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Strategic categories and competition: Significant clustering for strategic groups

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Strategic categories and competition: significant clustering for strategic groups

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Purpose

Strategic groups research has been hampered by the poor alignment between theory and methods. This has been due in large part to the lack of significance tests for cluster analysis. Now that significance tests are available, the theoretical and methodological implications are discussed. The paper aims to discuss these issues.

Design/methodology/approach

The theory behind strategic groups is reframed to capitalize on the available significance tests. Subsequently, the significance tests are also modified to fit the proposed theory. Due to this integrative approach, this is both a theoretical and a methodological paper.

Findings

In lieu of significance tests, finding differences in performance emerged as the litmus test for the existence of discrete strategic groups. The concept of strategic groups gradually evolved to fit this requirement. Now that significance tests are available, these legacy effects of the structure-performance link can be removed. This reveals that three conflicting concepts have been sharing the label of strategic groups: strategic categories, interdependent strategic groups and strategic performance groups. The theory also reveals that the significance tests developed in ecological research need modifications for use in strategic groups research.

Research limitations/implications

A theory is proposed for interdependent strategic groups and a significance test of external isolation is proposed as part of this integrative solution.

Originality/value

This integrative solution appears to resolve the historical mismatch between theory and methods that has plagued this field since its inception. This creates a variety of intriguing areas for future research.

1. Introduction

While an industry might contain an extremely large number of competing firms, typically managers only focus on a small subset of direct rivals. The question is, which firms will fall into that subset? Which firms will engage each other as rivals? More broadly, what shapes the structure of rivalry within an industry? A variety of categorizational schemes has been used to study patterns of rivalry (Cattani et al., 2017), and a strategic groups analysis is particularly useful in this regard (McGee and Thomas, 1986; Tang and Thomas, 1992).

Given the strategic positioning of the firms, a strategic groups analysis can be used to infer: which firms are likely to interact with each other; what the nature of those interactions might be; and how those interactions could affect the performance of the firms. This applies the logic of the S-C-P model at the level of the group rather than the industry. This means that the intensity of competition might not be homogeneous within an industry. One strategic group might be engulfed in perfect competition while another group is able to maintain a pocket of oligopolistic competition. These group dynamics can generate true group-effects that cannot be captured by industry-level or firm-level factors (Dranove et al., 1998; Murthi et al., 2013).

Unfortunately, progress in strategic groups research has been hampered by the poor fit between theory and methods. This has been due primarily to the lack of significance tests for cluster analysis. In lieu of such tests, researchers have looked for differences in performance as a sign that discrete strategic groups exist. Unfortunately, the empirical results have been disappointing. Frustrated by the lack of progress, Barney and Hoskisson (1990) proposed three options. Preferably, researchers should develop significance tests for cluster analysis to detect the existence of discrete groups; failing that, they should develop a theory explaining when strategic groups would and would not exist; failing that, they should abandon the entire field of research. Several decades later, the first two options have not been realized, and the level of research activity in this area has indeed declined (Cattani et al., 2017).

Fortunately, ecologists have been busy developing significance tests for cluster analysis. When Clarke et al. (2008) illustrated a permutation test, their article triggered the launch of several programs that are now available in Matlab (Jones, 2015), PRIMER (Clarke and Gorley, 2015) and Clustsig (Whitaker and Christman, 2014).

This raises a big question in our own field: How would the introduction of significance tests for cluster analysis impact strategic groups research? The theoretical implications will be addressed first. The concept of strategic groups has evolved to fit other methods. Some of those changes should be removed while other changes are introduced so the theory behind strategic groups can make the most of these long-awaited significance tests. The methodological implications also need to be addressed. The significance tests were developed for ecological research, and it will become clear that some adjustments are necessary for use in strategic groups research. Due to the integrative nature of the proposed solution, this paper is necessarily both a theoretical and a methodological paper.

2. Implications for theory

Given the intuitive notion of strategic groups, the preferred method for supporting their existence would be a cluster analysis with significance tests indicating that discrete groups are present in the industry. In the absence of significance tests, methods based on the structure-performance (S-P) link were adopted out of necessity. The conceptualization of strategic groups has morphed over time to fit these methods. Revisiting the historical roots of strategic groups research helps to unravel those evolutionary changes. This reveals that three conflicting concepts have been muddled together under the rubric of “strategic groups.”

2.1 Conflicting views of strategic groups

2.1.1 Strategic categories

Hatten (1974) was the first to use cluster analysis in strategic groups research, and Hatten and Hatten (1987) provide a very sober assessment of the limits of cluster analysis without significance tests. They argued that clusters are nothing more than categories of firms invented by an algorithm and bemoan “a growing tendency for us to anthropomorphize the group and forget that it is our invention, not a real feature of industrial life discovered by fundamental research” (p. 334).

Other pioneers in the field (Newman, 1973, 1978; Porter, 1973, 1979) posited that groups are composed of direct rivals that interact with each other and form stable elements of industry structure. However, Hatten and Hatten (1987, p. 331) argue that such claims have “imposed conditions upon the application of the group concept which appear unnecessary.” Indeed, in fragmented industries, Hatten and Hatten (1987, p. 333) extol “the opportunity group analysis provides to exploit information on companies competing like you, but not with you.”

