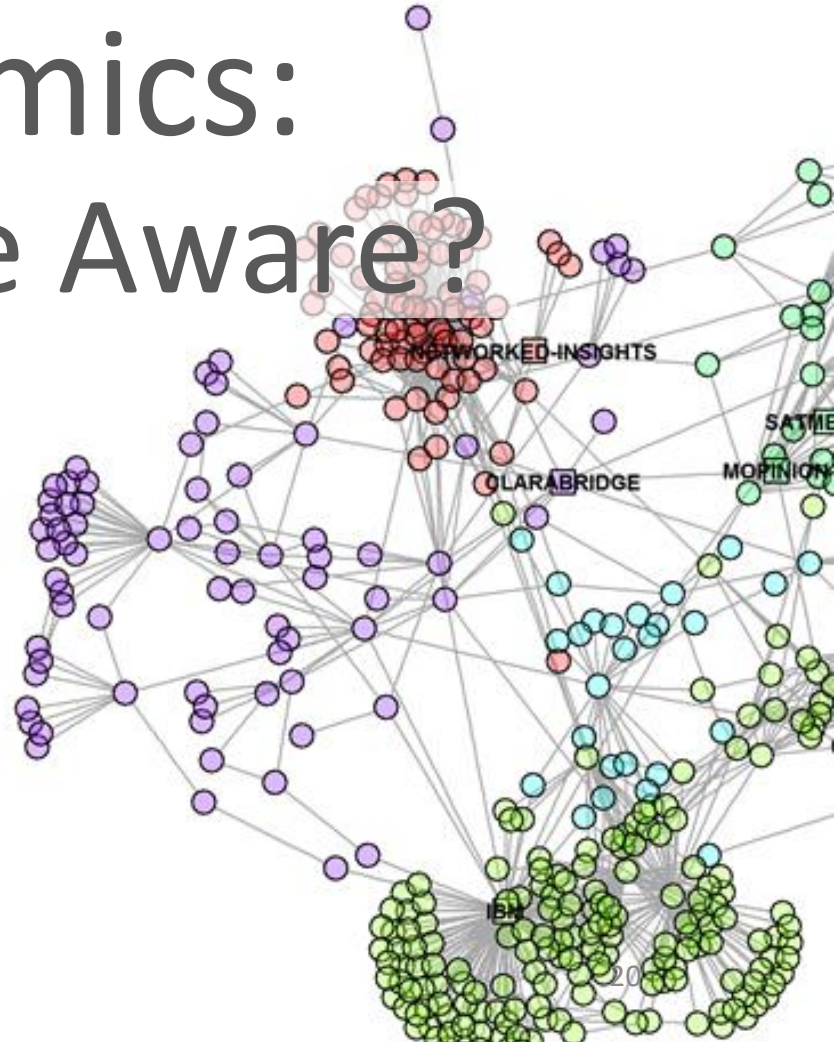

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Appendix

Inter-firm Relations

Cooperative

- shared value influencing innovative output
  - information exchange, research collaboration (e.g., Adner & Kapoor, 2010; Ahuja, 2000; Gilsing, Nooteboom, Vanhaverbeke, Duysters, & van den Oord, 2008; Powell, Koput, & Smith-doerr, 1996).
- Relational view of competitive advantage (Dyer & Singh, 1998) from dyadic source of rents, beyond:
  - Industry structure (Porter, 1980)
  - Firm heterogeneity in the RBV (Barney, 1991; Rumelt, 1984; 1991)
- Although the maintenance of cooperative relations is not without cost (Hernandez et al., 2015; Pahnke et al., 2015), such relations are essentially a resource (Dyer & Singh, 1998).

Competitive

- A “cost of doing business”
- Pertinent to myriad areas:
  - market entry (Haveman & Nonnemaker, 2000; Hill, Hwang, & Kim, 1990; Jensen, 2008; Markman & Waldron, 2014; Wu & Knott, 2006),
  - M&A (e.g., Cartwright & Schoenberg, 2006; Haleblian, Devers, McNamara, Carpenter, & Davison, 2009)
  - Market exists (Girma, Greenaway, & Kneller, 2003),
  - firm closures (Headd, 2003)
- Embeddedness lagging in strategic mgmt. research
  - Management scholars have acknowledged embeddedness for two decades (Gulati, Nohria, & Zaheer, 2000; Madhavan, Koka, & Prescott, 1998)
  - But its impact upon competitive actions has yet to receive sufficient attention (Bhardwaj, 1997)
  - We argue it is useful for extending the competitive awareness concept to emerging rivalry

Contrasting Network Models (Borgatti & Lopez-Kidwell, 2011)

Cooperative

- **Flow models:** value from resource flow
- treat ties (relations) as conduits for the flow of information and other resource among network members (eg, firms, people)

- Relational theories including:
  - social capital (Coleman, 1988)
  - weak ties (Granovetter, 1973)
  - small worlds (Milgram, 1967; Watts & Strogatz, 1998)
  - and structural holes (Burt, 1992).

