Networks-Affect-Pricing Theory in Modern Production Industry: Three Network Studies of the Giant Industrial District of Tokyo

http://tinyurl.com/z4uqk

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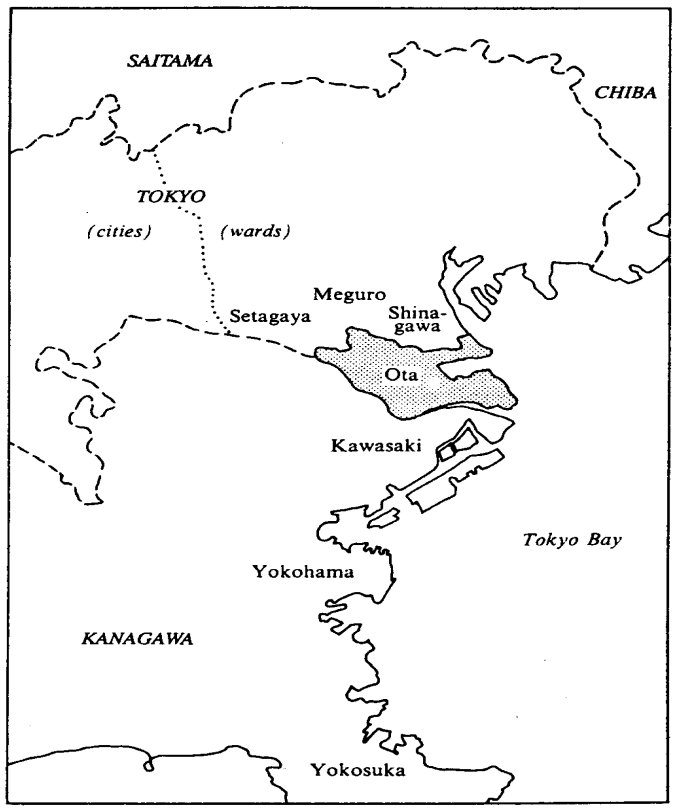
adopted from Whittaker (1997)



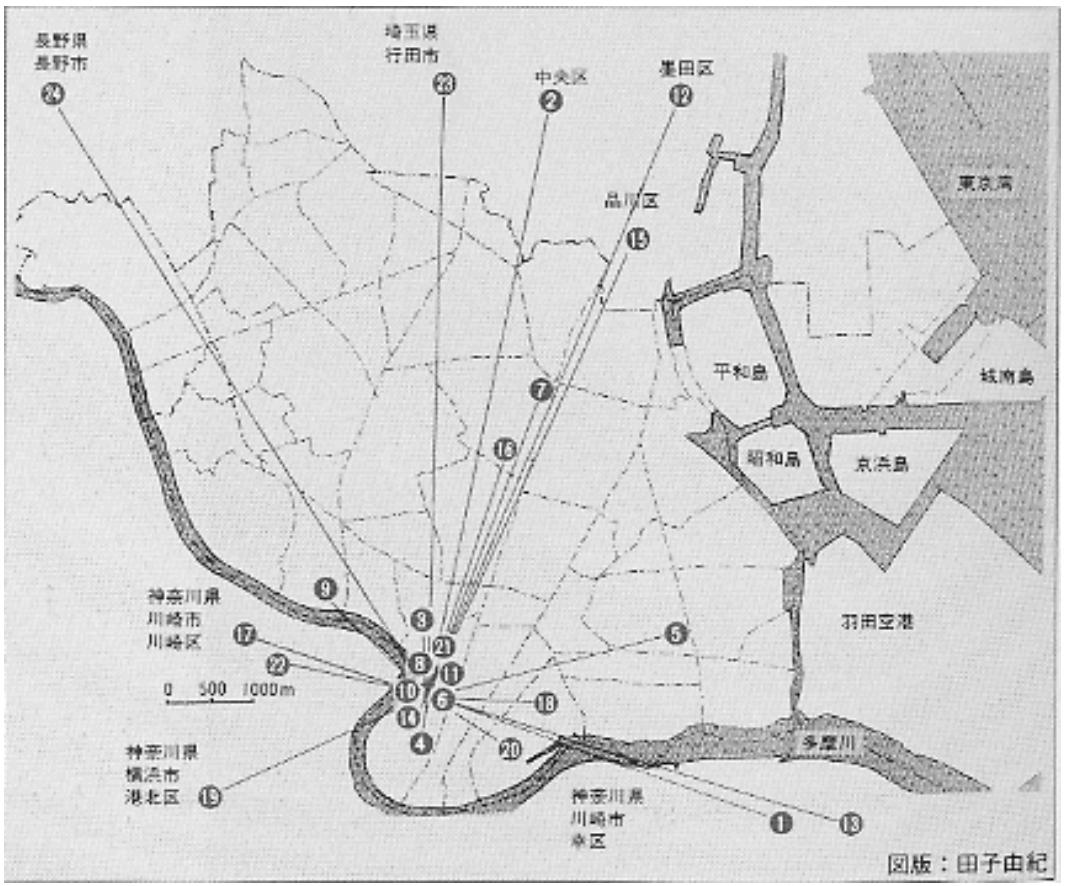
Outline

- Background to Ohta Industrial District
- Network: Small World?
- Scale-Free?
- Directed acyclic graph (DAG)?
- Structurally Cohesive?
- How are pricing structures favored by:
  - Network macro-structure?
  - Network micro-structure?
- Integrating engine of the industrial district?