Hatten and Hatten (1987) reject the notion that group members are aware of their interdependence as “‘concretizing the concept’ and anthropomorphizing groups” (p. 331). In other words, they warn against reification without justification – making groups real or bringing them into existence with no logical basis for support. In their view, attempts to breathe life into these statistical creations by imbuing them with attributes of a cohesive social structure would be pure folly. Hatten and Hatten implore researchers to constrain their theoretical arguments to stay within the limits of the methods. They prefer the term “groupings” rather than “groups,” because the latter has too many social connotations. We shall refer to these as strategic categories.

2.1.2 Interdependent strategic groups

In sharp contrast, Tang and Thomas (1992) were well aware of the limitations of the methods, but their focus, and that of much of the field, has been on the richness of the phenomenon. Strategic groups constitute interdependent, interacting subsets of firms that reflect the social structure of rivalry within an industry. Porter (1979) argues that firms that are interdependent tend to be aware of that fact. Thus, strategic groups could constitute pockets of oligopolistic competition within an industry (McGee and Thomas, 1986; Porter, 1979). We refer to these collectives as interdependent strategic groups:

> If such groups exist they will clearly have implications for the patterns of competition within industries, will contribute to our understanding of oligopolistic interdependence, and may enrich the structure-conduct-performance paradigm of industrial organization theory (McGee and Thomas, 1986, p. 142).

While the literature had embraced this richer view, a traditional cluster analysis was woefully inadequate for operationalizing it (Barney and Hoskisson, 1990; Hatten and Hatten, 1987; Ketchen and Shook, 1996). To move beyond the limited interpretation advocated by Hatten and Hatten (1987), some evidence was needed to support the existence of meaningful groups. Presumably, performance differences are only possible if discrete strategic groups (with mobility barriers) exist. Thus, finding performance differences emerged as the de facto litmus test for the existence of strategic groups. Unfortunately, this fueled the mistaken belief that strategic groups should always differ in performance. This is a basic error in logic. Simply put, if there are differences in performance, then discrete groups must exist ($p \rightarrow q$). However, this does not mean that if discrete groups exist, then they must differ in performance ($q \rightarrow p$). Indeed, Barney and Hoskisson (1990) argue that strategic groups are supposed to capture the structure of rivalry in the industry, and the structure of some industries simply would not generate differences in performance. In such cases, the "failure" to find performance differences across strategic groups would be a feature, not a bug.

2.1.3 Strategic-performance groups

While the S-P link is not suitable as a validity test, it is very popular. It is probably more appropriate to treat it as a desired product feature that lead users are requesting. Indeed, it captures the zeitgeist of strategic management as a field (Meyer, 1991; Durand et al., 2017):

> True to its general management orientation, the field of strategy has consistently viewed firm-level performance as the definitive dependent variable. Indeed, some strategists maintain that "*research questions are inherently uninteresting or trivial unless they include an explicated linkage to performance*" (Italics in original) (Meyer, 1991, p. 825).

Clearly, there is a strong demand for analytical tools that can link a firm's performance to strategic variables that managers can control. Day et al. (1995, p. 621) argue that the problem with strategic groups is that they are only based on strategy. To find the S-P link, the groups should be identified using both strategy and performance variables as input. The term strategic-performance groups has been suggested (DeSarbo et al., 2008; Epure et al., 2011), but it has not yet been widely adopted. The following studies illustrate this concept and the variety of creative methods that have been employed.

For instance, data envelopment analysis (DEA) has been used to benchmark firms on their ability to maximize performance outputs while minimizing strategic inputs (Day et al., 1995; Athanassopoulos, 2003; McNamara et al., 2003; Prior and Surroca, 2006; Surroca et al., 2016). A maximum likelihood approach was used for simultaneous multidimensional unfolding and cluster analysis (DeSarbo et al., 1991). This was followed up with a non-parametric alternative using a clusterwise bilinear spatial MDS model (DeSarbo et al., 2008). Finally, Murthi et al. (2013) used latent class regression to assign firms to classes of strategy (i.e. groups) that explain the maximum variance in performance. All of these techniques attempt to identify groups of firms that are homogeneous in terms of both strategy and performance.

2.2 Differentiating between conflicting concepts

It appears that the term strategic groups has been applied to a confusing amalgamation of concepts: strategic categories, interdependent strategic groups and strategic-performance groups. These categorizational schemes were developed for different audiences – scholarly microcommunities (Durand et al., 2017) espousing different schools of thought. Yet, they have been jumbled together due to: their common use of the term “strategic groups”; and their common reliance on the S-P link to establish legitimacy.

Due to this confusion, each approach has been inappropriately criticized based on the criteria associated with the other concepts. Notably, the harshest criticism lumps all strategic groups studies together and complains that they do not consistently find performance differences. This unconditional demand to find performance differences is perhaps suitable for strategic-performance groups, but it clearly does not make sense for the other approaches.

The most frustrating aspect of the ongoing debate is that each microcommunity can derive different conclusions from the same body of research, so the opposing positions never seem to gain any traction. For decades, the S-P link has been used to discredit the concept of interdependent strategic groups while the concept of interdependent strategic groups has been used to discredit the S-P link. There can never be a logical winner in this debate. The microcommunities are merely talking past each other as they espouse incommensurate schools of thought addressing different research questions. Hopefully, disambiguating these concepts will allow all three streams to move forward, albeit in different directions. As Durand et al. (2017, p. 11) argue, “specialization into subfields is both inevitable and conducive to the advancement of knowledge.”

