Types of Complementarity, Combinative Organization Forms and Structural Heterogeneity: Beyond Discrete Structural Alternatives[1]

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Prologue

"If any approach to defining organizational forms can be regarded as standard, it is one that regards forms as particular *clusters of features*. The example par excellence is Weber's specification of rational-legal bureaucracy in terms of the nature of authority (...), procedures (...), and the employment relation of the official (…)." (Polos, Hannan, Carroll 2002). In spite of the broad consensus on the above concept, originating in the sociology of organization, apparently there has been much less effort and consensus on a systematic definition of *which* are the fundamental 'features' of organization, and according to which laws they are supposed to cluster. In the first Section, this paper offers a critical re-reading of the notions of organization forms in organization theory and organization economics aimed at singling out what has been established and what stands up to scrutiny on those two important issues[i] . In the second Section, building on these elements and on earlier works by the present authors (Grandori 1997; 1999; Grandori and Furnari 2008), the paper provides a typology of organizational 'features', a theory of how they are expected to combine inspired by an analogy with chemistry,

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and a formalized operationalization of the main propositions through an innovative application of Boolean algebra.

Limits of the 'discrete structural alternatives' view of organization forms

A view of organization forms as *discrete clusters* of features or attributes has been dominant in the major traditions of study concerned with organization internal structure and external networks. Organization theory has characterized organization forms as, for example, unitary-functional versus divisional forms, mechanistic versus organic forms, adhocratic versus bureaucratic, and so on. Organizational features have been typically conceived as devices for partitioning and coordinating activities, including the Weberian features of specialization and distinct responsibility, legal authority and formal procedures, enriched by a variety of 'team-like' and mutual adjustment devices (Thompson 1967; Mintzberg 1979). Organizational economics has enlarged the notion of organization and governance forms to include the division of labor and the modes of coordination between firms, and has envisaged 'discrete structural alternatives' such as markets, hierarchies and hybrids. The Weberian features of authority and rule-like governance have been accompanied by price/incentive and exit mechanisms as they are central for defining market governance forms, as well as by the informal coordination mechanisms of teams and culture, employed for defining clan forms (Grandori 1999).

As to the laws of combination among the above mentioned features, classical organization theory argued that each coordination mechanism is to be found in an organized system, under conditions of effectiveness, conditional on the presence (or the presence at some specified intensity) of some contingency variable, such as uncertainty, strategies, technology, type of interdependence, system size (Lawrence and Lorsch

1967; Thompson 1967; Pugh et al 1969; Van de Ven et al. 1976). As a corollary, in this approach, features/mechanisms of various kinds cluster as they are cumulatively employed in the same system to govern activities and transactions with different characteristics (e.g. more or less uncertain and interdependent activities).

Organizational economics has more explicitly characterized organization forms as bundles of attributes, supposed to be similar to each other within a form, and 'different in kind' across forms: *"alternative modes of governance (markets, hybrids, firms, bureaus) differ in kind – which is to say in discrete structural ways"* (Williamson 2004, 285). The author maintains that, as a corollary, *features/mechanisms of different kinds cannot cluster* under conditions of effectiveness (the so-called 'impossibility of selective intervention') (2004, 287): *"selective intervention breaks down because the internally consistent syndromes of incentive, control, and contract law attributes that define markets and hierarchies differ"*. Each internally consistent 'syndrome of attributes' is presumed to be superior in the governance of transactions with different characteristics (e.g. more or less uncertain and more or less specific transactions).

There are various limitations in these interpretations of the notion of discrete structural alternatives.

- The term was originally used by Simon (as Williamson stresses) who pointed out that organizational choices (like all social choices) are not based on judgments focused "on how variables are equated at margin" but "focused on qualitative and structural questions, typically, on the choice among a small number of discrete

institutional alternatives" (Simon 1978, 6). Those choices among qualitatively different structural devices has been interpreted in organizational economics as choices among real, full 'institutions', such as 'the market' and 'the firm'. However, and this is the key difference between the approach taken here and that of organizational economics, qualitative differences, and related choices, can be referred to *features* or mechanisms themselves, not about packages or clusters of features, i.e. organization form. Actually, Simon's own examples of 'structural questions' (1978, 6) tend to be referred to single governance mechanisms or practices. In his words: "Not 'how much flood insurance will a man buy' but 'what are the structural conditions that make buying insurance rational or attractive'?" Not 'at what levels will wages be fixed' but when will work be performed under an employment contract rather than a sale contract?'" Nothing is really said on how these qualitatively different structural elements may or may not combine into more complex, multi-feature, organization forms. Hence, the proposition that qualitatively different elements cannot cluster together is not really a corollary of Simon's thesis. Nor does that proposition seem to have a clear empirical basis: quite to the contrary, organizational solutions that combine devices as different in kind as incentives, communities, rules and authority seem to be more the rule than the exception in successful modern economic organization.

Finally, what constitutes similarity and difference 'in kind' has not been clearly defined. While it is clear that a qualitative comparative analysis is different from a

quantitative marginal analysis (Simon's concern); it is not clear when a structural element is 'different in kind' from another element (Williamson's concern).

- In the organization theory tradition, the clustering of features is considered as a result of one-to-one correspondences between each feature and a context. There has been little modeling, and especially theoretical modeling, of the interaction effects of the application of various organizational mechanisms; i.e. whether the employment of, say, programs, at some intensity, interacts positively or negatively with, say, the use of teamwork, and at which intensity level.

