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Modeling Multidimensional Fit through Boolean Algebra: New Methods for Combinative Organization Design¹

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Introduction

The fit among the components of an organizational system has been shown to crucially affect firm performance since the origin of organization science. Despite the importance of fit has been consistently emphasized in organization research, the notion of fit has been changing over time. While early contingency studies worked out a *dicotomous notion of fit* as "pairwise" association between two variables, such as the "internal fit" between strategy and structure (Chandler, 1962) or the "external fit" between structure and environment (March and Simon, 1958; Lawrence and Lorsch, 1967), over time the focus of organization design research has gradually shifted to a *multidimensional notion of fit*, understood as the relationship among *sets* of elements or activities. Examples of this new notion of fit have been widespread over the last two decades across strategy, organization and economics-oriented design research. For instance, configurational researchers empirically discovered that patterns or profiles of organizational attributes (namely, "organizational configurations" or "gestalts"), rather than single structural variables, are related to firm performance (Miller and Friesen, 1984; Meyer et al, 1993), while economists created mathematical frameworks to model the existence of complementarities among firm practices (Milgrom and Roberts, 1995).

Although multidimensional fit presents an attractive concept across different fields, its formal operationalization into design propositions on how to design better organizations has been facing theoretical and methodological concerns (Grandori and Furnari, 2006). As a result, multidimensional fit remains a rather underdeveloped construct and the empirical evidence on the impact of multidimensional fit on performance has been equivocal (Ferguson and Ketchen, 1999).

This paper contributes to the development of the multidimensional fit concept by introducing Boolean Comparative Analysis (BCA), a new methodology that, we'll argue, is suited to formalize a more satisfactory model of multidimensional fit than those currently available in the literature. The paper is organized as follows. The first two sections are devoted, respectively, to a brief

¹ This work has been published as book chapter in Golzio L. E., Fabbri T. M. (ed.). 2007. *Relazioni di Lavoro e Forme Organizzative: Nuovi Modelli Progettuali*, Carrocci Editore, Roma. When the chapter was published, the author was PhD Candidate at Bocconi University in Milan, Italy.

literature review and the introduction of the BCA methodology. A final section uses an example drawn from the combinative perspective on organization design (Grandori, 1997; 2001; Grandori and Soda, 2006; Grandori and Furnari, 2006) to develop a Boolean model of multidimensional fit.

From Dicotomous to Multidimensional Fit: Genesis of a Metamorphosis and its Pathologies

The concept of fit has been first emphasized in early contingency studies. These studies proposed a *dicotomous notion of fit* as "pairwise" relationship between two variables, such as firm structure and uncertainty (Lawrence and Lorsch, 1967). The bivariate models of fit proposed by contingency theorists have been undergone two significant criticisms worth emphasizing here.

First, the functional form of the relationship has been shown to be rather imprecise. While most of the contingency theoretical propositions do not specify how the interaction between the pair of variables should be modelled (e.g. whether the interaction term is to be formalized as a multiplicative, maximizing or harmonic function), the correlational statistical procedures commonly used by contingency researchers *de facto* imposed an assumption of linearity and simmetry on the relationships studied in the contingency framework (Schoonoven, 1981). This simmetrical property of contingency arguments is important because it led to an overemphasis on simmetrical combinations of values (high-high vs low-low) as potential sources of fit.

A second critique has taken the lead from the evidences that organizations often operate in contexts of multiple, co-existing, often conflicting contingencies and that organizations' structures and practices are often interconnected rather than isolated components.

Drawing on these evidences, many scholars questioned the rather reductionist contingency emphasis on bivariate relationships, suggesting a systemic and holistic view of the structure-environment-strategy triad, where *configurations* of elements, rather than isolated variables, relate to differences in firm outcomes. Theoretically, configurationists attribute the increased effectiveness of a configuration to the internal consistency among the patterns of relevant contextual, structural and strategic factors (Doty, Glick and Huber, 1993). Expanding the number and type of elements to be considered as components of the "object" to be designed (what in contingency was the structure) and emphasizing the internal consistency, or internal fit, among the elements of a configuration as the core precitor of performance, configurational studies imply *a shift from a dicotomous to a multidimensional notion of fit*, understood as the relationship among *sets* of elements.