A Division of Labor among the Firms:

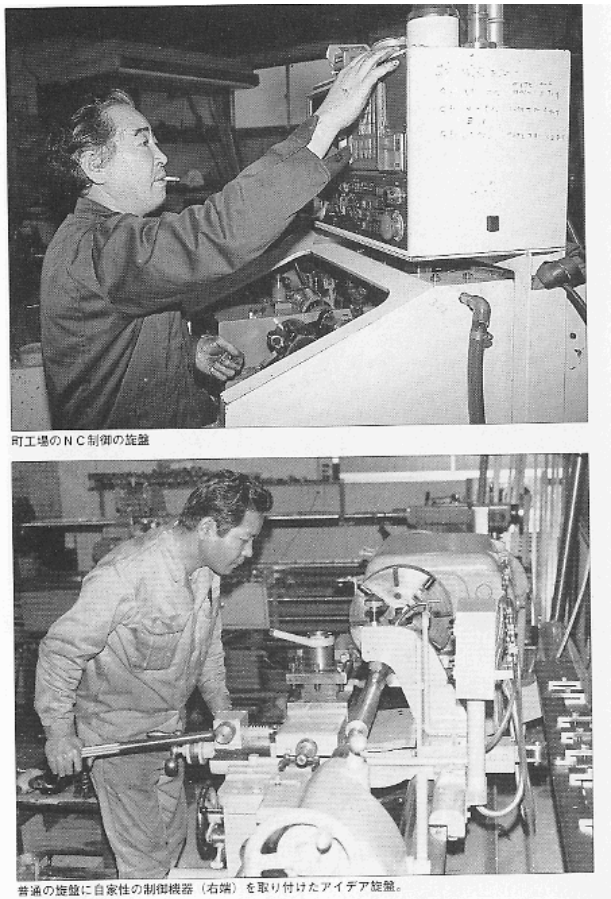
e. g. 24 firms engaged to manufacture a can-crashing machine

Note: Figures adopted from *Explorative Guide Book* (Folk Museum of Ota, 1994:72-3)



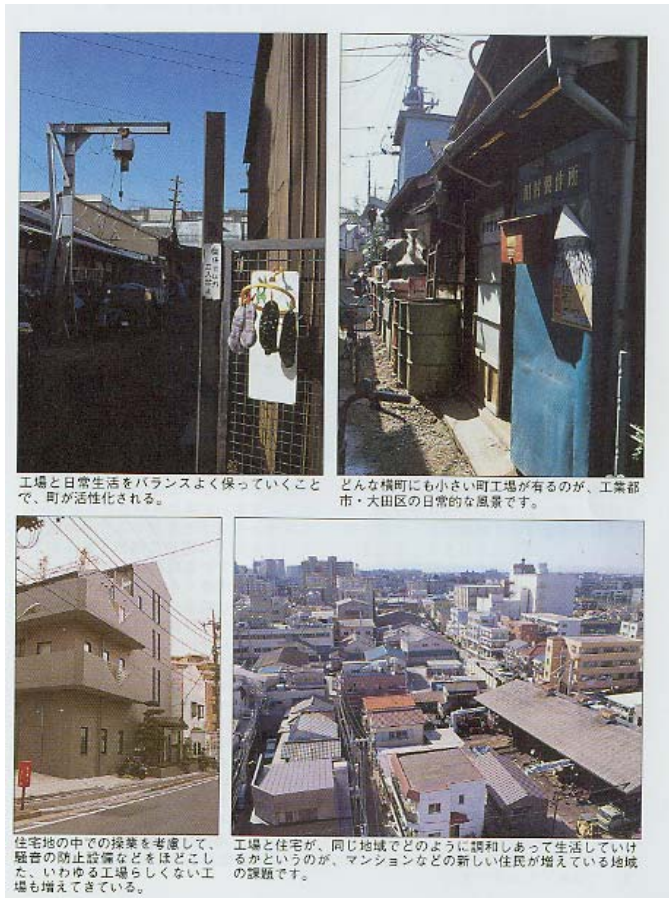
Visually…

Note: Photos adopted from *Explorative Guide Book* (Folk Museum of Ota City,1994:63)



町工場のＮＣ制御の旋盤

普通の旋盤に自家性の制御機器（右端）を取り付けたアイデア旋盤。



工場と日常生活をバランスよく保っていくことで、町が活性化される。

どんな横町にも小さい町工場が有るのが、工業都市・大田区の日常的な風景です。

住宅地の中での操業を考慮して、騒音の防止設備などをほどこした、いわゆる工場らしくない工場も増えてきている。

工場と住宅が、同じ地域でどのように調和しあって生活していけるかというのが、マンションなどの新しい住民が増えている地域の課題です。

Regional Supplier Network in Ohta

Small- and medium-sized enterprises (SMEs) work for or with original equipment manufacturers (OEMs): Over 7000 SMEs "suppliers" in Ohta work for or with OEMs ("prime buyers") mainly located outside Ohta

"Anything can be done in Ohta as long as manufacturing" from a piece of screw, high tech devices, automotive components,to the key parts of the U.S. Space Shuttle, aircraft or large tanker

SMEs the base of the Japan's high-tech economy, as a pool of technology and tacit knowledge used by leader top brands

Composition:

(1) a variety of manufacturing processing activities including metal-cutting, molding; lathing; polishing etc. by SMEs.