- In both organization theory and organizational economics, it is supposed that there is 'one best way of organizing under any given circumstance' (defined in terms of the independent contextual variables), i.e. possible equifinalities among forms are neglected.

The two last limitations have been to some extent overcome by more recent configurational views of discrete structural alternatives - the 'configurational' approach in organization studies; and the 'complementarity-based' approach in organizational economics- especially because they have considered the interaction effects among features.

The configurational approach has defined an organization form as *"Any multidimensional constellation of conceptually distinct characteristics that commonly occur together"* (Meyer et al. 1993), as 'tightly interdependent and mutually supportive

elements' assuming that *"what is crucial is that a relatively small number of these configurations or types encompass a large fraction of the population of organizations"* (Miller, Friesen 1984, 1). Research in this perspective have looked at the actual, observed combinations among wide arrays of organizational devices (actually, devices of all sorts: from formal rules and policies in budgetary processes or in personnel management, to task forces and committees, to environmental scanning procedures, to central staff units, to the use of equity, and so on and so forth) and correlated these combinations with indicators of performance. Typically, configurational approaches posited *"higher effectiveness for organizations that resemble one of the ideal types defined in the theory. The increased effectiveness is attributed to the internal consistency among the patterns of relevant contextual, structural and strategic factors"* (Doty, Glick and Huber, 1993, 1196).

The complementarity-based approach in organizational economics, has been pointing in a similar direction. Organizational attributes are defined as 'complementary' if doing (more of) any one of them increases the returns to doing (more of) the others (Milgrom and Roberts 1995). Organizational 'features' or 'attributes' have been conceived as 'practices' of any sort: in empirical studies, large sets of practices have been considered, such as teamwork and incentive pay, flexible job assignment and knowledge management (Laursen and Mahnke 2001; Ichniowski et al. 1997); or process and project organization, horizontal integration, delayering, outsourcing, and alliances (Whittington et al. 1999); and the observed combinations among them have been correlated with performance.

These approaches have addressed some of the problems of the earlier notion of organizational and governance form as discrete structural alternatives, but have opened up new problems as well. Most notably, on the positive side, interactions among organizational attributes are considered and are at center stage. Second, the notion of complementarity is wider than that of consistency by 'similarity in kind', as complementarities can also stem, in principle, from differences among the clustering features. Third, equifinality is admitted: i.e. the possibility that more than one configuration is effective under any given circumstance (Gresov and Drazin 1997). However, the following problems remain or have emerged (Grandori and Furnari 2008)**:**

- The lists of features or practices considered have been very extensive and different according to the organization problem considered. Field-specific operationalization is certainly fine, but is there any underlying common logic? Content lists are infinite and prediction is impossible if some general properties of elements, predicting the likelihood of different types of links or combinations, are not formulated.

- Combinative laws have been rather *post-hoc*: whatever elements are observed to be combined in practice and correlated to performance are said to be 'complementary' (i.e. *any* combination of elements found under positive performance is defined as an "internally consistent" configuration); hence the explanatory law is inferred from the very pattern it should explain. No theory of

combination is provided, that would make it possible to predict and explain effective combinations, let alone to design new ones.

- Configurational researchers have been using correlational methods that obscure the possible equifinality and non-linearity relationships among organizational attributes. In other terms, the methods applied can be deemed not well suited to support configurational inquiry (Fiss, 2007).

- Forms are defined using each and all the features that appear in the initial list of elements. This does not allow to 'polish the list', to detect which 'features' are more or less *relevant* in affecting performance outcomes, which differences make a difference.

Organization forms as chemical formulas

On the basis of the above discussion, it can be concluded that the two basic ingredients for defining organization forms as 'clusters of features' – i.e. a general notion of organizational 'features' or components; and general laws of combinations among them - have not been satisfactorily defined thus far. They deserve further and different attacks. The approach illustrated here does represent a rather different attack to those problems. It is different because it shifts the unit of analysis from the 'attributes' of a whole entity to its constitutive 'elements'. Differences and similarities may become much clearer if analyzed at the level of the elementary building blocks of organization, rather than as 'attributes' of an entity or organism. It is the difference that passes

between classic zoology –observing and classifying animals into different species because they have different 'attributes' (height and weight, blood temperature, hair or skin, legs or wings) or evolutionary biology (how these attributes have been selected over history) - and chemistry or genetics (what are the basic elements of which all matter is composed and how they combine to generate different organic and inorganic forms of life). The present contribution starts from what may constitute a basic analysis of the latter type, namely, a 'chemistry of organization'.

A table of organizational elements

Some basic qualitative distinctions among features can be defined by using the classical, stylized, and generally agreed upon characterization of an organization form as a set of modes of 'division' and of 'connection' among parts of a system (Mintzberg 1979; Marturana and Varela 1980). These 'modes' can be said to be qualitatively different if:

- the system is partitioned into units that are vertically and horizontally differentiated or is unsegmented;
- units are connected through partner-specific communication (either directly or through brokering hubs), or through impersonal generally available information (such as prices or rules and norms);
- actions are decided upon in an ad hoc way or in a programmed, rule-guided way;
- decision rights are evenly or unevenly distributed among units (to all of them in a full democracy, or, at the other extreme, to one party only in a fully centralized system).