The notion of multidimensional fit is central also to recent design-oriented contributions from the field of organizational economics, such as the complementarity-based view outlined by

Milgrom and Roberts (1995). In this perspective, multidimensional fit among elements of an organizational combination has been defined as complementarity, where *'attributes are complementary if doing (more of) any one of them increases the returns to doing (more of) the others'* (ibidem,1995).

Although the concept of multidimensional fit is central and appealing in recent organization design research, the theoretical development and formal operationalization of this concept has remained unsatisfactory in both configurationism and complementarity-based views. The reasons why we believe these perspectives need to be developed are best illustrated in a recent study providing a comprehensive critical treatment on the topic (Grandori and Furnari, 2006: pp. 2-7). Thus, we refer to this study for an extended review of the problems encountered in configurationism and complementarity-based views, limiting to address those problems very briefly here below.

Theoretically, the primary concern with both configurationism and complementarity-based views is the underspecification of some general combinatory laws specifying what elements are expected to be complementary or "internally consistent" if combined together. The lack of a combinatory theory is manifested also in the rather post-hoc and empiricist approach of both these research streams: *"whatever elements are observed to be combined in practice with superior results are said to be complementary (or internally consistent); hence the explanatory law is inferred from the very pattern it should explain"* (Grandori and Furnari, 2006: 6).

A straightforward consequence of this limit has been the equivocal empirical evidence obtained in configurational and complementarity-based research. Indeed, while research cast doubt on the link between configuration membership and performance (Delery and Doty, 1996; Ferguson and Ketchen, 1999), the core finding of Milgrom and Roberts' study (1995) -the clustering of elements into the classical dichotomy "mass production" vs "modern manufacturing"- has been going through a consistent series of empirical falsifications, such as internal (Zenger and Hesterly, 1997; Foss, 2003) and external (Grandori, 1997; Child, 2002) hybrids, "swift" organization forms (Meyerson et al, 1996; Grandori and Soda, 2004) and a plethora of combinations of teamwork, incentives and knowledge management practices (Laursen and Manke, 2001; Cohendet et al., 2004).

Further, despite the neglect of multiple contingencies in contingency theory has been one of the main issues advanced by configurationists, the problem of how different sets of co-existing contingencies can influence organizational combinations has not been explicitly modelled neither in configurationism nor in complementarity research. Similarly, in both these perspectives there has been no attempt to model what distinctive combinations of elements can be employed to pursue different organizational functions or goals. These further theoretical losses are substantial, given

that some of the elements of the configuration can be found to be internally consistent or complementary just because they are coping with different, yet co-existing, contingencies or with the pursue of different goals simultaneously (Grandori and Soda, 2006; Grandori and Furnari, 2006).

Methodologically, while both complementarity-based view and configurationism stressed the importance of multiple interaction effects among a set of elements, both these approaches have largely relied on linear methods, which are not well suited to take into account many interaction effects simulatenously. For instance, interaction effects have been included into OLS models to study organizational configurations (Baker & Cullen, 1993; Dess et al., 1997; Miller, 1988). However, three-way interactions currently constitute the empirical limit of interpretable regression analysis (Ganzach, 1998), while theoretically there is no reason why an organizational combination should be limited to three elements only. Moreover, linear interaction effects assume that the estimated relationship is relevant for all cases under examination. Thus, they are in explicit contrast with the idea of equifinality. Similarly, the Milgrom and Roberts (1995)' test of supermodularity is based on bivariate comparisons of elements' pairs, thus it may not detect complementarities and substituitabilities due to the simultaneous presence and/or absence of more than two elements in the same combination (Grandori and Furnari, 2006).

Further, linear methods are not suited to detect easily asymmetry in multidimensional relationships among a set of variables². This, quite implicit, reliance on linearity perpetuates the symmetry assumption originally hidden in contingency theory, extending it to multidimensional relations. As a consequence, the internal organization elements of a configuration have been frequently clustered around two or more low-low vs high-high poles, interpreting deviations from the poles as misfits to be avoided (Baligh, Burton et al., 1996). This has contribued significantly to reinforce an archetypic view of organizational forms and design, as the Milgrom and Roberts' (1990) proposed dicotomy between "modern manufacturing" and "mass production" seems to confirm (Grandori and Furnari, 2006).

² The same holds for the super-modularity test based on the comparison of incremental increases of value.