(2) Parts, components, modules production by SMEs and assembling by OEMs

(3) Only 10-20% of SMEs possess their own brand products

Regionally embedded network: local communities and geographic proximity as industrial agglomeration

Network Data: size and geography

- Subcontracting or supplier networks in 1994-95
- Name-generating questionnaire (three prime buyers of each of 5111 SMEs in Ohta)
- Collected by *Ohta-ku Sangyo Shinko Kyokai* (Ohta-ku Sangyo Shinko Kyokai 1997; Ohta-ku Sangyo Shinko Kyokai 1997) (70% response rate)
- 5,111 SMEs in Ohta listed
- Of which 2,710 listed up to 3 firms as prime buyers
- 4,077 prime buyers named
- Of which, 841 prime buyers (supplier-prime buyers) located in Ohta and 3,236 prime buyers located outside Ohta
- In total, 8,311 firms in the network data

Typical Graphic Presentation

Prime buyers

Suppliers

Question 1. Is the Ohta industrial network small-world? (largest component of 4,500 firms) Stanley Milgram, Manfred Kochen

Large Sparse Network (LSN)

Watts (1999) conditions:

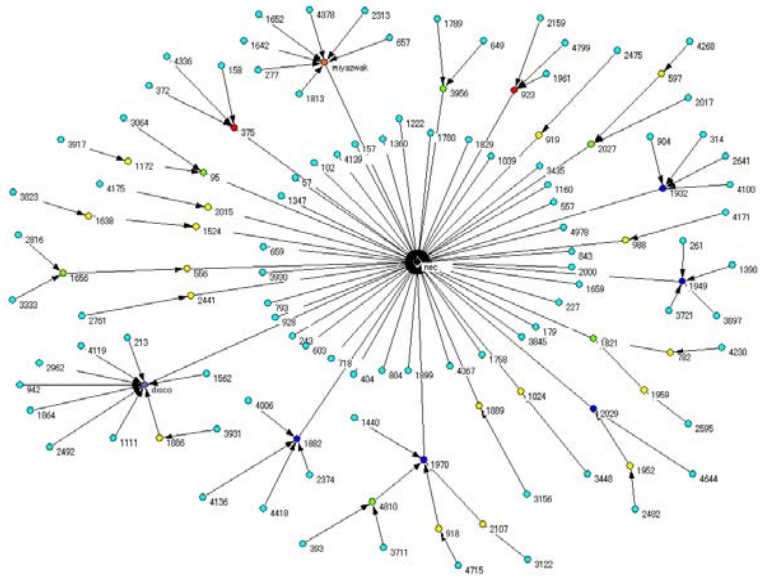
- Large component
- High clustering coefficient (many clusters)
- Short average geodesic path
- No dominant node: degree centrality

* other measures available but we follow the previous organization studies

Q1. Local Structure

Double hub-and-poke as division of labor organized by hubs
(flexible specialization theory)

e.g. NEC's egocentric network (Double-hub-and-spoke)



Note.—Graph produced from data in *Ohta-ku Akusesu Deta 1 & 2* (Ohta-ku Sangyo Shinko Kyokai 1997a; 1997b). Colors by in-degree.

Question 2. Is the Ohta industrial network a scale-free network of preferential node attachments? (the Barabási model)

e.g. hubs such as Toshiba, NEC, Hitachi,…

Top prime buyers by in-degree centrality

Centrality rank order	Identification number	Number of In-degree	Lables	Firm name
1	7654	112	toshiba	toshiba corporation
2	7986	53	nec	nec
3	8046	45	hitachi	hitachi
4	6701	37	mbshihv	mitsubishi heavey industries
4	5596	37	sony	sony
4	417	37	canon	canon
7	217	34	ebara	ebara
8	4043	29	tokimec	tokimec
9	2063	22	ricoh	ricoh
10	8154	21	fujitsu	fujitsu
10	7129	21	ihi	ishikawajima harima industries
10	6698	21	mbshimot	mitsubishi motors
13	8159	20	fujiel	fuji electric
14	1859	19	mituise	mitui seiki
15	5748	18	nikon	nikon
16	5450	17	komatsu	komatsu
17	6927	16	matsuel	matsushita electric
17	6926	16	matsucom	matsushita tsushin
17	5702	16	tokico	tokico
17	5244	16	isuzu	isuzu
17	106	16	ikegmi	ikegmi communications
22	7822	15	nissan	nissan motors
22	1497	15	nsk	nippon seiko
24	7960	14	nkk	nihon kokan
25	7011	13	mhi	mitsubishi heavy industries