The remainder of this paper focuses on interdependent strategic groups since it is the only approach that: addresses the structure of rivalry; and requires significance tests for cluster analysis. To move forward with this view, the primary challenge is to weed out the issues related to the S-P link that have permeated the strategic groups literature.

2.3 S-P legacy effects in interdependent strategic groups

Theories and methods tend to coevolve. While this could be a sign of learning and progress, there is a risk that some changes that were once adaptive could endure long after the need for them has disappeared. These are called legacy effects (Cuddington, 2011), and the ones associated with the S-P link are remarkably pervasive and deeply rooted in the history of the field.

For instance, Harrigan (1985) recommended using cluster analysis to identify groups of firms that are following similar strategies. However, she suddenly shifts attention from the homogeneity within groups to the heterogeneity between them. “Clustering analysis generates descriptions of the boundaries segregating groups” (p. 59). Since these boundaries are derived from the attributes of the firms, the cost of changing the attributes is “suitable for estimating the heights of mobility barriers which segregate strategic groups” (p. 59).

Ultimately, researchers were advised to use their knowledge of the industry and/or the results of preliminary analyses to identify variables related to performance (Harrigan, 1985; McGee and Thomas, 1986). Thus, the use of cluster analysis was originally to: identify homogeneous groups of firms with respect to strategy; but the strategy variables should really reflect mobility barriers; and it ultimately comes down to hand-selecting variables that are likely to yield performance differences across groups. The operationalization has wandered away from the concept of strategic groups by taking a series of shortcuts to get to performance differences.

The S-P legacy effects have not been confined to the fine print for operationalizing concepts. They have crept into formal definitions. "Definition: A strategic group exists if the performance of a firm in the group is a function of group characteristics, controlling for firm and industry characteristics" (Dranove et al., 1998, p. 1030). The existence of strategic groups is literally defined by the desired effect on the dependent variable (performance) rather than the nature of the groups themselves (e.g. firms following similar strategies).

2.4 Putting the C back in the S-C-P model

The S-C-P model argues that the structure of the industry completely determines the conduct of the firms, and the conduct of the firms completely determines their performance. Thus, by transitivity, the structure of the industry completely determines the performance of the firms (Cool and Schendel, 1987). Eliminating conduct (C) creates a simpler model with exactly the same predictive power. This is very attractive, and much of the empirical industrial organization research has used the S-P link (Caves and Porter, 1978; Einav and Levin, 2010).

However, this argument only holds for two extreme cases: monopoly and perfect competition. Since interdependent strategic groups are supposed to capture the boundaries of competition, "[o]ligopolistic interdependence and homogeneity of firms become recognizable not at the industry level but at the strategic group level" (McGee and Thomas, 1986, p. 156). Hence, conduct can differ across groups. More to the point, it can fluctuate quickly and frequently within a single group over time (Caves and Porter, 1978). The industry structure could remain exactly the same, but the conduct and hence the performance of the groups could fluctuate wildly. This means that the S-P link cannot be generalized to cases involving oligopolies. This includes studies of interdependent strategic groups.

2.5 Are we asking the right questions?

Since the S-P link has often played a critical role in empirical studies, ruling it out could create some uncertainty regarding the appropriate research questions. Traditionally, "the central research question […] was the extent to which strategic group membership influenced firm-level profitability. A secondary question was the extent to which such groups reflected patterns of competition among firms" (Cattani et al., 2017, p. 65). This bodes well for research on strategic-performance groups. However, both the priorities and the order of the questions should be reversed for research on interdependent strategic groups. First, how are groups related to patterns of competition? Second, how do those patterns of competition influence performance? This still strives to link strategic groups to performance, but it returns to the logic of the S-C-P model – no shortcuts.

If groups are supposed to capture the patterns of interactions, then the fundamental question would be, what distinguishes a cohesive group of rivals (á la Tang and Thomas, 1992) from an arbitrary grouping of firms (á la Hatten and Hatten, 1987)? What drives some rivals to engage each other while ignoring other rivals in the same industry? Given the confusion regarding different views, it is helpful to quickly clarify what is, and what is not, relevant for interdependent strategic groups.

2.6 Clarifying the interdependent view of strategic groups

The transactions between suppliers and buyers provide a straightforward example of interdependence driving vertical interactions among firms. Presumably, firms are attracted to a strategic position by the potential for profitable vertical transactions. It follows that firms pursuing the same strategy might compete: upstream to acquire the resources needed to fuel that strategy; and/or downstream to attract the customers best served by that strategy. Consequently, firms holding similar strategic positions are likely to be interdependent due to cross-elasticities in supply and/or demand. Presumably, firms holding very different positions would be relatively independent (Nightengale, 1978; McGee and Thomas, 1986; Cattani et al., 2017). Horizontal interdependence provides the economic incentives for rivals to engage each other using a mixture of cooperative and competitive behaviors in an attempt to manage their interdependence (Axelrod, 1984; Zagare, 1984; Brandenburger and Nalebuff, 1996).

Now shift the level of analysis from dyadic relationships between two firms to the dispersion patterns of all of the firms throughout the industry. If firms are uniformly scattered across strategic positions and a firm at one end of the industry suddenly exhibits aggressive competitive behavior, that act could trigger a domino effect in which that firm’s neighbors would retaliate, which would trigger their neighbors to retaliate, and so on. The result would be a cascading wave of tit-for-tat reactions washing over the entire industry.