Criteria for a "Good" Model of Multidimensional Fit

We have briefly examined the theoretical and methodological flaws of the current formalizations of multidimensional fit. Here below we use these flaws to define a check-list specifying five criteria to be met by a "good" model of multidimensional fit:

1. Combinatory Rules

What are the rules regulating the relationships of a set of organizational elements? What elements are more likely to be complementary or equifinal under a given set of contingencies and in order to pursue a set of goals? Any model of multidimensional fit is should be grounded on theory answering these questions.

2. Asymmetry

Asymmetrical combinations of elements (low-high, med-high, med-low) have been radically underestimated as potential cases of fit or misfit by current theories. Part of the reason of this underestimation has been the predominant use of linear methods in empirical studies. A "good" model of multidimensional fit should be able to detect asymmetry more reliably.

3. Multiple Interaction Effects among Organizational Elements

With the available variety of linear methods, we are not able to take into account reliably combined interaction effects among more than three elements (Ganzach, 1998). A "good" model of multidimensional fit should be able to uncover reliably multiple (more than three) simultaneous interaction effects among the elements of an organizational combination.

4. Multiple Contingencies

How multiple contingencies impact on complementarities and substitutabilities among elements of an organizational combination? A "good" model of multidimensional fit should show how interaction effects change across multiple combinations of contingencies.

5. Multifunctionality

What purposes are different combinations of organizational elements best suited to? A "good" model of multidimensional fit should uncover how the interaction effects among elements of a combination change across multiple combinations of functions.

Boolean Comparative Analysis: a New Methodology for Multidimensional Fit

In this section we'll argue that through Boolean Comparative Analysis it is possible to formalize a model of multidimensional fit to meet the criteria defined above. More specifically, we are going to show how, *given a set of theoretically grounded combinatory rules* (criterion no.1 above), Boolean Comparative Analysis is suited to handle asymmetry, multiple interaction effects, multiple contingencies and multifunctionality. In order to do that, we first introduce this new methodology, illustrating in a separate section a Boolean model of multidimensional fit with the use of an example.

Introducing Boolean Comparative Analysis

One of the most important advance in late 80's comparative sociology has been the use of Boolean algebra to formalize a systematic methodology for cross-case comparisons known as Boolean Comparative Analysis (BCA hereon) or Qualitative Comparative Analysis (Ragin, 1987).

In BCA hypotheses are conceptualized in terms of set relationships. Suppose we hypothesize that teamwork will foster firm innovation outcome. The causal condition is "adoption of teamwork" and the outcome to be explained is "innovation". The firms of our sample can be interpreted as members or not members of two sets: the "set of firms adopting teamwork" and the "set of firms with high innovation". Thus, we may state our hypothesis in terms of set relationship as *"the set of firms adopting teamwork will be a subset of the set of firms with high innovation"*. Labeling the former set "T" and the latter one "I", our hypothesis can be formally stated as:

$$T \subset I$$

The same hypothesis can be expressed through a Boolean logical statement such as:

$$T \text{ ---> } I$$

where, following Boolean algebra notation, ---> denotes the logical implication operator, capital letters indicate the presence of a causal condition or outcome in a given case (the case is member of the set), whereas lower-case letters indicate the absence of a causal condition or outcome in a given

case (the case is not a member of the set)³. Thus, the above statement could be also read as "the presence of T implies the presence of I".

Starting from this basic settlement, the typical objective of a Boolean analysis is to determine the simultaneous presence and absence causal conditions under which a certain outcome is present. In order to do that, cases are formalized as *combinations of elements* through the use of Boolean algebra operators "AND" ("*") and "OR" ("+"). For example, suppose we suspect the adoption of teamwork would not be sufficient *per se* to foster firm innovation outcome without an economic individual rewarding system (IR). This hypothesis could be formalized as following:

$$T * IR \rightarrow I$$

Where "*" denotes the logical boolean operator "AND". Thus, the above statements could be read as: the occurrence of outcome I requires the presence of both elements T and R. This means that organizational elements connected by AND are complementary between each other: they both are necessary to achieve an outcome. Let's now suppose that there are two other complementary elements that can also produce the outcome, say, K and FR, representing respectively knowledge management and firm-based reward systems. Then, the Boolean expression will be:

$$T * IR + K * FR \rightarrow I$$

where "+" denotes the logical operator "OR". The above statement could be read as: if *any* of the two combinations is present, the outcome will occur. This means that elements connected by "OR" can be interpreted as *substitutable* and *equifinal* combinations for a given outcome. Starting from these formalizations, BCA employs logical minimization algorithms and probabilistic tests in order to identify the necessary and sufficient combinations of elements to achieve given outcomes⁴.

