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PRIVATE STRATEGIES, PUBLIC POLICIES & FOOD SYSTEM PERFORMANCE

AN ALTERNATIVE MEASURE OF AGGREGATE CONCENTRATION WITH AN APPLICATION TO THE AGRIBUSINESS SECTOR

by

Julie A. Caswell

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I. Introduction

Aggregate concentration is conventionally measured as the share of an economic variable such as value added or assets held by the largest firms in a sector or the economy as a whole.[1] Other measures focus on the distribution of a relevant economic variable over the entire population of firms.[2] Both types of measures implicitly assume that firms are independently owned and operated, having only market contact with each other. They are flawed as a means of measuring the relative importance of large scale enterprise to the extent that top firms are not independent but are linked by interfirm organizational structures.

This paper presents an alternative measure of aggregate concentration based on the network clique, or group of related firms, rather than the firm as the unit of observation. Firms are associated in cliques based on the number and intensity of the interlocking directors they maintain with other firms. An application to the agribusiness sector suggests that conventional measures may underestimate aggregate concentration by 15% to 40%.

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[1]This is commonly referred to as CRK where K is the number of top firms included in the measure (e.g., CR100). Studies using this measure include White (1981), Shepherd (1982), Weiss (1983), and Hughes and Kumar (1984).

[2]These include the Herfindahl-Hirschman Index (H-index); the U-index proposed by Davies (1980); the Hannah and Kay (1977) family of indexes based on a numbers equivalent of the summation of individual firm market shares to the n^{th} power, where n does not equal one; and the Hart and Prais (1956) and Prais (1976) variance of logarithms of firms' sizes. For a discussion of these measures see Curry and George (1983).

II. The Network Clique as Unit of Observation

Contact between firms at levels above that of firm management is extensive. This interaction occurs primarily through families and companies that are large stockholders in the firms and through interlocking directors who sit on more than one board of directors. Herman (1981), Kotz (1978), and a U.S. Senate study (1974), for example, found many families and companies that hold significant blocks of stock in multiple firms. These multiple holders are frequently financial institutions that manage large pools of pension funds.

Multiple stockholdings are often reflected in patterns of interlocking membership on boards of directors (Herman (1981), Kotz (1978)). Interlocking is a more formal mode of contact than stockholding since regular board meetings provide an on-going forum for discussion. Typically, membership on boards includes the firm's top managers and representatives of large shareholders, lenders, suppliers, buyers, and others with an interest in the firm. Under Section 8 of the Clayton Act, direct competitors are barred from sitting on each other's boards. Mintz and Schwartz (1985), Mizruchi (1982), Herman (1981), and Dooley (1969) document the extensive degree of interlocking among American firms. These interlocks establish a network of contacts that has been remarkably stable over time.

For measures of aggregate concentration, the key issue raised by this network of contacts is the degree of integration of decision making among firms it represents. Such integration, like multimarket contact among firms (Scott 1982), is likely to lead to poorer market performance as competition is weakened. On the one hand, the resource dependency school argues that managers choose board members who are representatives of organizations that

have resources the firm wants access to. By placing them on the board, the managers in effect coopt the representative's home organization (see, e.g., Burt (1980), Pfeffer and Nowak (1976), Pfeffer (1972)). According to this school, the existing network of contacts is not substantial because it is an artifact of the individual firm's autonomous choice of directors.

On the other hand, the interest group school argues that organizations that possess important resources, such as financial institutions that control access to credit, demand seats on firms' boards of directors (see, e.g., Mizruchi (1982), Kotz (1978)). These seats are a quid pro quo by which the outside institution acquires a formal voice in the firm's decision making. In this case, patterns of contact indicate significant integration of decision making among related firms.

Use of network cliques of related firms as the unit of observation in measuring aggregate concentration is an outgrowth of the interest group model.[3] The premise is that the strength and stability of interlocking directors over time suggest that they reflect working relationships between firms and are established in order to secure regular forums for exchange of information. This interfirm structural organization may integrate decision making to a significant degree. Network clique based measures of aggregate concentration provide a concrete means of capturing this integration. Conventional firm based measures that cannot gauge this effect are likely to underestimate the relative importance of large scale enterprise.

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[3]Network cliques are an application of network analysis; an emerging conceptual framework and set of empirical methods for analyzing the complex sets of relational data found in the social sciences (see, e.g., Knoke and Kuklinski (1982)).