Now consider an industry with discrete groups. Firms would be densely packed around a few strategic positions that are separated from each other by empty space. If proximity reflects interdependence, then distance (empty space) reflects its inverse – indifference. An outbreak of aggressive competition would spread from neighbor to neighbor within the initial group, but it might not jump to the relatively distant firms in other groups. If groups are sufficiently separated, the competitive contagion could be contained. The effects of strategic groups are the emergent properties that arise from interactions of interdependent firms within isolated groups. Thus, interdependent strategic groups can be thought of as islands of interdependence separated by a sea of indifference.

There are countless definitions of clustering, but the nature of interdependent strategic groups is best captured by Cormack (1971): clusters exhibit internal cohesion and external isolation. Cohesion in the context of strategic groups has the obvious connotation of homogeneity with respect to strategy. However, it also hints at the role of interdependence as a cohesive force (a social bond) which binds adjacent firms together in cooperative and competitive interactions. Isolation in this context refers to the empty space between the clusters. This is absolutely essential to protect the delicate balance of interactions within a group. If an isolated group only contains a few members, those firms could maintain cooperative interactions even if groups located elsewhere in the industry were consumed by cut-throat competition. If conduct can differ across groups, so too can performance (Mas-Ruiz and Ruiz-Moreno, 2011). These effects due to group dynamics are called true group effects (Dranove et al., 1998; Murthi et al., 2013), and interdependent strategic groups are uniquely designed to study them.

2.6.1 Separating strategic groups and mobility barriers

The historical reliance on the S-P link exerted pressure on researchers to find performance differences across groups. Clustering firms on variables related to mobility barriers (Harrigan, 1985; McGee and Thomas, 1986) ensures that each group is protected by some kind of barrier, thereby preserving differences in profitability if they existed. "Mobility barriers are a corollary to the existence of strategic groups […]. A group structuring carries no meaning without costs attached to the imitation of strategy by other firms" (McGee and Thomas, 1986, p. 153). While pragmatic at the time, this approach conflates the two concepts. Significance testing makes it possible to disentangle them.

Interdependent strategic groups focus on the boundaries of rivalry. Horizontal interdependence is the cohesive force binding firms together in a mixture of cooperative and competitive interactions. It is what distinguishes a meaningful group from an arbitrary collection of firms. To be clear, it is not a force of attraction, like gravity, that pulls rivals closer. It is analogous to an electrical arc flowing between the ends of two wires in close proximity. The electrical arc represents a social bond – a connection between adjacent firms that are interacting. Hence, a map of interdependent strategic groups indicates were the sparks will be most intense. The space between the groups insolates the bundles of wires, thereby reducing the likelihood of sparks between groups. This is a critical distinction from the traditional view. The space between groups inhibits the spread of competitive behaviors, not the movements of firms (á la Harrigan, 1985; McGee and Thomas, 1986).

Mobility barriers address entirely different issues and must be handled in a separate analysis. Mobility barriers can be seen as the undulating terrain of the industry, indicating the relative difficulty of moving in various directions. Firms are constantly changing and adapting to their environment, and strategists must chart a course for the firm that exploits the sloping terrain to the firm's advantage. Carroll et al. (1994) use a canonical correlation analysis to link the movements of firms to temporary dips in their performance. Interestingly, this method also found mobility aids in which movements temporarily boosted performance – a rising-star effect, if you will. This resembled what Penrose (1959) referred to as economies of growth (as opposed to economies of scale).

2.6.2 Reimagining strategic groups and mobility barriers

While the bulk of these arguments are not new, they are usually applied in the context of the S-P link. The pervasive legacy effects are even visible in the metaphors depicting the concepts. The image of a wealthy kingdom protected by a tall stone wall (Cool and Dierickx, 1993) gives the impression that groups and barriers are inherently bound together. The static nature of this image is also outdated.

The Tour de France bicycle race provides a more dynamic metaphor. Rival firms within strategic groups act more or less collectively to achieve an advantage in much the same way that rival teams of cyclists work together in a peloton (a pack) to break away from the larger field of riders. Competitive moves (attacking or defending) could exploit the existing terrain.

For example, a peloton composed of hill-climbing specialists might emerge and break away at the base of a long uphill climb to maximize the value of their strengths.

An analogous business scenario could involve pioneering firms in high-tech industries planning for the next generation of innovations on the horizon. Rather than expending their resources to improve their efficiency in using the current technology, they positioning themselves to pounce on the anticipated innovation when the time is right. A group of rival pioneers could coordinate their efforts to collectively establish the parameters of the next dominant design to ensure that it favors their strengths and/or targets the weaknesses of rival groups (e.g. efficiency-experts). This metaphor captures the dynamism of contemporary strategic management. More to the point, it disentangles the concepts of strategic groups and mobility barriers. Each can exist without the other.

2.7 Overall impact on theory

A key theme in this paper is that theory and methods tend to coevolution. The reliance on the S-P link as a litmus test for the existence of strategic groups led to a gradual evolution of the concept, but the results remain disappointing (Cattani et al., 2017). Now that significance tests are available, the legacy effects of the S-P link can be removed. This reveals that three conflicting (but equally valid) concepts have been sharing the label of strategic groups. Disentangling these concepts should allow each stream of research to progress in its own direction. Strategic groups and mobility barriers can also be disentangled and analyzed separately to reflect the distinct nature of each concept.