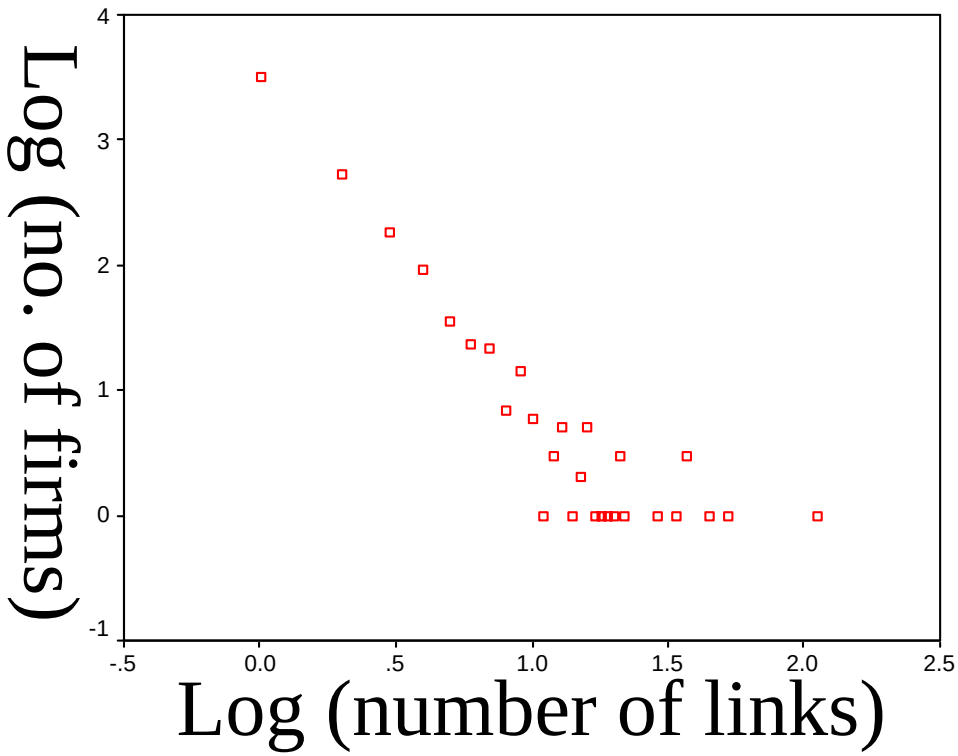
Note.—Figures were calculated based on data from *Ohta-ku Kusesu Deta 1 & 2* (Ohta-ku Sangyo Shinko Kyokai 1997a; 1997b), using Pajek

Node Links Distribution subject to Power Law?

Scale-free network with $1539.4x^{-2.2862}$ and $R^2 = 0.8537$ *

α ~ 1.8 to 2.5 for scale-free preferential attachment networks of size 4-8,000 (White and Johansen 2005:17)

* Fitting procedure of Goldstein, Morris and Yen (2004)



- But not power law as Barabási conceptualized:

  Not based on preferential attachments from the bottom to the center as it it the hubs that do most of the organizing

  (e.g. NEC ego network, given the built-in roles in the division of labor of flexible specialization)

- Nor S-W as Watts defined:

  Extremely low local clustering and relatively very short average distance (component of 4500 firms more efficient than random net)

Question 3. Is the Ohta industrial network a directed acyclic graph?
(hierarchy model: DAG)