These fundamental properties can be used to define classes of organizational elements (analogous to a 'Table of elements' in natural chemistry) that can be said to be different in kind as the nature of the nodes and links is different (analogously, we believe, to the grouping of natural elements into gases, metals and non metals according to their atomic structure).

Four general classes of elements, in economic organization, can be defined as different in kind according to the above general properties (Fiske 1992; Miller 1992; Grandori 1999)[ii], and are adopted as a starting 'table of elements' for a 'chemistry of organization' (Grandori and Furnari 2008):

- 'market' elements, whereby different parts of a system are connected by value-based exchange devices (such as incentives, prices, stocks and exit); a converse of non value-based, 'resource pooling and associational' elements;
- 'bureaucratic' elements (including all kinds of de-personalized rules and specialized office systems); a converse of elements of 'personalism, informality and generalism';
- 'democratic' elements: devices through which each node is 'represented' (e.g. through vote and voice rights, or residual decision rights); a converse of elements of 'centralization';
- 'communitarian elements', aligning knowledge and preference through identity and community building, and knowledge sharing; a converse of elements of 'differentiation'.

Table 1 - adapted from Grandori and Furnari (2008) - shows the four fundamental types of organizational elements, the single elements identifiable within each of the four types, and a set of contemporary relevant organizational practices predominantly containing each type of element, along with the references to the studies that have discussed the use of these elements. This 'Table' is not exhaustive, but not even the Table of elements in natural chemistry was so (many new elements have been identified since its formulation). The important step is to specify elements in terms of general structure and properties – so that new elements can be discovered and so that the composition of any 'dirty' and noisy, more or less complex, observable practice (e.g. 'MBO', to quote one that typically includes multiple elements) can be understood. .*A fortiori*, the 'description' of a whole organization and governance 'form' would no longer be expressed as an array of features and practices, but as a compact chemical 'formula', specifying its 'composition' in terms of elements of community, democracy, bureaucracy and market (see examples in next paragraph). This language is general enough to describe the organization and governance forms of systems of economic action at various levels: from the micro-system of work to entire firms, to the organization of industries and networks.

TABLE 1 ABOUT HERE

Doses of an element

In addition to classes of elements, 'states' or 'values' or 'numbers' of elements should

be defined in order to formulate meaningful combinatory laws. How can one say that a particular element, for example 'all to all direct mutual adjustment' or 'teaming', can or cannot combine with others? What is needed are doses of the element, e.g. low versus high doses of teaming, as well as some indication of the doses of other elements it can be combined with for generating different substances. In other words, an analogue of the number of atoms of an element entering a chemical formula is required. Through the analogy, it also clearly appears that complementarities can arise among elements employed at any dose. *low values are as interesting as high values*. Indeed, there is nothing interesting or valuable in employing 'more of an element'.

In other terms, refining and generalizing Milgrom and Robert's (1995) notion, rather than defininig complementarity only in reference to marginal *increases* in the application of elements ('more of' X), we define complementarity as referred to any variation in the intensity of application of an element. It may well be that 'more of X' is complementary with 'less of Y' or with an intermediate dose of Y. Hence, we will analyze complementarity among *elements in a state, or at a dose: two elements are complementary, in certain doses, if the returns of applying them in these doses are higher than in other combinations of doses*.

Which levels of an element may be considered low, medium or high depends on the type of system analyzed and the context – even the 'normal' level of iron in blood may vary across climates, races and ages. Hence, in our organizational chemistry it seems sensible to define these levels in empirical and relative terms, rather than in absolute terms. Here, whatever the sample of systems considered, we have so far defined 'high' and 'low' in reference to some average or normal value (Grandori and Furnari 2008).

Types of complementarities and combinatory laws

Two goods are complementary if the demand for one increases the demand for the other, because the value of their joint use is much higher than the value of their disjoint use (for example, pasta and tomatoes or shoes and bag of the same style). In fact, Milgrom and Roberts (1995) seminal contribution defines complementarity in an unbounded set as $V(x',x'')>V(x')+V(x'')$, where x' and x'' are any two organizational devices.

We accept this definition, but a further question needs to be answered before a complementarity based explanation of organization forms can be given*: what is the origin of the surplus value of the 'joint application' of two organizational devices, i.e. where does complementarity come from?* In addition, when, precisely, can an application of organizational devices be said to be 'joint'?

Answering these questions leads to a distinction among different possible sources of complementarity. Looking at the gastronomy and fashion examples mentioned above, one may notice that complementarity stems from different sources in the two cases. A pair of shoes and a bag of the same style are complementary because they share similar features but they deploy these features in different parts of a system. Pasta and tomato sauce, on the other hand, have different attributes and their contributions to a good dish are inseparable (i.e. the quality of the dish is basically due to interaction effects). Using the notion of 'difference in kind' among organizational elements developed above, it is possible to distinguish two types of organizational complementarities according to whether the elements applied together are different or similar. In addition, though, it

should be clarified what ‘applied together’ means. As the above examples highlight, here too there are at least two ways: the application is to the same system but in different parts, or it is to the very same part (the same activity, transaction, resource etc). Using the phrase “application domain” to designate the ‘part’ of a system to which an element is applied its ‘application domain’, we have:

a) *‘symbiotic’ complementarity*, if surplus value is generated by different elements applied to the same application domain;
b) *‘pooled’ complementarity* if surplus value is generated by similar elements applied to different application domains.