The theoretical foundation for interdependent strategic groups is that the dyadic interdependence between firms interacts with the industry-wide dispersion patterns of those firms to generate the emergent properties of strategic groups. This exploits the ability to test for the presence of discrete groups. Presumably, this would satisfy Barney and Hoskisson's (1990) recommendation to develop a theory indicating when and why (the effects of) strategic groups would be observed.

Perhaps the broadest implication of introducing significance tests for clustering is that it opens the door to areas of theory development that might otherwise be scoffed at. Hatten and Hatten (1987) exemplify the necessary academic discipline that keeps empirical scientists grounded in reality. Yet, there stance also illustrates how methodological limitations can constrain the nature of the problems and the types of solutions that are deemed legitimate. The advent of significance tests for clustering finally offers statistical support for the presence of discrete groups. This creates possibilities, not just in this field, but in countless other areas of research involving groups. Kudos to the ecologists!

3. Implications for methods

The historical lack of significance testing has been a serious problem in this field. Cluster analysis has been described as "a methodological stigma rather than a contribution, for 'the empiricism inherent in this method has been forever branded upon our collective backside'" (Meyer, 1991, p. 826). Fortunately, ecologists recently made significance tests available in statistical packages such as Matlab, PRIMER and Clustsig. Presumably, these would satisfy Barney and Hoskisson's (1990) methodological recommendations for salvaging strategic groups research.

However, in the previous section the legacy effects of the S-P link were removed to clarify the theoretical foundations of interdependent strategic groups. In doing so, it became clear that the term "clustering" means different things in different fields (Cormack, 1971). The tests developed in ecology are not entirely appropriate for strategic groups research. Paradoxically, the theory that was spawned by the introduction of significance tests will now be used to develop the significance tests that had ostensibly spawned it. In this section, the mechanics of the significance tests are briefly discussed and a simple algorithm is outlined for the requisite test of external isolation.

3.1 Computationally intensive significance tests

Permutation tests (Jones, 2015; Clarke and Gorley, 2015; Whitaker and Christman, 2014) and Monte Carlo tests (Bíl et al., 2013; Milligan and Sokol, 1980) are referred to as computationally intensive (a.k.a., "brute force") techniques. While they have only recently become available in user-friendly packages, their use in cluster analysis can be traced back to at least the 1960s (e.g. Mantel, 1967; Edgington, 1969). To create the conditions of the null hypothesis (no clustering), permutation tests randomize the original data to destroy any multivariate clusters. In contrast, Monte Carlo tests generate cluster-free artificial data. Both tests empirically generate a null distribution for the clustering statistic (e.g. total within-group variance) by applying the cluster analysis to many samples of random(ized) data (say, 9,999). Since cluster analysis always identifies clusters, even in random data, these null distributions are "dearly desirable" (Milligan, 1980, p. 331).

A final iteration is performed on the real data to get the observed value of the test statistic. One then simply counts the number of times out of 10,000 attempts that the clusters in the random(ized) data were as compact as those in the real data. If it was rare ($p \leqslant 0.05$), then the real clusters have a statistically significant degree of internal cohesion. That is, the firms within the groups are homogeneous with respect to strategy.

3.1.1 A multi-method approach

Like all statistical techniques, permutation tests and Monte Carlo tests have flaws, but the weaknesses of one correspond with the strengths of the other. Thus, a multimethod approach is recommended to exploit the complementary of these techniques (Brewer and Hunter, 2006; Carroll, 2018).

Permutation tests have trouble isolating the effects of multivariate clustering. The test permutes (shuffles) the observations for each variable separately. This destroys multivariate clustering, but it also destroys any other multivariate structure in the data (Clarke et al., 2008). Hence, the null distribution actually tests for the absence of any multivariate structure, not just clustering.

Monte Carlo tests use artificial data to generate the null distribution (Bíl et al., 2013; Milligan and Sokol, 1980). This makes it easier to impose the conditions of the null hypothesis (no clustering). However, this requires researchers to make assumptions about distributions (e.g. Arnold, 1979) – a problem that permutation tests avoid. The SIMPLAN procedure in SPSS (IBM Corp., 2017) exemplifies a user-friendly package for implementing these tests. Univariate clustering is removed by replicating multimodal distributions with the unimodal distributions that empirically provide the best fit to the data. The correlation matrix can also be replicated to control for various forms of multivariate structure – a serious problem that permutation tests. The complementary strengths and weaknesses of these two techniques sound promising. However, cluster analysis has a particularly difficult problem that still needs to be resolved.

3.2 The dreaded duality

Clarke et al. (2008) warn about the duality of clustered observations and correlated variables. Consider the relative orientation of distinct clusters like Figure 1(a). In certain positions, the clusters "create" correlated variables. Now consider a distribution of correlated variables like Figure 1(b). A cluster analysis would arbitrarily slice that distribution into segments, "creating" a series of small, compact clusters resembling a string of beads. While the difference between Figures 1(a) and 1(b) is visually striking, clustering techniques based solely on internal cohesion (e.g. Ward's method) are blind to this distinction.

Carroll and van Heyningen (2018) demonstrated that highly correlated variables resembling Figure 1(b) were always flagged as statistically significant by the cluster analysis procedure in Matlab (a 100 percent error rate). Granted, this sounds horrible, but the pioneers of strategic groups research have at times embraced the use of arbitrary partitioning. When Porter (1979) tested the implications of strategic groups, he imposed arbitrary cut-offs by hand if natural breaks did not exist between leaders and followers in an industry. Hatten and Hatten (1987) argue more generally that the arbitrary partitions imposed by a clustering algorithm (e.g. small, medium and large firms) might not identify naturally occurring discrete groups, but they can still provide useful categories of homogeneous firms following similar strategies.