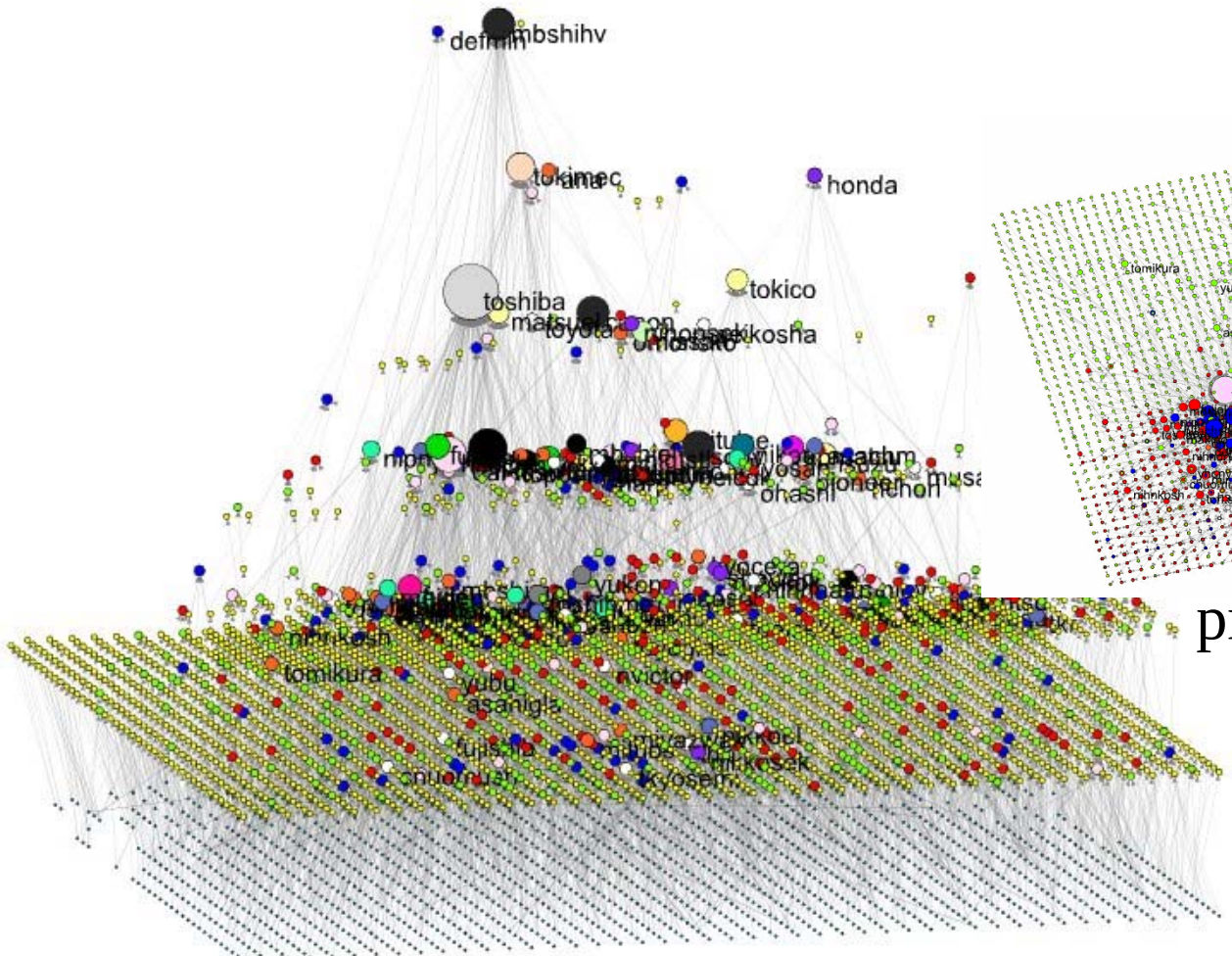
In fact, no cycles found in Ohta
All relations directed, antisymmetric

- This would imply an Acyclic Depth Partition

Algorithm:

All first vertices that do not have an in-degree are assigned as Depth 1. These vertices and corresponding lines going out from the vertices are removed for the next step. After the second round of calculations, all vertices that do not have an in-degree are assigned as Depth 2, and the vertices and corresponding lines going out from the vertices are removed again, for the next step. The procedure continues until it reaches the last class of vertices, from which no line is going out (Batagelj and Mrvar 2003).

A Global Structure
Largest component of 4500 firms by acyclic depth



Top-down projection of clustering

Note.—The left graph shows subcontracting layers, according to the acyclic depth partition of the 4,500 firms in the main supplier/buyer component from the *Ohta-ku Akusesu Deta 1 & 2* (Ohta-ku Sangyo Shinko Kyokai 1997a; 1997b) data. The sizes of nodes reflect firm in-degree, or times listed by others as a prime buyer.

DAG in Ohta: Structural Characteristics

Seven linked classes of firms: The entangled hierarchical linkages started at class 1 (Depth 1) and ended at class 7 (Depth 7)

Numerous channels for flows of manufacturing processes that were producing various components and end products from the industrial district (hierarchically clustered)

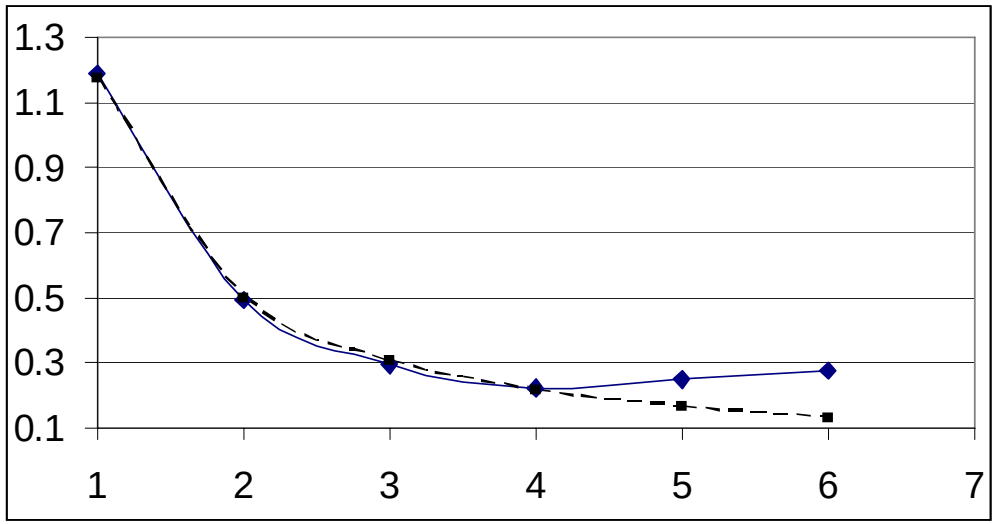
From class 1 toward 7, the manufacturing processes and services come closer to end products