Competitive

- **Architecture models**: value from node alignment
- no direct exchange of information, resources
- benefits (costs) accrue (deduct) by position
  - adjacency to specific neighbors, their neighbors, etc.
- Relational theories including:
  - Social resource theory (Lin, 1982; 1999a; 1999b)
  - Principal-agent theory (Rees, 1985; Eisenhardt, 1989) – "work is done on behalf of another"
  - Transactional knowledge theory (Hollingshead, 1998; Argote, 1999; Moreland, 1999) – knowledge is contributed but not transferred
  - Network exchange theory (Cook et al. 1983; Markovsky et al. 1988); network role theory (Borgatti & Everett, 1992)

✓ **Suits our investigation of emerging rivalry**

Measures

Network statistic g_R of Network Risk:

$$g_R(\mathbf{y}^t) = \sum_{i=1}^{n}\sum_{j=1}^{n} y_{ij}^t \cdot R_i^t, \qquad \forall j \neq i$$

- $R_i^t = \left(\frac{n-1}{\sum_{j=1}^{n} w_{ij}^t}\right), \quad \forall j \neq i$: Network Risk of firm *i* at *t*
- $w_{ij}^t = \begin{cases} d_{ij}^t\left(2 - D\left(G_i^t\right)\right), & G_i^t = G_j^t \\ d_{ij}^t\left(2 - D\left(G_i^t, G_j^t\right)\right), & G_i^t \neq G_j^t \end{cases}$: density-weighted competitive distance
- d_{ij}: competitive distance between firms i and j
- $D\left(G_i^t\right) = \sum_{i,j \in G_i^t; i \neq j} \left\{\frac{y_{ij}^t}{|G_i^t|(|G_i^t|-1)/2}\right\}$: the CNG density
- $D\left(G_i^t, G_j^t\right) = \sum_{i \in G_i^t} \sum_{j \in G_j^t; i \neq j} \left\{\frac{y_{ij}^t}{|G_i^t| \cdot |G_j^t|}\right\}$: the CNG cross-density

Measures (2)

Network statistic g_{C_k} of k-cycles: Desmarais & Cranmer, (2012):

$$g_{\mathrm{C_k}}(\mathbf{y}^t) = \sum_{i=1}^{n}\sum_{j=1}^{n}\dots\sum_{k=1}^{n} y_{ij}^t \cdot y_{jl}^t \cdot \dots \cdot y_{ik}^t\,, \qquad \forall k \neq \dots \neq j \neq i$$

- adds one whenever all the competitive ties (y_{ij}^t,…,y_{ik}^t) are present during the same time period, forming a cycle.

Network statistic g_S of Structural Similarity:

$$g_S(\mathbf{y}^{\mathrm{t}}) = \sum_{i=1}^{n}\sum_{j=1}^{n} y_{ij}^t \cdot S_{ij}^t \quad \forall j \neq i$$

- $S_{ij}^t = \left|C_i^t - C_j^t\right|$: the absolute difference of constraint (Burt, 1992)
- $C_i^t = \sum_{j\in V_i}\left[\left(p_{ij}^t + \sum_{l\in V_i} p_{il}^t p_{lj}^t\right)^2\right], \forall j \neq l \neq i$: the constraint measure for firm *i* at *t*

Controls

- Network structural controls:
  - Number of **edges** in the network (baseline competition, like a linear regression intercept term)
  - Geometrically-weighted edgewise shared partner (GWESP) distribution (eg, Hunter and Handcock, 2006; Hunter 2007)
  - Competition persistence (DV lag) (Cranmer, Heinrich, & Desmarais, 2014)
  - Shared partner similarity
  - Network group (CNG) homophily
- Firm-specific and firm-dyadic controls:
  - Firm age
  - Firm firm branch multi-market contact
  - Geographic homophily
  - Operating status differential homophily (private vs public)

Competition Network Dyads Summary Stats

- 475 firms (by 2016)
- 6 x 1-yr periods
- 324,586 period-dyad observations
- Dyadic observation correlation p-values were all but one significant at < 0.001
- P-vals not reported here since violated assumptions (non-linearity, dependence) make their interpretation misleading