It is possible to control for the correlations among variables with a Monte Carlo tests, but the dreaded duality creates a vexing dilemma. If the correlation matrix is not replicated, then the correlated variables in Figure 1(b) would be flagged as statistically significant even though isolated clusters do not exist. Replicating the correlation matrix would avoid that error. However, if clusters do exist resembling Figure 1(a), then replicating the correlation matrix would generate artificial data resembling Figure 1(b). The null distribution would be generated by slicing Figure 1(b) into small, densely packed segments. The original clusters might not be unusually compact compared to the artificial segments. Thus, replicating the correlation matrix could wash out the effects of isolated clusters when they do exist.

Given the problems associated with the dreaded duality, it might seem surprising that these tests are quickly gaining popularity in the field of ecology (Kilborn et al., 2017). It turns out that these issues are not terribly relevant in that field. For example, ecological impact studies identify geographic regions that are homogeneous with respect to flora and fauna to see if a potential source of pollution (e.g. an off-shore oil well) has created a region with a different mix of wildlife. External isolation (i.e. empty space) between regions is not required. In fact, if unpopulated gaps did exist between clusters, ecologists might focus more on the gaps than the clusters they separate, because something has rendered those gaps uninhabitable.

The point is that the meaning of the term "clustering" differs across fields. When studying interdependent strategic groups, true group effects can only emerge if the clusters are isolated (see Figure 1(a)). No single test has been shown to handle this problem. However, in one of the earliest studies on strategic groups, Hatten and Schendel (1977, p. 102) established a precedent for a two-pronged approach. "[I]t would be prudent to put theory to the test, to see whether these subpopulations are internally homogeneous (in addition to testing for differences between groups)."

3.3 Testing for external isolation

When considering methods that capture both internal homogeneity and external heterogeneity, multivariate statistics associated with MANOVAs and discriminant analysis quickly spring to mind (Milligan, 1981; Milligan and Cooper, 1985, 1987). However, Milligan and Cooper (1985, p. 177) found that the performance of the standard multivariate normal criteria such as trace W, trace $W^{-1}B$, and $|T|/|W|$ were so poor that "[t]he field of clustering might be well served if mathematical statisticians considered alternative distributional strategies."

Cluster analysis poses an unusual mix of challenges. Multivariate statistics based on the general linear model not only perform poorly, the logic of does not fit the nature of the phenomenon. For instance, if the distribution in Figure 1(b) were divided into a string of clusters, a one-way MANOVA might indicate that significant differences do exist, and the t-tests might reveal that the groups on opposite ends of the distribution were significantly different from each other. Yet, none of the segments would be sufficiently isolated to allow differences in group dynamics to emerge.

Of the countless unique definitions of clustering in the methodological literature, the concept of interdependent strategic groups is best captured by Cormack's (1971) pithy summation: clusters exhibit internal cohesion and external isolation. To put this in perspective, fuzzy clustering refers to populated regions that partially overlap; firms can belong to more than one cluster. Hard clustering refers to populated regions do not overlap; firms can only belong to one cluster (Figure 1(a) and 1(b)). However, the firms on opposite sides of the hard boundary could be very close to each other. External isolation is harder than hard; the populated regions must be separated by unpopulated regions (only Figure 1(a)). This isolation is essential for issues related to group dynamics (e.g. pockets of oligopolistic competition).

Network analysis (Scott, 2017) is often handier than multivariate statistics for discussing contagion models describing the spread of disease, the diffusion of knowledge, the adoption of innovations, or in this case, the spread of competitive behaviors. Once again, consider strategic groups as islands of interdependence separated by a sea of indifference, but this time the distance between islands quarantines them from the spread of disease. In network analysis terms, the close proximity (internal cohesion) of the members on an island would constitute a (quasi-)clique based on their strong, densely connected ties of interdependence. These dense connections would ensure that if one member becomes infected, the contagion would spread rapidly to all of the members on that island. Hence, the health of the entire island would be determined by the health of its most vulnerable members. If the gap between two islands were narrow or non-existent (e.g. Figure 1(b)), one good sneeze would allow an airborne virus to waft across the tiny gap and infect the nearest neighbor on the adjacent island. Having spanned that structural hole, the contagion would spread like wildfire to the rest of the densely connected members on that island. Thus, the effectiveness of a quarantine (a structural hole) is determined by the gap between the nearest neighbors belonging to different groups.

3.3.1 The smallest-gap test

To model this with cluster analysis, a test for external isolation could be as simple as finding the two closest firms belonging to different groups. These are the most vulnerable members of each group and the distance between them is the smallest gap (i.e. the narrowest structural hole).

The algorithm for this test is quite simple. We need to know the distances between all of the firms. Since the (squared) Euclidean distances matrix is symmetric, the lower triangle would be sufficient. Reshape this into a column vector and append a series of columns identifying firmi and firmj as well as the clusters to which they are assigned. This new rectangular matrix can then be sorted in ascending order based on the distances between the two firms. Start with the shortest distances and search in ascending order for the first pair of firms that belong to different groups. This is the narrowest gap separating the most vulnerable members of the two closest groups. Save this distance.