The description of the above features make clear that BCA is well suited to address at least two of the five criteria defined above for a good model of multidimensional fit, namely asymmetry and multiple interaction effects. Indeed, BCA incorporates, by design, a concept of "chemical"

³ In standard Boolean analysis, the membership of cases into sets is coded as "1" (present) or "0" (absent). This requires data to be in binary form. A further advance of standard boolean logic is the introduction of fuzzy-set methods, where cases are coded on a 0 to 1 scale according to their degree of membership in a set (Ragin, 2000).

⁴ Boolean Logic Minimization algorithms and necessity/sufficiency tests are especially important when the number of elements to be combined is high. For an example of their use see (Grandori and Furnari, 2006).

causation, where the outcome is seen as the result of the conjuncture of multiple present/absent elements. Thus, the number of elements to interact can be multiple (more than three) and it would be easy to detect asymmetrical combinations of elements⁵.

A Boolean Algebra Model of Multidimensional Fit: an Example from Combinative Design

In this paragraph we introduce a Boolean Algebra model of multidimensional fit by the use of an example⁶ inspired by two recent empirical studies in the combinative design perspective (Grandori and Soda, 2006; Grandori and Furnari, 2006). The paragraph is structured as following. In the first section, we illustrate the setup of the example, defining the basic elements of the problem at stake. In the second section, we illustrate how BCA can help formalize the combination of organizational elements across multiple contingencies when the objective function to be performed is only one. In the third section, instead, we'll consider the case of organizational combinations performing multiple functions in presence of a single contingency. Finally, we'll examine how Boolean Algebra can help the analysis of interaction effects among organizational elements in presence of *both* multiple contingencies and multiple functions.

Example Setup

The starting point of the example is a set activities and resources which need to be coordinated due to interdependence and resource constraints of various origins (specificity, rarity, etc) on their use. Activities and resources can be defined at various levels of analysis, such as the production system of a firm, the value chain of an industry, the task structure of a work unit, the boundaries of a network of firms. Whatever level of analysis we chose, the problem at stake is the same: to compare the advantages and costs of different combinations of organizational elements across multiple contingencies and functions. One way to solve this problem is to hypothesize that the set of organizational elements is a portfolio of coordination mechanisms that can be classified in different "classes" as they have different properties in information processing and conflict resolution respects (Grandori, 1997; 2001). In the example we hypothesize that at least four general classes of elements

⁵ Due to the reliance on present/absent dummies of BCA, asymmetry in the "intensity of use" of elements in a combination is be easily detected. However, the development of fuzzy-methods should counterbalance this limit.

⁶ The exclusive objective of the example is to illustrate how BCA can be used to model multidimensional fit. For this reason, minor attention will be devoted to explaining why some organizational combinations are be considered more effective than others. For the theory behind that please see Grandori and Furnari (2006), Grandori and Soda (2006)

are available (market-like, bureaucratic, communitarian and democratic elements) and that those classes can be embodied in the practices reported in Table 1⁷:

Organizational Practices and Classes of Elements		
Boolean ID	Organizational Practices	Classes of Elements
PAYIND	Individual-based Pay for Performance	MARKET-LIKE
PAYFIRM	Firm-based Pay for Performance	
OUTSOURC	Outsourcing	
MOBIL	Internal Labor Market Mobility	
MONIT	Personnel Evaluation and Monitoring	BUROCRATIC
PROC	Process Organization	
RULES	Formal Rules and Procedures	
HIERAR	Hierarchal Coordination/Adhoc Decision Making	
KNOWLEDGE	Knowledge Management	COMMUNITARIAN
PROJ	Project Organization	
TEAM	Teamwork	
COM	Community Building	
DESIGN	Job Design	DEMOCRATIC
DECRIGHTS	Diffusion of Decision Rights	
PROPRIGHTS	Diffusion of Property Rights	
REPRIGHTS	Diffusion of Representation Rights	

Table 1 - Organizational Practices and Classes of Elements

These classes of elements are different in how they solve conflict and handle information processing under condition of efficiency; and their differences are known thanks to economic and organization design contributions (March and Simon, 1958; Thompson, 1967; Lawrence and Lorsch, 1967; Williamson, 1991; 1993; Herbst, 1976; March, 1996). Drawing on these known differences in the general properties of the elements, a set of combinatory rules regulating their effective combination can be hypothesized. We hypothesize the following basic combinatory rule to underly our example: *elements belong to the same class are quasi-substituable because they perform similar functions, elements belonging to different classes are complementary because they perform different functions* (Grandori and Furnari, 2006). Further, we assume that the system whose activities and resources need to be coordinated can pursue three different objective functions, or goals (Grandori and Furnari, 2005):

- 1) *Efficiency*, a proxy of cost minimizing;

⁷ The table is drawn from Grandori and Furnari (2006) empirical study.