The potential bias involved can be shown by a simple example involving an economy made up of ten firms, each with the market share shown in Table 1. If interfirm organizations or network cliques are ignored, the aggregate four firm share (CR4) is 70% and the Herfindahl-Hirschman Index (H-index) is 1650. Now suppose that the decision making of the second, fourth, and sixth firms is integrated so that they form a clique. The other seven firms do not have such links and remain independent as one member cliques. Using the network clique as the unit of observation, the aggregate CR4 in the economy is 80% and the H-index is 2350. Thus failure to recognize linkages between firms that compromise their independent operation will systematically underestimate the relative importance of large scale enterprise in an economy.

Network clique based measures of aggregate concentration require an ordered list of large scale enterprises that combines closely related firms. This grouping may be based on stockholding, interlocking directors, or a combination of these and other factors. The next section presents two methods of grouping based on the number and intensity of the firm's interlocking directors. The final section compares firm and clique based measures of aggregate concentration for a sample of agribusiness firms.

III. Use of Full and Strong Directional Network Cliques in Measures of Aggregate Concentration

Interlocks between firms represent varying degrees of integration of decision making. The taking of a seat on the board of firm B by the chief executive officer of firm A, for example, represents a conscious decision by the two corporations to establish a formal link. This CEO may also sit on the board of C creating a coincidental interlock between B and C. Many other coincidental interlocks are created by prominent people who are not firm

Table 1. Comparison of Firm and Network Clique Based Measures of Aggregate Concentration.

Firm as Unit of Observation		Network Clique as Unit of Observation	
Firm Number	% Market Share	Clique Number	% Market Share
1	30	1	35
2	20	2	30
3	10	3	10
4	10	4	5
5	5	5	5
6	5	6	5
7	5	7	5
8	5	8	5
9	5		
10	5		
CR4	70%		80%
H-index	1650		2350

officers but sit on multiple boards of directors (e.g., representatives of philanthropic organizations). Thus both the content of (i.e., who makes the link) as well as the number of interlocks are important factors in identifying network cliques that represent integration of decision making between firms.

Identification of network cliques based on interlocks involves a three step process: definition of the universe of firms, enumeration of interlocks between universe firms, and grouping of firms into cliques based on interlocks. The universe is defined broadly enough to include all firms and organizations that are likely to be significant participants in the network. For measuring economy wide aggregate concentration, for example, a universe including manufacturing, banking, life insurance, utility, retail trade, and transportation firms is desirable.

Enumeration of interlocks requires listing and matching the officers and directors of all members of the universe. The set of matches or interlocks is the basic data for network models that group related firms into cliques. The model and algorithm for this grouping presented here was developed by researchers at SUNY-Stony Brook[4] and is described in detail in Caswell (1987). Its use to generate an alternative measure of aggregate concentration is a novel application of this model.

The model uses relational data on director interlocks to generate centrality scores (c_i) for each of the firms in the universe or network. These scores can be informally thought of as a measure of popularity. A firm's centrality score is based on who it interlocks with and the intensity of its interlocks. The general form of the centrality measure for firm i is

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[4]See Bearden et al.(1975), Mariolis (1975), Mizruchi(1982), and Mintz and Schwartz (1985).

$$c_i = \sum_{\substack{j=1 \\ i \neq j}}^{N} r_{ij} * c_j , \qquad (1)$$

where r_{ij} is intensity of the link between firm i and j, c_j is centrality of firm j, and N is number of firms in network. Thus a firm's centrality score is a weighted summation of the intensity of its board interlocks with other firms where the weights are the centrality scores of the interlocking firms. The weights allow for links with different degrees of importance. A link to a highly interconnected firm that has a relatively high centrality score, for example, will contribute more to a firm's centrality score than a link to a firm that is weakly connected.

Two measures of r_{ij}, the intensity of the link between two firms, are defined. These distinguish between the set of all interlocks and the subset that is more likely to represent integration of decision making between firms. The two definitions form the basis for identification of full and strong directional network cliques.

Under the full network definition, r_{ij} is based on the set of all interlocks between firms regardless of who makes the interlock. Thus r_{ij} is defined as

$$r_{ij} = \frac{b_{ij}}{\sqrt{d_i d_j}} , \qquad (2)$$

where b_{ij} is number of board members in common, d_i is number of members on board of firm i, and d_j is number of members on board of firm j.[5] The numerator is the number of interlocking directors between the two firms while

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[5]The r_{ij} measures rely on interlocking board membership. Thus firms with no board (i.e., cases where d_i or d_j equals zero) are excluded from the analysis.

the denominator controls for the potential number of interlockers from each firm.