A null distribution would be generated by repeating that process 9,999 times using cluster-free random(ized) data. If the smallest gap in the real data is unusually wide compared to the smallest gaps found using random(ized) data, then the real clusters exhibit a significant degree of external isolation. In other words, compared to random(ized) data, there is an unusually wide natural break between the two groups. If the two closest groups are clearly separated, it follows that the rest of the groups with wider gaps are also clearly separated. The computational costs of adding this test for external isolation would be negligible, because it would be applied to the same samples as the test of internal cohesion. There is no need to generate more random(ized) data.

This two-pronged test handles the general problem of the dreaded duality that trips up clustering methods based on cohesion. The distinguishing feature between Figures 1(a) and 1(b) is the natural break between clusters. This test also handles the problems associated with each of the brute force technique. The problem with a permutation test is that the null distribution actually tests for multivariate structure, not just multivariate clustering. The smallest-gap test would weed out any multivariate structure in which contiguous firms were arbitrarily split into groups, because those groups would lack a natural break.

The smallest-gap test also solves the dilemma associated with Monte Carlo tests. Replicating the correlation matrix would control for the effects of correlations when clusters do not exist (Figure 1(b)), but it risks washing out the effects of the clusters if they do exist (Figure 1(a)). Since the smallest-gap test can catch the correlations (Figure 1(b)), there is no need to control for them by replicating the correlation matrix. This avoids the risk of washing out the effects of existing clusters. Thus, Monte Carlo tests should only replicate the distributions of the variables, not the correlation matrix.

3.3.2 Interpreting the two-pronged test

The concept of interdependent strategic groups is a special case of strategic categories (á la Hatten and Hatten, 1987). Strategy variables should be selected if firms holding similar positions tend to vie for vertical transactions. Further, the dispersion pattern of the firms must constitute internally cohesive and externally isolated groups. The two-pronged test makes it possible to determine if the clusters are indeed discrete groups.

Starting with the simple case, if neither test is significant, then Hatten and Hatten's (1987) interpretation of clusters applies; researchers can not reject the possibility that firms are randomly positioned. Notably, a non-significant finding does not mean there is nothing to talk about. Hatten and Hatten (1987, pp. 340-341) argue that even in the absence of significance testing, "strategic groups are one of the most valuable analytic concepts in the armory of the strategist, practitioner or researcher."

If there is a significant degree of cohesion but not isolation (e.g. Figure 1(b)), then the firms are homogeneous within these strategic categories, but there is no natural break between (some of) them. These are the kinds of clusters that trip up methods focused solely on internal cohesion; they also create the dilemma in Monte Carlo studies. These groups might be due to correlated variables or other forms of multivariate structure in which adjacent firms are arbitrarily divided into different clusters.

If there is a significant degree of isolation but not cohesion, then the strategic categories are clearly separated by natural breaks, but the firms within the clusters are not unusually homogeneous compared to random(ized) data. Clustering algorithms like Ward's method always find the closest firms, so even with random data, the clusters always show some degree of homogeneity (Milligan, 1980). It is difficult to draw conclusions from a non-significant finding, but relatively speaking, the effects of interdependence might be somewhat weaker or more diffuse.

If the clusters exhibit a significant degree of both internal cohesion and external isolation (Figure 1(a)), then they represent interdependent strategic groups – a special case of strategic categories. The close proximity of firms within each group increases the likelihood that they vie for vertical transactions and are therefore interdependent. Conversely, the distance between the groups decreases their interdependence, thereby insolating them from competitive behaviors in other groups.

The combination of internal cohesion and external isolation is necessary (but not sufficient) for generating true group effects. It provides the fertile ground in which the emergent properties of interdependent strategic groups could potentially sprout up. Of course, there is no guarantee that firms would behave in a collectively optimal manner. Indeed, this lack of deterministic forces is why the S-P link cannot be used with oligopolies.

3.4 Overall impact on methods

The cluster analysis programs in Matlab, PRIMER and Clustsig now provide user-friendly significance tests for the most popular clustering methods in strategic groups research (Ward's method using squared Euclidean distance). Presumably, these tests would satisfy Barney and Hoskisson's (1990) methodological recommendations for salvaging strategic groups research. Indeed, believing that this problem was solved, we proposed a theory of interdependent strategic groups to capitalize on this long-awaited methodological breakthrough. Surprisingly, developing that theory led to the realization that the available tests of internal cohesion are fine for ecological research, but research on interdependent strategic groups also requires a test of external isolation. The proposed smallest-gap test teases apart the dreaded duality that causes problems for clustering methods based on cohesion (e.g. Ward's method). It also solves the specific problems associated with each statistical technique (e.g. permutation tests, Monte Carlo tests).

4. Conclusion

Strategic groups research has been severely hampered by the misalignment between theory and methods. Barney and Hoskisson (1990) recommended: develop significance tests for cluster analysis to detect the existence of groups; develop a theory explaining when strategic groups would and would not exist; or abandon the entire field of research. Ironically, it appears that Barney and Hoskisson might have been overly optimistic in their appraisal. Their recommendations are posed in an either/or format, suggesting that either a theoretical or a methodological breakthrough would be sufficient. This does not seem to be the case.

The significance tests available in Matlab, PRIMER and Clustsig should satisfies the methodological advice, but they do not fit with the existing theoretical foundation of strategic groups. A theory of interdependent strategic groups is proposed that should satisfy the theoretical advice, but it does not fit with the available methods developed in ecology. The theory and methods were finally aligned when the theory that was inspired by the significance tests was subsequently used to develop the significance test that ostensibly had spawned it.