Both types of complementarity involve interaction effects (by definition of complementarity), in the sense that the value of the (symbiotic or pooled) sum is greater than the sum of the values of the parts. The case of symbiotic complementarity is obvious. A puzzle could be a good example of pooled interaction: puzzle pieces are all similar, the value of any single piece alone is almost zero, only the pooling of all parts has a positive value (see an image). As examples of pooled complementarity among organizational practices, one may cite the use of incentives in line and staff units, or the involvement in community building of all units and not merely of some units. Examples of symbiotic complementarities among organizational practices are found when, say, pay for performance, teamwork and formal standardized procedures of performance evaluation are applied to the same people or units.

It will be shown that the distinction is useful as these two types of complementarity

have different implications for the laws of combination of organizational elements. In addition, the double distinction between similarity-/difference-based complementarity, and of same/different application domain, implies that there are another two possible combinations that do not generate complementarity:

c) elements that are similar in kind and have the same application domain, are substitutes, i.e. their combinations are *redundant*;
d) elements that are dissimilar and have different application domains are *independent* (neither substitutable nor complementary).

The four types of relationships among two generic types of organizational elements are summarized in Table 2.

TABLE 2 ABOUT HERE

Evaluation functions and multifunctionality

In order to be substantively more precise in specifying which kind of differences may generate complementarity, an evaluation function must be defined. What is a 'good outcome' with respect to which a combination of elements may be evaluated?
We propose to use distinct functions rather than one overall performance function (as it has been typically been done in the assessment of discrete structural alternatives), for several reasons.

- The relationship between the overall performance of a system and its organizational configuration is too 'noisy';
- The performance of economic systems is usually measured financially, which is a useful yardstick for some purposes; but it is not a good indicator of the utility or value generated by a system, as no monetary single indicator is a good indicator of the value of complex goods in general, in particular where multiple beneficiaries and complex trade-offs are involved (Sen 1999). Hence, it is preferable to use a portfolio of functions, as it is typically done in design theory in other fields, such as architecture (Boland and Collopy 2004; March 1976);
- Operationalizing results into qualitatively different consequences allows detection of counter-intuitive combinations between configurations and consequences. For example, it is entirely conceivable to have highly communitarian, identity based combinations generating brilliant economic results (and perhaps too oppressive socialization); and highly market-like, incentive driven systems, generating very poor economic results (but perhaps an exciting sports-like social atmosphere).

Among the qualitatively different, relevant parameters against which an organizational combination may be evaluated, at least three seem to be important beyond any reasonable doubt: efficiency, effectiveness and equity (Grandori 1999). Then, in the laws presented below, all these three types of outcomes will be considered. It is worth pointing out that these outcomes received also an initial test in the empirical study (Grandori and Furnari 2008) mentioned below (the effectiveness parameter used in the study has been the rate of innovation outcome).

Here it can be further noticed that elements may be more or less specialized with respect to particular outcomes. Some elements are more 'generalist' and multifunctional, while others are more 'specialist' and mono-functional**.** Possible consequences of the different degree of multifunctionality of elements for combinatory laws are:

- more generalist elements should more frequently be useful components in organizational formulas, i.e. in formulas that are effective at producing different types of results, while specialized elements should be useful in the production of only one type of result;
- more generalist elements may be more 'stable', i.e. less in need of combination with other elements, and be substitutable by other generalist elements or by a combination of many specialist elements; by contrast, specialist elements should be more 'unstable', i.e. they need complements in order to deliver good outcomes, and more precisely they need complements of a different kind.

Expressing organizational formulas through Boolean Comparative Analysis

In an earlier paper (Grandori and Furnari 2008), we used Boolean Comparative Analysis (Ragin, 1987; 2000) to formalize organization forms as chemical formulas and test a set of basic combinatory laws on a medium-sized sample of firms. Here below, we briefly introduce the language of Boolean Comparative Analysis (BCA hereafter), illustrating only the technical features of this methodology that are strictly necessary to understand the subsequent formalization of the combinatory laws.[iii]

Let us hypothesize that the adoption of one market-like element (say, monetary incentives to human resources) will be *per se* sufficient to produce a level of firm efficiency above the industry average. Labelling the causal condition "presence of one dose of market" as M_1 and the outcome "presence of efficiency above the average" as $E_{>A}$, this hypothesis can be translated into the following Boolean algebra statement:

$$M_1 \text{ ---> } E_{>A}$$

where, according to standard Boolean algebra notation, ---> denotes the logical implication operator and capital letters indicate *the presence* of a causal condition or outcome .[iv]

The typical objective of BCA is to determine the *simultaneous presence <u>and</u> absence of causal conditions* under which a certain outcome is present. To this end, cases are formalized as *combinations of elements* through the use of Boolean algebra operators "AND" ("*") and "OR" ("+"). These operators allow to specify the relations between more than one causal condition: suppose for example that the adoption of highly powered incentives is not sufficient *per se* to foster firm efficiency without the application of one bureaucratic element (say, an adequate monitoring system). This hypothesis can be formalized into the following Boolean statement:

$$M_1*B_1 \text{ --> } E_{>A}$$

where "*" denotes the logical Boolean operator "AND". The above statement reads as "M_1 **AND** B_1 imply $E_{>A}$ ": the occurrence of outcome $E_{>A}$ requires the presence of one element of *both* B *and* M, i.e. B and M in one dose are strictly complementary in the achievement of that outcome. The Boolean operator "AND" therefore represents relations of *complementarity*.