The strong directional network definition of r_{ij} is more stringent; including only board interlocks made by an officer of one of the interlocked firms. As noted, these ties represent a conscious decision to associate and are more likely to involve some degree of integration of decision making. In addition, in this measure r_{ij} is defined so that the firm sending the interlock (the officer's home firm) gets the bulk of the increase in centrality scores due to the link while the receiving firm gets the balance. This formulation recognizes that the direction of the interlock indicates the flow of influence between the two corporations.

Formally, in the strong directional network r_{ij} is defined as

$$r_{ij} = \frac{W_s * s_{ij} + W_r * t_{ij}}{N\sqrt{d_i d_j}}, \qquad (3)$$

where s_{ij} is number of officers of firm i who sit on the board of firm j (sending), t_{ij} is number of officers of firm j who sit on the board of firm i (receiving), W_s is weight of sender, W_r is weight of receiver, and $W_s + W_r$ equals 1.[6]

The full and strong directional networks are each a set of N simultaneous equations in the matrix form:

$$C = RC \qquad (4)$$

where C is an Nx1 vector of centrality scores and R is an NxN matrix of the

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[6]Following Bearden et al. (1975) and Mizruchi (1982), W_s is set at .9 and W_r at .1 in the application that follows.

full (Equation 2) or strong directional (Equation 3) overlap measure r_{ij}.[7] The centrality scores calculated by each set of equations are used to rank corporations in the network from most to least central.

An algorithm called peak analysis is then employed to group related firms into cliques based on their own centrality scores and the scores of firms with which they are interlocked. In this process, a firm is defined as a peak, or the most central firm in a clique, if all other firms it is interlocked with are less central than it (i.e., have lower centrality scores). A firm is defined as a member of the clique associated with a peak firm if all firms more central than it that it is interlocked with are also members of that clique. Formally:

$$E_i \neq 0 \text{ iff } \forall\, j,\ r_{ij} \neq 0 \rightarrow c_i > c_j \tag{5}$$

$$j \in E_i \text{ iff } \forall\, k,\ r_{jk} \neq 0 \text{ and } c_k > c_j \rightarrow K \in E_i \tag{6}$$

where E_i is the clique associated with firm i, r_{ij} is the measure of overlap ($r_{ij} = 0$ if there are no interlocks), and c_i is the centrality of firm i. Under peak analysis, a firm is identified as a member of a clique (including peaks), a mixed member of more than one clique, or an isolate that maintains no interlocks with other firms in the network.

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[7]The system of equations $C = RC$, or $(R-I)C = 0$ has a nonzero solution only under the unlikely condition that $\det(R-I) = 0$. But Bonacich (1972) shows that multiplying the left side by a constant λ, does not violate the spirit of the model and allows a solution to the equations. The system $\lambda C=RC$ is solved by finding eigenvalues and eigenvectors. Here, λ is chosen to equal the largest eigenvalue; the elements of its related eigenvector are the centrality scores. Since the system has one more unknown than equations, the actual values of the centrality scores are arbitrary. The scores are chosen so that the most central firm has a score of 1.0; therefore, the scores range from 0 to 1.0.

Two alternative measures result from use of full and strong directional cliques, respectively, as the unit of observation in calculations of aggregate concentration. In both cases, a new ranking of the largest enterprises in an economy or sector of the economy is generated by combining the assets, sales, or other relevant economic variables of clique members. Firms that are mixed members of more than one clique or isolates are not grouped and appear in the ranking as independent entities. Commonly used measures of aggregate concentration such as CRK, H-index, and the numbers equivalent Herfindahl-Hirschman Index (NH-index) can then be computed for the new rankings. These clique based numbers are alternative, and arguably more accurate, measures of aggregate concentration and the relative importance of large scale enterprise. In the next section, conventional and alternative measures of aggregate concentration are compared for a sample of agribusiness firms.