While Barney and Hoskisson (1990) recommended fixing either the theory or the methods, we were unable to find a viable solution without doing both simultaneously. While the separate innovations in the theoretical and methodological components are perhaps incremental, the primary contribution here is the architectural innovation that integrates these theoretical and methodological components (Henderson and Clark, 1990). Arguably, this transcends Barney and Hoskisson's piecemeal approach and focuses instead on the broader mismatch between theory and methods that has plagued the field since its inception.

Obviously, this renders their third bit of advice moot. Rather than abandoning the field, we would sound a clarion call to interested researchers to seize upon the opportunities created by recent events. Here are a few suggestions for future research.

4.1 Future research

After half a century of research on computationally intensive methods, significance tests for cluster analysis are finally available in user-friendly statistical packages. While this could change the path of strategic groups research, statistical tests are no panacea. Significance tests say nothing about the effect size or the substantive significance of the findings (Kline, 2004).

An intriguing question for future research is, how much separation is needed to successfully quarantine groups from each other? The smallest-gap test assesses whether there is an unusually wide natural break between the two closest clusters, but is that a "safe" distance? What kinds of factors influence the minimum safe distance? It is conceivable that a well-disciplined oligopoly could resist the impact of a single firm near its border. However, there might be a critical mass of firms that could cause the competitive contagion to jump that gap. The number of firms needed to achieve that critical mass might vary depending on the distance between the groups or the strategic dimensions separating them. It is also plausible that firms could differ in their contribution to that critical mass. It might take many small firms to exert the same impact as a large, powerful firm like Microsoft. Further, the impact of the groups could be asymmetric: $group_x$ might be more reactive to $group_y$ than $group_y$ is to $group_x$.

We have proposed the smallest-gap test as a simple and computationally efficient first step just to get the debate started. On one hand, there is an enormous potential for developing more sophisticated models. On the other hand, the tit-for-tat strategy in game theory illustrates that very sophisticated models might not perform better than a simple, intuitive heuristic (Axelrod, 1980a, b). The possibilities are intriguing.

In addition to modeling how behaviors spread across various dispersion patterns within an industry, future research could also drill down to the nature of the dyadic relationships between the firms. The proposed theory only addresses the horizontal interdependence that is generated when two firms following similar strategies vie for vertical transactions. Future research should explore other sources of horizontal interdependence such as complementarity (Nohria and Garcia-Pont, 1991). However, that might be more relevant for the social structure of cooperative interactions (e.g. alliances) that form between groups, rather than within them. Value capture theory (Gans and Ryall, 2017) could also be used to expand the potential ways in which firms within a sector influence and interact with each other. Thus, the advent of significance tests for cluster analysis opens the door to a vast array of intriguing theoretical and methodological research questions.

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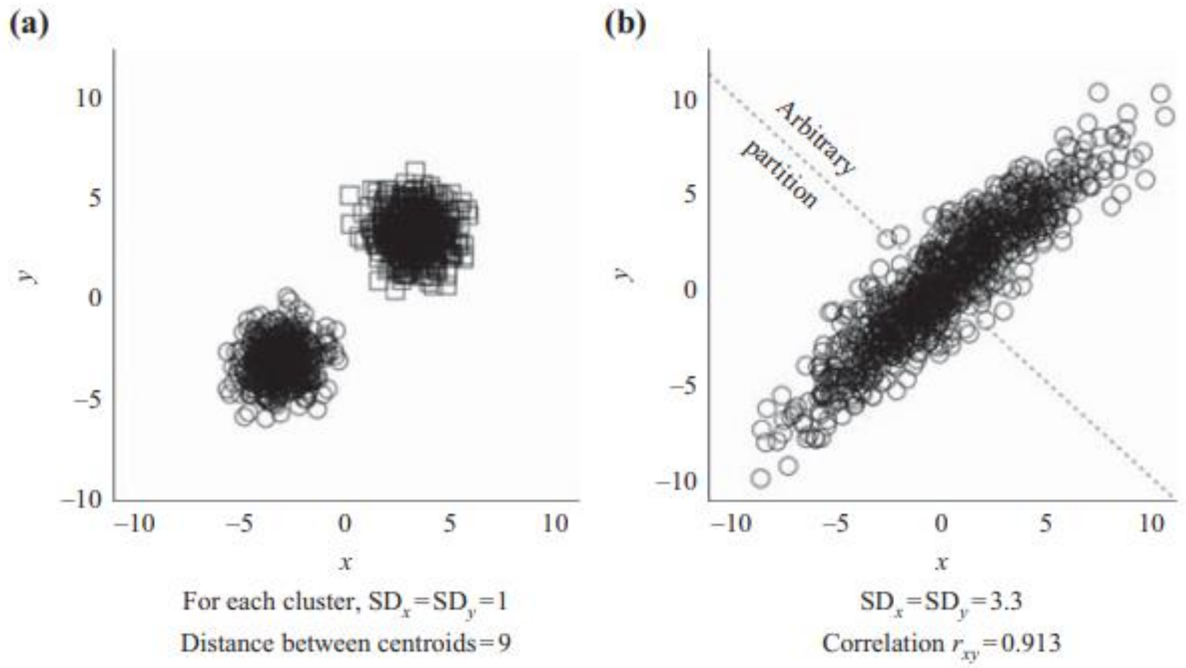
Figure 1

Comparing clustered observations to correlated variables with comparable descriptive statistics



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