Multiple overlapping “mountains” with “peaks” of OEMs’ supplier groups (no single firm dominance)

Thousands of dedicated SMEs serve as a technological tool shed for the OEMs

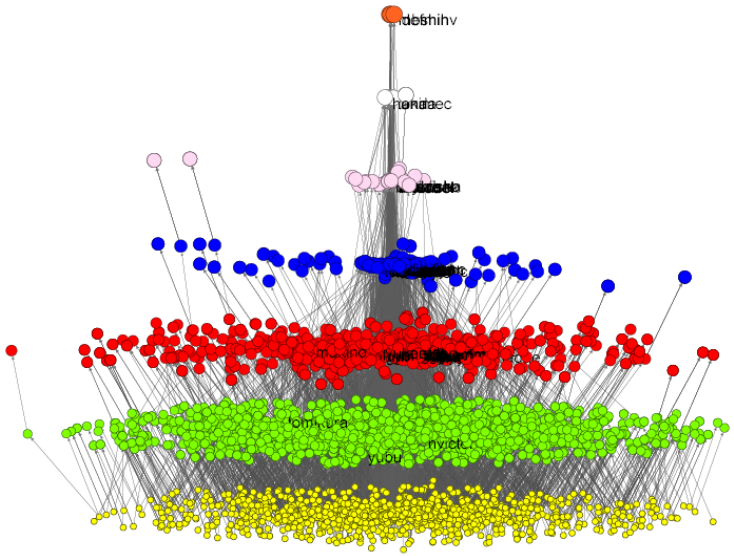
Question 4. Is there a structurally cohesive core in the complex network?

Of 8,347 firms in the dataset, a large bicomponent of 1609 firms is nested in the largest component of 4500 firms.



Assortative correlation by layers

Solid line shows actual number of links per node at each level; dotted line shows this ratio as extrapolated from power-law decay. A largest component of 4,500 firms by acyclic depth partition



subcontracting layers, according to acyclic depth partition of the largest component and a spring-embedding scaling for cohesion across layers among connected nodes. Fruchterman spring embedding graph scaling on the X-Y plane while holding Z fixed.

Question 5:

How and where do general and special equilibria occur in production-chain markets, from the point of view of social network analysis?

Comparison to Harrison White's model of modern production markets

(agree on: directed, hierarchical)

- His
  - Tradeoff profiles affect pricing

- Ours
  - Networks affect pricing
    - cohesion
    - microstructure

Biconnectivity and pricing equilibrium

- a large bicomponent with many plural buyers and plural suppliers is a critical "seeding" mechanism where quasi-optimal exchange can be achieved.

- multiple-buyer triads give suppliers choice in terms and conditions; avoidance of closure by the prime buyers

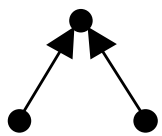
- multiple-supplier triads gives prime buyers price competition between the competing suppliers; hedging in case of contingency; minimum information sharing; and easy logistical coordination.

Question 6. What is the microstructure (ring cohesion) of the structurally cohesive core?

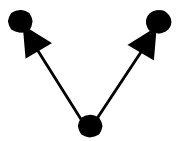
e.g., Triads Census

Triad Census of Largest Component and Bicomponent in Comparison

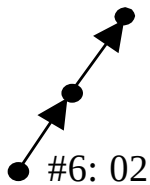
	Largest Component (4500 nodes)			Largest Bicomponent (1609 nodes)		
Triad Types	Actual	Expected	Ratio (Actual / Expected)	Actual	Expected	Ratio (Actual / Expected)
5 021 U	18009	3195	5.637	11737	1882	6.236
4 021 D	4644	3195	1.454	1658	1882	0.881
6 021 C	2727	6390	0.428	1181	3766	0.314
9 030 T	13	1.68	7.692	13	3.59	3.621
10 030 C	0	0.56	0	0	1.19	0