- 2) *Innovation*, a proxy of value generation and discovering new activities/resources;
- 3) *Justice*, a proxy of the distribution of value with allocative efficiency and justice.

Finally, drawing on a slightly adapted version of Grandori and Soda' model (2006) we assume three relevant contingencies, which correspond to different types of uncertainty:

- 1) *C-Uncertainty* (or Contingency Uncertainty): uncertainty about which contingency will occur, but with known classes of contingencies and relations with best actions;
- 2) *A-Uncertainty* (or Action Uncertainty): uncertainty on the relevant actions to be performed in a given setting;
- 3) *E-Uncertainty* (or Epistemic Uncertainty): uncertainty on what the relevant actions and contingencies are.

We further assume that, whatever of these three contingencies (or combination of them) will occur, there exist some level of resource tension in the system to be coordinated.

Organizational Combinations and Mutiple Contingencies

With this setup in mind, we can start developing our example in Boolean terms, coding each element of our problem -whether organizational practices, contingencies or objective functions- in two states: present (=1) or absent (=0).

Let's start assuming the set of activities we need to coordinate is confronted with only one type of uncertainty, say, "contingency uncertainty". In a similar situation, the application of formal procedures, coupled with a moderate use of monetary incentives to cope with some level of resource constraints should be sufficient to yield efficiency. We can express this situation in the following boolean statement⁸:

$$(C-UNCERTAINTY) * (RULES) * (PAYIND + PAYFIRM) \text{ ----> } EFFICIENCY \quad (1)$$

Factoring the contingency factor in the above statement, we can see that at least *two equifinal combinations, each composed by two complementary organizational elements*, can be used to

⁸ We do not report the absence of elements in the boolean formulas we'll show along the example. However, we believe the formalization of boolean formulas as combination of absence and presence conditions is most valuable for design purposes, given its ability to make asymmetry evident at a eye glance.

achieve efficiency under contingency uncertainty: formal procedures coupled with individual economic incentives *or* formal procedures coupled with firm-based economic incentives. Moreover, this statement suggests the distinction between the "core" (or necessary) elements from the substitutable elements that should be added to the core for the combination to be sufficient to achieve the outcome. This reading would suggest the following: under condition of contingency uncertainty, procedures can be identified as a core (necessary) element of highly efficient combinations; however, this element *per se* is necessary but not sufficient to achieve high efficiency, if not combined with *either* individual-based *or* firm-based incentives, which can be thought as substitutable elements. In this perspective, substitutable elements should not be thought of as less important than core elements. Indeed, without at least *one* of them, the formula will not produce the outcome (that is, it will be not efficient). Substitutable elements have just more alternatives in a formula than necessary elements, but they are at least as important as necessary ones for determining the occurrence of the outcome. Moreover, from a design perspective substitutability delimits the area of potential trade-offs among elements, suggesting the designer to choose among substitutable elements on the basis of a comparison of their relative costs more than their (supposedly quasi-equal) advantages. Thus, substitutable elements can be powerful in crafting the "attention space" of organizational designers.

Suppose now that variations in environmental conditions occur and that the actions required to cope with them are not easily classifiable: the system should be now cope with both contingency *and* action uncertainty at a time. In a situation like this, it should be necessary to add new elements to the former organizational combination in order to achieve efficiency. Candidate elements can be, for instance, some level of hierarchical decision-making to define priorities in the use of resources and activities, together with the distribution of decision rights among the actors of the system in order to allow them to adjust independently through ad hoc communication and information exchange. This new organizational formula for efficiency can be expressed as following:

$$(C\text{-UNCERTAINTY} * A\text{-UNCERTAINTY}) * (RULES * HIERAR * DECRIGHTS) \\ [(PAYIND + PAYFIRM)] \rightarrow \text{EFFICIENCY} \quad (2)$$

Factoring the two contingency factors, we can easily identify the *two equifinal combinations*, each composed by *four complementary elements*, that can be used to achieve high efficiency under the simultaneous presence of *both* contingency and action uncertainty. Again, equifinalities and complementarities are best understood in terms of combinations of core/substitutable elements (or of

necessary/sufficient elements): the combination of formal procedures, hierarchical decision-making *and* the distribution of decision rights constitutes the "necessary core" of the highly efficient formulas, with economic incentives to serve as substitutable attributes.