Let us now suppose that there are two other complementary elements of a different type that can also produce the same outcome $E_{>A}$: for example C_1 and D_1, representing respectively a community-like element (say, teamwork) and an element of democratic governance (say, the distribution of representation rights). The Boolean expression will be:

$$M_1*B_1 + C_1*D_1 \text{ --> } E_{>A}$$

where "+" denotes the logical operator "OR". The above statement could be read as "M1 AND B1 **OR** C1 AND D1 imply above average E": if *any* of the two combinations is present, the outcome will occur. Hence the Boolean operator "OR" represents relations of *substitutability (equifinality).* Using these operators, BCA employs logical minimization algorithms and probabilistic tests in order to identify the *necessary* and *sufficient* combinations of elements to achieve given outcomes (Ragin, 1987; 2000).

In using Boolean algebra language to formalize the hypothesized combinatory laws presented below, we generalize the notations used in the example above. Specifically, we agree to indicate types of elements in capital letters (M = Market-like;

B = Bureaucratic; C = Communitarian; D = Democratic) and the number of doses (or atoms) for each type of element with a small subscript at the bottom of the letters, as in chemical formulas. Thus, the generic *organizational formula* can be written in the form M_m- B_b – C_c – $D_{d..}$

The empirical study presented in Grandori and Furnari (2008) proposes a way of operationalizing and measuring the notion of 'one dose' or 'one atom' of an element. In that study a dose of an element is measured as the number of practices (see Table 1) employed beyond the average level. In some of the laws, a notion of 'maximum' level of application is also used. One way to operationalize this general notion of maximum is to consider the maximum average intensity of application across all the four elements in systems of a certain type in a certain context, as is done in the above mentioned empirical study (where this value is found to be 4).

The three organizational outcomes considered here will be indicated with capital letters (E = efficiency; I = innovation; F = fairness). The subscript '$_{>A}$' at the bottom of these letters indicates that the specific organizational outcome is achieved at a 'high level', operationalized as above average (of course other thresholds may be used for operationalizing 'high' performance).

Combination laws

Combination laws can be expressed as conditions that organizational formulas should respect. The first four laws (conditions I to IV) have been formulated and received an empirical test in Grandori and Furnari (2008); they are expressed in a more formalized manner here (this is useful for developing the more complex laws of

structural heterogeneity presented here). The character of the first four conditions is that of universal laws to which any high performing organizational formula should obey (this obviously does not mean that only one high performing formula exists). The laws of structural heterogeneity (conditions V to XII) are a distinctive contribution of the present paper (only the initial conditions V and VI were conjectured in our former study).

- It is extremely likely that in any system, even very simple ones, there are activities of different kinds; and that elements of different kinds are superior in order to regulate these activities (Grandori and Soda 2006). In addition, it is extremely likely that any system, even a small system, that tries to coordinate everything using only one kind of element, no matter which (say plans or incentives) is not viable (Stark 2007). Finally, it is conjectured that, at least at low doses, the four elements entail positive symbiotic complementarities (Grandori and Furnari 2008).

Hence: *The presence of (at least one dose of) elements of different kind is a necessary condition for an organizational formula achieving high performance of any sort ('Law of organizational core variety'*). Thus, a testable, formalized proposition is the following:

Condition I

$M_{\geq 1} * B_{\geq 1} * C_{\geq 1} * D_{\geq 1} \rightarrow E_{>A}$

$M_{\geq 1} * B_{\geq 1} * C_{\geq 1} * D_{\geq 1} \rightarrow I_{>A}$

$M_{\geq 1} * B_{\geq 1} * C_{\geq 1} * D_{\geq 1} \rightarrow F_{>A}$

Our discussion of the effects of similarity among mechanisms, leads to the observation that mechanisms which are similar in kind are complementary above all if they are used in different parts of the system, i.e. they can bring about pooled complementarity, not symbiotic complementarity. If similar elements are employed at increasing doses in the same domain, marginal benefits should decrease.

Hence*: There are decreasing marginal returns, and, beyond some point, negative returns, to increases in the intensity of the same kind of element in the same application domain* (*'Law of decreasing marginal returns to organizational homogeneity').*

In other words, a necessary condition for high performance is that each and every element is not applied over and above a certain value that we thus define as 'maximum'. Hence, a sufficient condition for low performance is the following:

Condition II

$X_{\geq max} \rightarrow Y_{<A,}$

where X indicates a generic type of element (M, B, C, D) and Y a generic type of outcome (E, I, F).

People's energy, cognitive capacity and behavioral flexibility is limited; hence, individuals are unlikely to be able to attend and respond simultaneously to: strong incentives; strong demands for identification; intense requirements of conformity to rules and the use of procedures; the right and duty to exert one's best judgment; the

need to be, at one and the same time, organizational citizens who are highly entrepreneurial, highly solidaristic, highly compliant, actively and critically participating to the life of the organization. In addition, practices are costly, and choice among alternative investments in different practices may become an issue as the total amount of investment increases.