	Mean	SD	Med	Min	Max
1. HQ geographic homophily	0.2	0.4	0.0	0.0	1.0
2. Firm Age	24.8	19.9	19.0	0.0	106.0
3. Firm Branch MMC	0.0	0.1	0.0	0.0	0.8
4. Persistence (DV lag)	0.0	0.1	0.0	0.0	1.0
5. CNG Homophily	0.2	0.4	0.0	0.0	1.0
6. Shared Partner Similarity	0.1	0.3	0.0	0.0	32.8
7. Network Risk	16.0	3.2	16.4	0.0	40.5
8. Constraint	1.0	0.4	1.0	0.0	2.0
9. Abs. Diff. of Constraint	0.4	0.3	0.3	0.0	1.0
10. 3-Cycles	0.2	0.6	0.0	0.0	35.0
11. 4-Cycles	1.2	4.3	0.0	0.0	126.0
12. 5-Cycles	12.5	34.9	1.0	0.0	1320.0

n = 324,586

TERGM Full Results

		Control	I	II	III	IV
Network Risk	H1		0.239*			0.456*
			[0.145; 0.289]			[0.343; 0.488]
3-Cycles				1.220*		0.756*
				[0.490; 1.743]		[0.542; 1.072]
4-Cycles	H2a			0.134*		0.066*
				[0.112; 0.190]		[0.052; 0.095]
5-Cycles	H2b			-0.017*		-0.017*
				[-0.021; -0.014]		[-0.022; -0.014]
Constraint					-0.482	-6.921*
					[-2.731; 0.831]	[-7.885; -3.554]
Absolute Difference of Constraint	H3				3.350*	5.158*
					[2.707; 5.109]	[3.999; 6.442]
Constant (network edges)		-8.173*	-11.585*	-8.365*	-9.479*	-11.798*
		[-11.235; -7.431]	[-13.569; -9.994]	[-10.995; -7.918]	[-12.691; -7.622]	[-14.471; -10.236]
GWESP		0.268	-0.205*	0.135	-0.002	-0.124
		[-0.270; 0.649]	[-0.333; -0.107]	[-0.423; 0.552]	[-0.272; 0.119]	[-0.530; 0.101]
Competition Persistence (DV lag)		10.438*	10.815*	10.395*	10.948*	10.372*
		[8.832; 16.054]	[9.120; 13.804]	[8.788; 16.701]	[8.988; 18.057]	[8.754; 14.001]
Firm Age		0.016*	0.016*	0.011*	0.015*	0.012*
		[0.012; 0.020]	[0.010; 0.020]	[0.005; 0.017]	[0.010; 0.019]	[0.005; 0.019]
Firm Branch Multi-Market Contact		0.55	-0.607	-0.819	-0.193	-1.316
		[-0.927; 1.734]	[-1.234; 0.517]	[-2.660; 0.614]	[-1.068; 1.131]	[-2.847; 0.430]
Geographic Homophily		-0.234	-0.211	-0.247	-0.23	-0.144
		[-0.346; 0.067]	[-0.297; 0.021]	[-0.364; 0.038]	[-0.347; 0.048]	[-0.262; 0.069]
Network Group Homophily		2.449*	3.602*	2.070*	3.380*	4.074*
		[1.441; 3.845]	[3.350; 4.452]	[1.273; 4.038]	[2.896; 4.607]	[3.598; 5.370]
Operating Status Diff. Homophily: Private		-0.831*	-1.106*	-0.333*	-0.676*	-0.825*
		[-0.967; -0.736]	[-1.275; -0.914]	[-0.514; -0.192]	[-0.884; -0.523]	[-1.046; -0.495]
Operating Status Diff. Homophily: Public		-0.271	-0.195	0.027	-0.213	0.019
		[-2.128; 0.233]	[-1.854; 0.277]	[-1.008; 0.397]	[-2.369; 0.333]	[-0.645; 0.339]
Shared Partner Similarity		1.339	1.213*	-0.755	1.622*	-0.215
		[-0.115; 2.219]	[0.352; 1.530]	[-1.651; 0.466]	[0.353; 2.674]	[-0.507; 0.182]
Num. obs.		34,669	323,045	97,918	225,298	324,586

* 0 outside the 95% bootstrapped confidence interval; 1,000 bootstrap resampled 95% confidence intervals shown in brackets

Goodness of Fit

- Assessment of GOF for any ERGM family is involved but incredibly important.
  - Our TERGM (model IV) is only valid if the network statistics capture the corresponding endogenous dependencies (Hunter, Goodreau, & Handcock, 2008; Leifeld et al., 2016b).
- Simulated 100 distinct networks from the parameters and covariates of model IV and use this simulated sample
  - used as a baseline for comparison with the observed network
  - find that model IV is particularly representative of the middle period (2013) but acceptable fit overall.
- Ran at three different time periods (2011,2013,2016), beginning, middle, end of data
  - dyad-wise shared partners, edge-wise shared partners, degree distribution and geodesic (shorted path) distance
  - all suitably reflect our observed network
  - especially accurate during the middle period due to changes in network composition after 2012 because the TERGM estimates reflect an average over the included time periods