IV. An Application to the Agribusiness Sector

The agribusiness sector of the U.S economy includes agricultural input manufacturers (machinery, feed, chemicals), cooperatives (supply and marketing), food manufacturers, restaurant chains, wholesalers and retailers. For this application, a sample of 212 of the largest firms operating in these industries in 1976 is used.[8] Since the population of firms is truncated to include only the largest firms in the agribusiness sector, the aggregate concentration figures reported here are measures of relative size among the

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[8]These 212 are a subset of a list of 222 agribusiness firms created by the Corporate Data Exchange (CDE) in the publication of the CDE Stock Ownership Directory--Agribusiness (1979). Ten of the 222 firms were excluded from the analysis because data on their board membership could not be found. A complete list of the sample firms is available from the author.

largest firms and enterprises rather than among all firms and enterprises in the sector.

The universe of firms used in the network clique analysis is defined to include the 212 agribusiness firms plus all firms that had a stockholding of at least 0.5% in one of the agribusiness firms as of 1976. There were 216 such stockholders according to the CDE Stock Ownership Directory--Agribusiness (1979). They are included in the universe because their stockholdings make them likely participants in the sector's network of contacts. In addition, the universe includes a group of 27 Fortune Top Fifty commercial banks and life insurance companies that were not agribusiness stockholders. They are included in order to cover the largest of these two types of firms comprehensively. Thus the network analyzed includes 455 firms.

The names of the officers and directors of the 455 network members were coded and matched, using biographical sources for confirmation when needed. Under both network definitions, maintenance of interlocking directors was common among the agribusiness firms. In the full network with all interlocks counted, 163 (76.9%) of the 212 agribusiness firms are interlocked with at least one other member of the network while 49 (23.1%) are isolates. In the strong directional network with only interlocks made by officers counted, 145 (68.4%) are interlocked with at least one other firm while 67 (31.6%) are isolates.

Centrality scores were computed and cliques identified in the full and strong directional networks. The degree of aggregation of individual firms into cliques differs quite dramatically between the two networks (see Table 2). In the strong directional network, a total of 205 firms belong to 64

Table 2. Distribution of Firms Among Cliques of Different Sizes, Mixed Members, and Isolates in Strong Directional and Full Networks.

Network Type	Number of Firms in Clique	Number of Cliques	Total Firms in This Category Number	Percent
Strong Directional:				
Firms in Cliques	25	1	25	5.5
	22	1	22	4.8
	12	1	12	2.6
	11	1	11	2.4
	10	1	10	2.2
	8	2	16	3.5
	6	1	6	1.3
	5	1	5	1.1
	4	4	16	3.5
	3	7	21	4.6
	2	17	34	7.5
	1	27	27	5.9
Clique Subtotal		64	205	45.1
Mixed Members		--	103	22.6
Isolates		--	147	32.3
Total		64	455	100.0
Full:				
Firms in Cliques	354	1	354	77.8
	2	5	10	2.2
Clique Subtotal		6	364	80.0
Mixed Members		--	0	0.0
Isolates		--	91	20.0
Total		6	455	100.0

cliques ranging in size from 25 down to a single member.[9] An additional 103 firms are mixed members of more than one clique while 147 firms are isolates. The full network, on the other hand, yields a much more centralized clique structure. Only 6 cliques are identified with no fewer than 354 of the firms belonging to a single large clique. The 5 other cliques have 2 members each, there are no mixed members, and 91 firms are isolates.

Agribusiness firms belong to 51 of the 64 cliques identified in the strong directional network (see Table 3). Sixty of the 212 firms belong to 13 cliques that have more than one agribusiness member.[10] For the alternative measure of aggregate concentration, the operating revenues or assets of agribusiness firms that belong to the same clique are added to form one large scale enterprise. Therefore, these 60 firms are combined to form 13 large scale enterprises. The remaining 152 agribusinesses are members of cliques with only one agribusiness firm, mixed members of more than one clique, or isolates. These firms are counted as individual enterprises. Thus the strong directional network produces an ordered ranking of a total of 165 large scale enterprises (13 cliques plus 152 independently ranked firms).

The full network's less discriminating definition of linkage (i.e., its inclusion of all interlocks regardless of how they are made) results in dramatically higher levels of combination of firms in cliques, as was noted above. While agribusiness firms belong to 5 of the 6 identified cliques, only 2 of these have more than one agribusiness firm (see Table 3). Fully 158 of

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[9]These single firm cliques have no members other than the peak because the other firms interlocked with the peak are mixed members of more than one clique and cannot be assigned to any single peak.

[10]Respectively, these 13 cliques had 9, 8, 6, 6, 6, 5, 5, 4, 3, 2, 2, 2, and 2 agribusiness firms as members.