Hence: *There are decreasing marginal returns, and beyond some point, negative returns, to increases in the intensity of all kinds of elements in the same application domain. ('Law of decreasing marginal returns to organizational variety')*

Formalized testable propositions deriving from the law are those expressed by the following condition:

Condition III

$M_{\geq max} * B_{\geq max} * C_{\geq max} * D_{\geq max} \rightarrow E_{<A}$

$M_{\geq max} * B_{\geq max} * C_{\geq max} * D_{\geq max} \rightarrow I_{<A}$

$M_{\geq max} * B_{\geq max} * C_{\geq max} * D_{\geq max} \rightarrow F_{<A}$

If only this condition III were valid (the simultaneous application of elements in high doses predicts low performance) but not condition II (the application of a single element in a high dose predicts low performance), it would mean that there are negative complementarities, beyond some level, among elements that differ in kind, and not among elements that are similar in kind.

Through an empirical investigation on the combinatory laws expressed above in a sample of 75 large Italian firms, Grandori and Furnari (2008) found strong evidence supporting the hypothesized relationships among similar/different organizational elements: 89% of highly efficient firms and 93% of highly innovative firms respect the combinatory rule 'all different types of organizational elements should be adopted in the firm, with values comprised between a lower and an upper bound' (operationalized as 1 and 3 in the study). In other words, any high performing formula is internally varied, at least at a base level, and the law of decreasing marginal returns applies to each single type of element: i.e. the prime origin of the upper bounds is decreasing or shows negative returns to one-sidedness and homogeneity, not the negative interactions among elements of different kinds. Testing for the necessity and sufficiency of these findings, the authors found respect of the laws to be a statistically significant, necessary and sufficient condition for high efficiency and a significant necessary condition for high innovation[v].

Introducing types of outcomes

In Grandori and Furnari (2008) we also advanced the hypothesis that *the optimal intensity of each element in an organizational formula (within the lower and upper bounds specified by the former laws) is contingent on the type of performance outcome generated ('Law of structural heterogeneity').*

As to efficiency and innovation, we hypothesized that bureaucratic elements are more specialized in the achievement of internal efficiency of a system, while market, communitarian and democratic elements are more specialized in the achievement of

innovation. The tested hypothesis tested was that highly efficient organizational formulas are enriched in bureaucracy, while highly innovative organizational formulas are enriched in one or more of the other elements. Hence, constraining all the doses of elements (m, b, c, d) to be > 1 due to the first 'law of organizational core variety':

Condition IV

$B_b*M_m*C_c*D_d \rightarrow E_{>A}$ if $b > m* c * d$

Condition V

$B_b*M_m*C_c*D_d \rightarrow I_{>A}$ if $m + c + d > b$

Fairness outcomes were not considered in our earlier study. Here, we hypothesize that they should be generated by *formulas enriched both in bureaucracy and communitarian or democratic elements*, as the former elements are specialized in generating transparency and de-personalization, while the latter in reducing or resolving conflict. Hence:

Condition VI

$B_b*M_m*C_c*D_d \rightarrow F_{>A}$ if $b * (c + d) > m$.

At this juncture, it should be noticed that there are still many formulas that satisfy these conditions, i.e. formulas that are equifinal in generating high innovation or high efficiency or high fairness. Here, we are going to further refine the laws of structural heterogeneity by introducing further discriminating contingencies (non organizational variables in varying states).

Introducing contingencies

The portfolio of equifinal formulas can be restricted if further conditions are added.. They can be represented by some contingencies to be met by the formulas. One parsimonious way of doing so is to summarize those contingencies in terms of the nature of tasks and interdependencies to be governed (as done in all research traditions we are drawing on). In particular, the different elements of organizing are known to be specialized to *the level of uncertainty* of tasks and inter-task relations.

Bureaucratic elements are good in generating static efficiency in stable tasks, hence the proposition that formulas enriched in bureaucracy generate high efficiency contained in our former study is likely to be valid only for static efficiency. A *combination of bureaucratic mechanisms with market elements* (especially through outsourcing and externalization of activities) is known to be good in generating *dynamic efficiency* in variable tasks (Mariotti and Cainarca 1986).

Hence, denoting uncertainty as U, qualifying it as either low ($_L$) or high ($_H$) and constraining all the doses of elements (m, b, c, d) to be > 1 due to the first law of organizational core variety, the law of structural heterogeneity for static and dynamic efficiency can be expressed as follows:

Condition VII

$U_L * B_b * M_m * C_c * D_d \rightarrow E_{>A}$ if $b > m * c * d$

Condition VIII

$U_H * B_b*M_m*C_c*D_d \rightarrow E_{>A}$ if $m*b > c*d$

If the effective organization of *innovation* is considered, a distinction can also be made between innovation in known tasks and techniques, versus innovation in settings where tasks and techniques have to be discovered altogether. Taking into account both classical works (Burns and Stalker 1961) and recent empirical works shading some light on the 'routinization of innovation' and innovation in mature industries (Kilduff and Sawyer 2003; Brusoni 2006), it can be hypothesized that in mature, known settings the organization of innovation can be more modular, while in highly dynamic and innovative settings it needs to be more integrated. Hence, organizational formulas for *innovation in less uncertain action fields could be richer in market and/ or bureaucratic elements (both infuse modularity into a system), while in more uncertain action fields, organizational formulas should be richer in community and/or democracy (both infuse integration).*

Condition IX

$U_L* B_b*M_m*C_c*D_d \rightarrow I_{>A}$ if $(m + b) > c*d + (m*b) > c*d$

Condition X

$U_H* B_b*M_m*C_c*D_d \rightarrow I_{>A}$ if $(c+d) > m* b$

If this were true, it would indicate that the set of formulas for high innovation under low uncertainty has an intersection with the set of formulas for high efficiency under

high uncertainty (the intersection, i.e. the multifunctional formula, being the market and bureaucracy enriched formulas).