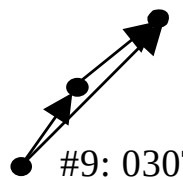
#5: 021U
18009/3195
Multiple Suppliers



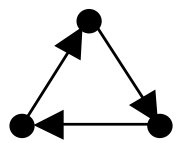
#4: 021D
4644/3195
Multiple Buyers



#6: 021C
2727/6390
Vertical Chain



#9: 030T
13/1.69
Transitive Vertical



#10: 030C
0/0.56
Directed Cycle

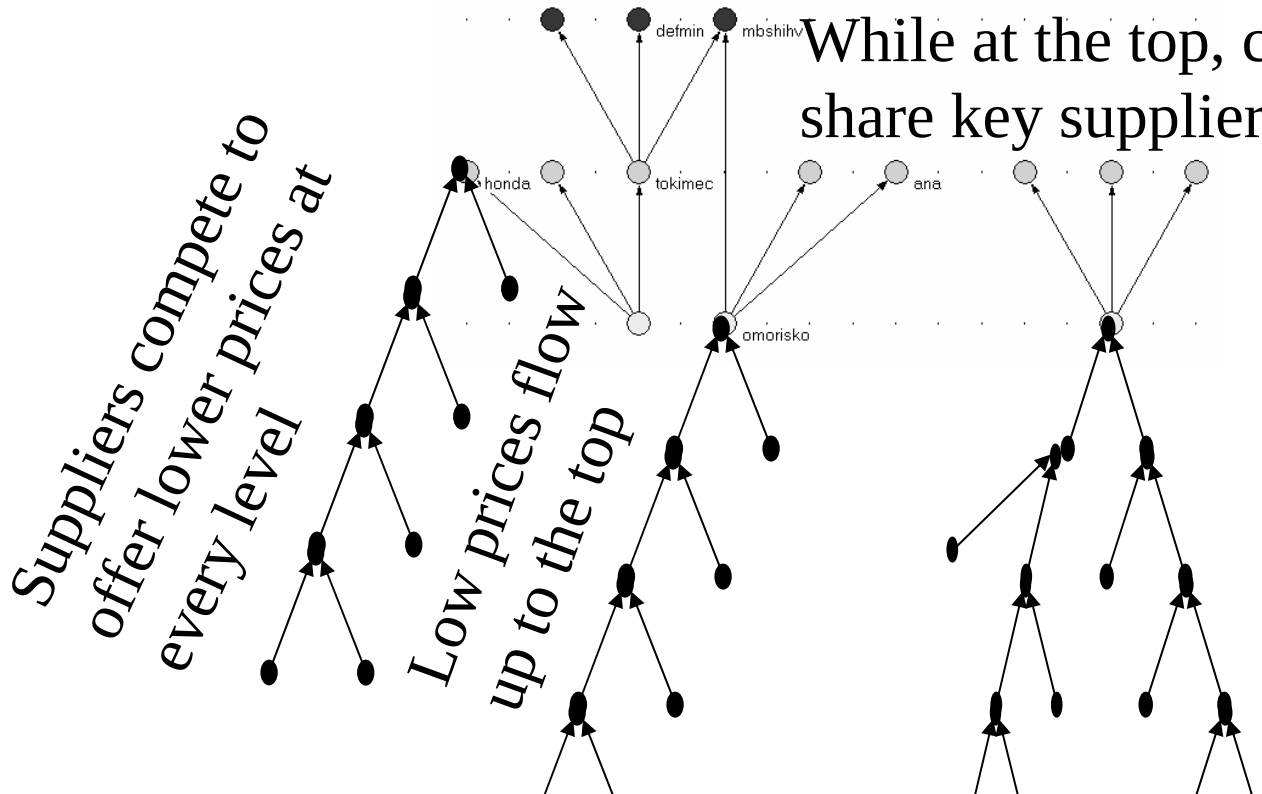
7 to 1 ratio of multiple suppliers to multiple buyers

How these triads are distributed in the large component of 4500 firms with 1609 in the bicomponent is key to the market structure of pricing

Multiple-suppliers triad / multiple-buyers triad ratio:

4 : 1 Overall 11,737 triads in bicomponent

1 : 12 However, in levels of depth 5-7



While at the top, core firms share key suppliers

Existence of an “Elite Club” as the Integrating Engine of the LSN

- Elite suppliers as powerful enough to bridge their extremely powerful top prime buyers, escaping from the overall power-law (spring-embedding graph scalings; assortative correlation; and triads census)

- Instead of Barabási’s node preferential attachments, the core organizes the LSN in the DAG

- The bicomponent provides a quasi-optimal pricing mechanism

- The detailed ring cohesion (subgraph) structure provides a mechanism for pricing benefits at the top

Nakano and White: articles submitted

- The Large-Scale Network of a Tokyo Industrial District: Small-World, Scale-Free, or Depth Hierarchy?
- Power-Law and “Elite Club” in a Complex Supplier-Buyer Network: Flexible Specialization or Dual Economy?
- The “Visible Hand” in a Production-Chain Market: A Market Equilibrium from Network Analytical Perspective*

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end

Emerging Problems in Ohta

- Job security of SME workers: “Dual economy” and “dual labor market”?
- “Hollowing-out”: Low value-added or simple manufacturing shifting to other Asian countries (competition)
- Succession of the retiring SME proprietors
- 3D industry: "dirty, dull, and dangerous," i.e., typically a "sweat shop" in manufacturing plants or factories.
- As manufacturing SMEs, they generally lack solid financial base and marketing capacity and skills

Alternative theories?

The egalitarian notion of *flexible specialization* is denied by the existence of the "elite core"

"Dual economy" not based on the firm size as explained from the Marxian framework, but on the foundations of node connectivity among the hubs

Resource dependence theory

Unequal Distribution of the Resources and Wealth?

Reputation

Marketing capacity

IT and advanced machining technologies

Network closure as an “elite club”?

Rise of Tier-1 suppliers?