Table 3. Distribution of Agribusiness Firms Among Cliques, Mixed Members, and Isolates, and Number of Large Scale Agribusiness Enterprises in Strong Directional and Full Networks.

Network Type	Number of Cliques	Agribusiness Firms	Enterprises
Strong Directional:			
Cliques with > 1 agribusiness firms	13	60	13
Cliques with 1 agribusiness firm	38	38	38
Mixed members	--	47	47
Isolates	--	67	67
Total	51	212	165
Full:			
Cliques with > 1 agribusiness firms	2	160	2
Cliques with 1 agribusiness firm	3	3	3
Mixed members	--	0	0
Isolates	--	49	49
Total	5	212	54

the 212 agribusinesses are added to form one large scale enterprise while 2 others belong to a separate enterprise. The remaining 52 firms are members of cliques with only one agribusiness firm or isolates. Both are counted as individual enterprises. Thus the full network produces an ordered ranking of a total of 54 large scale enterprises (2 cliques plus 52 independently ranked firms).

Conventional and alternative measures of aggregate concentration for the sample of agribusiness firms are compared in Table 4. Since results may vary depending on the measure of size used (Shalit and Sankar (1977)), these comparisons are presented for both operating revenues and assets for three commonly used measures of concentration: CRK, H-index, and NH-index. Columns 1 and 4 of Table 4 show results for conventional measures of aggregate concentration based on the firm as the unit of observation. The remaining columns present alternative measures based on the strong directional clique (columns 2 and 5) and the full network clique (columns 3 and 6) as the unit of observation.

The CRK measures for operating revenues with the strong directional clique as the unit of observation are on average about 11 percentage points higher than the firm based figures. When full network cliques are the unit of observation, aggregate concentration rises by about 60 points on average. This is a dramatic increase with the top 10 large enterprises accounting for about 95% of operating revenues. The CRK measures for assets (Columns 4 through 6) display the same pattern with average increases of 9 points for the strong directional and 54 points for the full network measures. The impact of using cliques as the unit of observation on H-index and NH-index measures of aggregate concentration are shown at the bottom of Table 4. As with CRK,

Table 4. Conventional and Alternative Measures of Aggregate Concentration Among Large Agribusiness Firms, 1976.

	Operating Revenues			Assets		
	(1)	(2)	(3)	(4)	(5)	(6)
	All Firms Independent	With Strong Directional Network Cliques	With Full Network Cliques	All Firms Independent	With Strong Directional Network Cliques	With Full Network Cliques
CR10	27.6	36.7	94.6	33.1	39.9	97.3
CR25	46.2	60.3	97.7	54.1	66.4	98.7
CR50	65.5	78.7	--	73.1	84.1	--
CR100	85.6	93.9	--	91.5	96.5	--
H-index	148	210	7455	180	239	8268
NH-index	68	48	1	55	42	1

these measures show increases in aggregate concentration with use of strong directional cliques and very dramatic increases with full network cliques.

This application to the agribusiness sector provides a gauge, however rough, of the magnitude of the underestimation of aggregate concentration resulting from assuming that firms are independently owned and operated. Recognition of interfirm organizational structures, through the device of strong directional and full network cliques, yields higher aggregate concentration numbers. The percentage increase depends on the concentration measure and clique type used. The strong directional measures show more modest increases ranging from a 5.5% increase for CR100 measured by assets to a 41.9% increase for the H-index measured by operating revenues. The percentage increases in the full network measures are much higher ranging from 82.4% for CR25 based on assets to nearly 5000% for the H-index based on operating revenues.

The true level of underestimation probably lies somewhere within the range defined by the strong directional clique measures. While the strong directional network definition is relatively conservative in grouping firms into cliques, the full network definition undoubtedly errs in the opposite direction. The single large, national clique that dominates the full network is much too loosely knit to be considered a single large enterprise. The cliques in the strong directional network, on the other hand, represent plausible groupings. Focusing on CRK with strong directional cliques, the underestimation of aggregate concentration by use of conventional measures is on average 11 points (23%) for operating revenues and 9 points (16%) for assets. The percentage underestimation based on H-index and NH-index measures range from 24% to 42%. Thus underestimation of aggregate

concentration on the order of 15% to 40% is suggested by this application to the agribusiness sector.

The degree of underestimation in other sectors and the economy as a whole is a subject for further empirical research. In any case, alternative measures of aggregate concentration such as those developed here promise more accurate appraisals of the relative importance of large scale enterprise in the U.S. economy.

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