Fairness in stable and known activities is also likely to be best achieved through different mechanisms than in uncertain conditions. While transparency and equal opportunities and treatment may generally associate fairness outcomes with some elements of bureaucracy, the level of uncertainty may discriminate between community and democracy as complements: communitarian elements are possibly sufficient in stable setting, while democratic mechanisms and organizational justice provisions should be more robust under uncertain conditions (Miller 1992; Grandori forth). Hence, *organizational formulas for fairness can be hypothesized to be richer in bureaucracy and community in stable settings, richer in bureaucracy and democracy in dynamic and uncertain settings*.

Condition XI

$U_L * B_b * M_m * C_c * D_d \rightarrow F_{>A}$ if $c*b > m*d$

Condition XII

$U_H * B_b * M_m * C_c * D_d \rightarrow F_{>A}$ if $d*b > m*c$

The organizational formulas generated by the above set of conditions are summarized in Table 3, which shows all the equifinal formulas written in extended form, assuming that the maximum number of each element is 4 (as found in our recent empirical study in the Italian context). Hence, Table 3 gives an immediate, substantive, picture of the

type and number of contingent formulas resulting from the analysis (equifinal formulas are indicated with the same color in different cells).

TABLE 3 ABOUT HERE

Conclusions

This work has revisited and revitalized the notion of organization forms as clusters of attributes, providing a systematic classification of attributes as 'organizational elements' – in analogy with natural elements in chemistry – and outlined a series of laws of combinations on how elements can combine into organizational formulas. Some notable features of the conjectured (and partially tested) combination laws are worth noticing:

- they include both universal and contingency laws (i.e. specify which 'features' are generally necessary in order to have a high performing organization and which are necessary only under particular circumstances);
- they admit equifinality and predict structural heterogeneity (e.g. it is argued that more than one 'cluster of features' can achieve high performance under the same circumstances, and it is specified which ones).

Among the substantive conclusions, it is worthwhile to highlight that:

- Bureaucratic elements are highly multifunctional , especially under low uncertainty
- Democratic elements are multifunctional under high uncertainty, especially in the achievement of innovation and fairness.;

- Market elements are more specialized elements, especially with regard to innovation and uncertainty.
- in stable settings, either efficiency and innovation or fairness and efficiency can be achieved with the same formula (enriched in bureaucracy and either market or community).
- There is no formula in common between efficiency and innovation in dynamic settings or between fairness and innovation in stable settings. This result indicates an area of trade-off for designers, giving an idea of the outcomes that are more difficult to achieve simultaneously in the two settings.
- There are many ways of being innovative in highly uncertain settings (the set of equifunctional formulas is particularly wide). This is an interesting result, that provides a solution for a phenomenon that is currently considered a 'puzzle': how is it possible, and is it 'right' or 'wrong', that diverse organizational arrangements, in particular highly communitarian and highly market-rich arrangements, are observable in the governance of knowledge – intensive activities? (Foss 2007).

The results also have implications for organization redesign and change. Some changes, in terms of meeting different contingencies or of achieving different mixes of outcomes, requires to change more elements, while others may imply changing just one element. For instance, only one additional D element is required in order to find several formulas able to achieve all three objective functions in uncertain settings. This is a significant refinement with respect to the usual application of the notion of complementarity to organizational change. We suggest that the idea that the wider the

set of practices that are changed together, the better (due to the presence of interactions among practices) is too rough and resource wasting, and derives from not knowing where complementarities lie. The organizational chemistry framework illustrated here should help in making hypotheses on what elements are complementary, in what doses and under what circumstances; hence, in enhancing our capacity of selective intervention and ad hoc organization design, including a diagnosis of what elements may be kept invariant while other change.

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Table 1 – Organizational Elements and Practices

Types of organizational elements	Single Elements	Practices predominantly embodying the element	References
Market-like Elements	❑ Price	❑ Pay for performance *(individual)* ❑ Pay for performance *(team and firm-based)*	Von Hayek 1945 Hirschman 1970 Williamson 1975; 1993 Zenger and Hesterly 1997
	❑ Exit	❑ Outsourcing ❑ Internal labor mobility	
Bureaucratic Elements	❑ Formal Rules	❑ Evaluation System ❑ Formal procedures and programs	Gouldner 1954 Blau and Scott 1962 Pugh et al 1969
	❑ Hierarchy	❑ Vertical Articulation of formal structure (no authority implied)	
Communitarian Elements	❑ Knowledge Sharing	❑ Knowledge sharing techniques ❑ Project-based self-organization	Hofstede 1980 Ouchi 1980 Kogut and Zander 1996
	❑ Preference Sharing (objectives alignment)	❑ Teaming ❑ Community building practices	
Democratic Elements	❑ Weighting of organizational members preferences	❑ Competence- and/or preference-based job design ❑ Empowerment	Gouldner 1954 Lammers and Szell 1989 Blair 1995 Harrison and Freeman 2004
	❑ Diffusion of decision rights holding	❑ Responsibility Centers ❑ Diffusion of decision and reward rights to units	