Elite Core as the Engine of the LSN

SMEs in lower tiers possess neither global reputation and brand equity, marketing capacity and skills, nor interface with consumers at large, given their limited financial and human capital

Therefore, the elite core as:

- The origin of the status differentiations between the elite supplies and powerful OEMs on the one hand and the rest of the SME suppliers on the other
- The origin of the role structure in the production-chain
- Organizing and integrating engine of the complex production hierarchy

Complex Systems and Organization Studies

Watts (1999) explained formation process of the small-world on the basis of local clustering and short path distance (Milgram 1967; White 1970) while Barabási (2002) proposed a preferential attachment model as an alternative

➔Many simulation studies of LNS as complex systems emerged

Applied empirical research in organization studies as S-W

1. Corporate interlocks (Kogut and Walker 2001; Davis, Yoo et al. 2003)
2. Alliances and joint venture projects (Baum, Shipilov et al. 2003)
3. Industry formation (Uzzi and Spiro 2005)

Studies of Industrial Districts and Organizational Sociology

- Started from fieldwork studies of industrial clusters in the Third Italy (Emilio Romana)
- Piore and Sable (1984): *Flexible Specialization* Theory
- Renewed interest after the 1990s as with the notion of social capital (e.g. embedded inter-firm and personal networks)
- Actively debated and studied globally from qualitative fieldwork approaches ever since（Watanabe 1998；Seki & Kato 1990; Lazerson 1995; Putnam 1993; Pyke & Sengenberger 1992）

Limitations of the Existing Studies

1 . The concept of flexible specialization implicitly focuses on local structure of the interfirm network and neglects global properties

2 . While many patterns of industrial agglomerations exist and no generalization should be possible (Paniccia 1998), the existing qualitative approaches cannot articulate the structural properties

3 . The existing research predominantly studied small-scale industrial districts with a few industries if not single are embedded, large-scale industrial districts such as in Ohta are a complex system where a variety of manufacturing processes, industries, and firms are embedded in the regional production-chain market as the entangled threads weaving through a gigantic network

(Thus, we used quantitative social network analysis of complex systems)

Recent Developments in the Large-Scale Network (LSN) Studies (White)

- Marriage, elite and political Networks in Mexico

  ➔Found an "invisible state" to bind large regions with the common cultural heritage together beyond the political boundaries through structural endogamy (Douglas White 1997)

- Predictive Cohesion Theory (NSF funded research), e.g., White and Harary 2001, Moody and White 2003
- Ring Cohesion Theory (White 2004)

- Network Dynamics (White and Johansen 2005)
- Recent evolution of interfirm networks in life sciences (Walter Powell et al. 2005)

Pajek as a powerful analytical tool

How efficient is the bicomponent?

A Largest Bicomponent: Number of Firms with In-degree by Out-degree

# of firms by in-degree (prime buyers)	# of firms by out-degree (suppliers)				
	0	1	2	3	total
0	0	0	537	245	782
1	0	95	86	50	231
2	270	21	23	22	336
3	97	7	8	10	122
4	35	2	1	3	41
5	19	0	3	2	24
6	15	0	2	1	18
7	12	0	1	1	14
8	7	0	0	0	7
9	3	1	1	0	5
10	2	0	0	0	2
11	2	0	0	0	2
12	4	0	0	0	4
13	2	0	0	2	4
14	2	1	0	0	3
15	2	0	0	0	2
17	1	0	0	0	1
18	1	0	0	0	1
20	1	0	0	0	1
21	1	0	0	0	1
22	0	0	1	0	1
28	1	0	0	0	1
29	1	0	0	0	1
30	1	0	0	0	1
32	1	0	0	0	1
36	1	0	0	0	1
41	1	0	0	0	1
93	1	0	0	0	1
total	483	127	663	336	1609

Networks-Affect-Pricing Theory in Modern Production Industry: Three Network Studies of the Giant Industrial District of Tokyo

Abstract. We analyze general price equilibrium mechanisms of production-chain markets, comparing the producer market model proposed by Harrison White with hypothesized network effects on pricing that emerge from empirical analysis of trade relationships among over 8,000 firms in a large-scale industrial district in Tokyo. Consistent with White's model, the supplier-prime buyer relationships are strictly hierarchical and constitute a directed acyclic graph (DAG). There are no exchange cycles that would promote price equilibrium. We argue, partly from a Simmelian approach to triad configurations, that three linked network configurations are likely to affect pricing. First, a particular form of structural cohesion as defined by multi-connectivity (bicomplete connectedness within a large bicomponent) is a critical "seeding" mechanism where quasi-optimal exchange can be achieved as the "visible hand" in production-chain markets. Second, a powerful core of elite firms was detected that organizes status differences among firms and serves to institutionalize role structures in the production markets. Third, structural advantages in pricing accrue to elite core firms because suppliers upstream in the hierarchy operate through a 4:1 preponderance of multiple-supplier to multiple-buyer triads, which enforces competition among themselves rather than among the buyers. These pricing benefits to buyers are passed along to the downstream elite firms. The elites exert power over the hierarchy from the top down, share elite suppliers with other elite end-producers, and can dominate price-setting from the top.

Abstract and powerpoint on the web site: http://tinyurl.com/z4uqk