Difference between two generic types of organizational elements	Application Domain (transaction, activity, resource) to which the two generic elements are applied: **Same domain**	**Different domain**
Same Type	*Substituability*	*Pooled Complementarity*
Different Type	*Symbiotic Complementarity*	*Independence (neither substitutability nor complementarity)*

Table 2 - Types of Relationships among Organizational Elements

	EFFICIENCY	**INNOVATION**	**FAIRNESS**
LOW UNCERTAINTY	*Formulas enriched in B* $M_1*B_2*C_1*D_1$ + $M_1*B_3*C_1*D_1$ + $M_2*B_3*C_2*D_2$ + $M_1*B_3*C_2*D_2$ + $M_1*B_3*C_2*D_1$ + $M_2*B_3*C_1*D_1$ + $M_2*B_3*C_1*D_2$ + $M_1*B_3*C_1*D_2$ + → $E_{>A}$	*Formulas enriched in B and M* $M_2*B_2*C_1*D_1$+ $M_3*B_3*C_1*D_1$ + $M_3*B_3*C_2*D_2$ + $M_3*B_3*C_1*D_2$ + $M_3*B_3*C_2*D_1$ + $M_3*B_2*C_1*D_1$ + $M_2*B_3*C_1*D_1$ → $I_{>A}$	*Formulas enriched in B and C* $M_1*B_2*C_2*D_1$ + $M_1*B_3*C_3*D_1$ + $M_2*B_3*C_3*D_2$ + $M_1*B_3*C_3*D_2$ + $M_2*B_3*C_3*D_1$ + $M_1*B_3*C_2*D_1$ + $M_1*B_2*C_3*D_1$ → $F_{>A}$
HIGH UNCERTAINTY	*Formulas enriched in B and M* $M_2*B_2*C_1*D_1$ + $M_3*B_3*C_1*D_1$ + $M_3*B_3*C_2*D_2$ + $M_3*B_3*C_1*D_2$ + $M_3*B_3*C_2*D_1$ + $M_3*B_2*C_1*D_1$ + $M_2*B_3*C_1*D_1$ → $E_{>A}$	*Formulas enriched in C or D* $M_1*B_1*C_1*D_2$ + $M_1*B_1*C_1*D_3$ + $M_2*B_1*C_1*D_3$ + $M_2*B_2*C_1*D_3$ + $M_2*B_2*C_2*D_3$ + $M_2*B_1*C_2*D_3$ + $M_1*B_2*C_2*D_3$ + $M_1*B_2*C_1*D_3$ $M_1*B_1*C_2*D_1$ + $M_1*B_1*C_3*D_1$ + $M_2*B_1*C_3*D_1$ + $M_2*B_2*C_3*D_1$ + $M_2*B_2*C_3*D_2$ + $M_2*B_1*C_3*D_2$ + $M_1*B_2*C_3*D_2$ + $M_1*B_2*C_3*D_1$ → $I_{>A}$	*Formulas enriched in B and D* $M_1*B_2*C_1*D_2$ + $M_1*B_3*C_1*D_3$ + $M_2*B_3*C_2*D_3$ + $M_1*B_3*C_2*D_3$ + $M_2*B_3*C_1*D_3$ + $M_1*B_3*C_1*D_2$ + $M_1*B_2*C_1*D_3$ → $F_{>A}$

Table 3 - Equifinal Organizational Formulas (by function and contingency)

[i] Recent and relevant contributions in organizational sociology concerned with organization forms, such as the just quoted article by Hannan et al or neo-institutionalism, are not considered. The reason is that in those approaches the definition of organizational features and the patterns of their clustering are seen as conforming to the expectations of reference groups and of the dispensers of legitimacy. Hence those approaches do not offer inputs for specifying elements and combinatory laws in a micro-analytic way.

[ii] These contributions are the only ones to our knowledge that conceive these types of elements as classes of mechanisms to be combined in order to explain or construct any organizational system, rather than as full institutions, that is, as 'discrete structural alternatives' themselves, e.g. 'the market', 'the firm', etc. (as they are in apparently similar typologies drawn up by others, such as Williamson, Lindblom, or Etzioni). Fiske's 'fundamental elements of sociality' are 'market pricing', 'authority ranking', 'equality matching', and 'communal sharing'; Grandori and Miller contribute to identifying single elements within each class, such as pricing, exit, voting, teaming, negotiation, authority and agency, rules and procedures, norms and culture, property rights.

[iii] The concepts and procedures employed in BCA are illustrated in greater detail in Ragin (1987; 2000) and on the website www.fsqca.com. Two methodological papers (Fiss 2007; Furnari 2007) address specifically the motivations underlying the use of BCA in organization design studies.

[iv] In standard BCA notations, lower-case letters indicate *the absence* of a causal condition or of an outcome. Lower case notations will not be used in this paper for the sake of simplicity.

[v] No statistically significant sufficient condition was found for innovation. This is an interesting asymmetry in the predictability of the outcomes of organizational formulas, although it may appear obvious,as innovation is uncertain by definition and organization can set necessary conditions but not guarantee the outcome.