If we further add epistemic uncertainty to the contingency factors, we would need to rethink the organizational formula to include some element enabling the discovery of what are the relevant actions and contingencies. Candidate elements can be: teamwork joint-decision making *or* some knowledge management mechanisms. As a consequence, the revised formula would look like:

$$\begin{aligned} & (C\text{-UNCERTAINTY} * A\text{-UNCERTAINTY} * E\text{-UNCERTAINTY}) * \\ & (RULES * HIERAR * DECRIGHTS) [(PAYIND + PAYFIRM) * (TEAM + KNOW)] \\ & \rightarrow \text{EFFICIENCY} \end{aligned} \tag{3}$$

The combination of procedures, hierarchical decision-making and distribution of decision rights is not sufficient *per se* to foster high efficiency in condition of extreme uncertainty. In order to do so, these elements should be combined with four other combinations of substitutable elements, which can be read as: *either individual pay for performance or firm-based pay for performance combined with either teamwork or knowledge management practices*. We may summarize the results of this example in the following table:

	Unicontingent Organizational Combinations	Bi-contingent Organizational Combinations	Multicontingency Organizational Combinations
	<i>(C-Uncertainty)</i>	<i>(C-Uncertainty and A-uncertainty)</i>	<i>(All three types of uncertainty)</i>
Complementarities <i>(assuming efficiency as as the only function)</i>	(RULES) * (One between PAYIND and PAYFIRM)	(RULES) * (HIERARCH)* (DECRIGHTS)* (One between PAYIND and PAYFIRM)	(RULES) * (HIERARCH)* (DECRIGHTS)* (One between PAYIND and PAYFIRM) * (One Between TEAM and KNOW)
Equifinalities <i>(assuming efficiency as as the only function)</i>	PAYIND + PAYFIRM	PAYIND + PAYFIRM	PAYIND + PAYFIRM TEAM + KNOW

Table 2 - Organizational Combinations and Multiple Contingencies

Organizational Combinations and Multifunctionality

Let's recall for a moment the Boolean statement no. 1, introduced in the previous paragraph:

$$(C\text{-UNCERTAINTY}) * (RULES) * (PAYIND + PAYFIRM) \text{ ----> } EFFICIENCY \quad (1)$$

What happens if the outcomes to be achieved are both efficiency *and* innovation? Although the system of activities in question is confronted only with "contingency uncertainty" -thus, it can be thought of as a quite routinized system- nevertheless we may want to foster some level of product or process innovation in the system, without losing efficiency along the way. To do so, we may need to infuse in the above organizational formula new types of elements, whose properties can facilitate the combination of competences, such as teamwork and knowledge management devices.

$$\begin{aligned} &(C\text{-UNCERTAINTY}) * \\ &(RULES) * [(PAYIND + PAYFIRM) * (TEAM + KNOW)] \\ &\text{----> } EFFICIENCY * INNOVATION \end{aligned} \quad (4)$$

Suppose now we would like our system to achieve not only efficiency and innovation, but also an acceptable level of allocative justice. In this case, a infusion of more democratic mechanisms is like to be necessary, such as an enlarged representance of stakeholders in firm governance:

$$\begin{aligned} &(C\text{-UNCERTAINTY}) * \\ &(RULES) * (REPR) [(PAYIND + PAYFIRM) * (TEAM + KNOW)] \\ &\text{----> } EFFICIENCY * INNOVATION * JUSTICE \end{aligned} \quad (5)$$

From the above statement, we may deduce that, even when a system is confronted with a single contingency, effective combinations may combine different types elements due to multifunctionality. We may summarize the results of the example in the following table:

	Unifunctional Organizational Combinations	Bifunctional Organizational Combinations	Multifunctional Organizational Combinations
	<i>(Efficiency)</i>	<i>(Efficiency and Innovation)</i>	<i>(Efficiency, Innovation and Justice)</i>
Complementarities <i>(assuming contingency uncertainty as the only contingency)</i>	(RULES) * (One between PAYIND and PAYFIRM)	(RULES) * (One between PAYIND and PAYFIRM) * (One between TEAM and KNOW)	(RULES)* (REPR)* (One between PAYIND and PAYFIRM) * (One Between TEAM and KNOW)
Equifinalities <i>(assuming contingency uncertainty as the only contingency)</i>	PAYIND + PAYFIRM	PAYIND + PAYFIRM TEAM + KNOW	PAYIND + PAYFIRM TEAM + KNOW

Table 3 - Organizational Combinations and Multifunctionality

Organizational Combinations across Multiple Contingencies and Functions

Let's suppose now we would like to discover what organizational combinations are best suited to pursue all the three functions (efficiency, innovation and justice) at once when all the three types of uncertainty are simultaneously in place. In this case, we can hypothesize the effective organizational formula will encompass the necessary elements included in both formulas 3 and 5. Thus, the resulting formula may look like:

$$\begin{aligned}
 & (C\text{-UNCERTAINTY} * A\text{-UNCERTAINTY} * E\text{-UNCERTAINTY}) * \\
 & (RULES * HIERAR * DECRIGHTS * REPR) [(PAYIND + PAYFIRM) * (TEAM + KNOW)] \\
 & \rightarrow \text{EFFICIENCY} * \text{INNOVATION} * \text{JUSTICE}
 \end{aligned}
 \tag{6}$$

This formula shows that highly multifunctional organizational combinations able to cope with multiple simultaneous contingencies at once could be characterized by a reinforced core of bureaucratic *and* democratic mechanisms, which should be completed by at least one element of market-like and communitarian mechanisms.

Implications for the Study of Complementarities and Substituabilities

The examples reported above show that BCA is well suited to take into account asymmetry, multiple interaction effects, multiple contingencies and multifunctionality. Thus, this methodology is promising for addressing the limitations encountered in available operationalizations of multidimensional fit, both in configurationism and complementarity view.

Finally, we would like to stress a final theoretical implication by arguing that the use of these methods can help to discriminate the distinctive sources of complementarities and substituabilities among the elements of an organizational combination. Both complementarity view and configurationism interpret the empirical co-occurrence of elements under performance as the neat evidence of endogenous value-reinforcing effects among the co-occurring elements. However, endogeneity can be *one* explanation which need to be tested against competing theoretical explanations. For example, the joint application of a set of practices can be due the multi-contingency, multi-task nature of the system under analysis, *"so that the payoff of combining mechanisms is partially due to the effectiveness of each single practice in solving different problems"* (Grandori and Furnari, 2006). Indeed, as the boolean formulas above show, even simple system of action can be characterized by a variety of heterogeneous coordination mechanisms under effectiveness (Grandori and Soda, 2006). The desired level of multifunctionality of a system can complicate the matters further, constituting another competing source of complementarities and equifinalities), well distinct from endogeneity. Nevertheless, quite surprisingly, there have been no systematic attempts to test these competing explanations against each other.

BCA provides a well established formal methodology to address this problem through the use of set theory. Indeed, the elements to be combined or substituted under multiple contingencies can be thought as a first set of elements. Presumably, portions of this first set will be shared by a second set of elements, representing organizational elements to be combined or substituted in order to achieve multiple goals at the same time. Endogeneity will be seriously challenged as theoretical argument to explain why the elements of these two sets combine or substitute within each set. Plausibly, in this case, multi-contingency and multifunctionality would be more robust sources of complementarity/substituability. This does not mean that the endogeneity explanation should be completely disregarded or that the endogeneity-effect can not interact with the other two hypothesized sources. On the contrary, when complementarity and substitutability among elements were systematically detected to confront the same *single* contingency or pursue the same *single* function, an endogenous interaction effect is more likely to be in place. In this context, BCA and set theory can further help in understanding how and to what extent the endogenous effects encountered

at the level of various contingencies/functions, separately considered, are persistent as an increasing number of contingencies/functions is added to the model. When unstable patterns of complementarity or equifinality across contingencies/functions will be detected. This can help to clarify further the relationship between interaction effects and conflicting or reinforcing contingencies/functions. In this way, the elements empirically found to combine or substitute among each other under effectiveness, could be described as elements of three different, yet interrelated, sets as in the picture showed below. The intersection of these sets will constitute the core of the multifunctional multicontingency highly performing organizational combinations.

Sources of Complementarities and Substituabilities

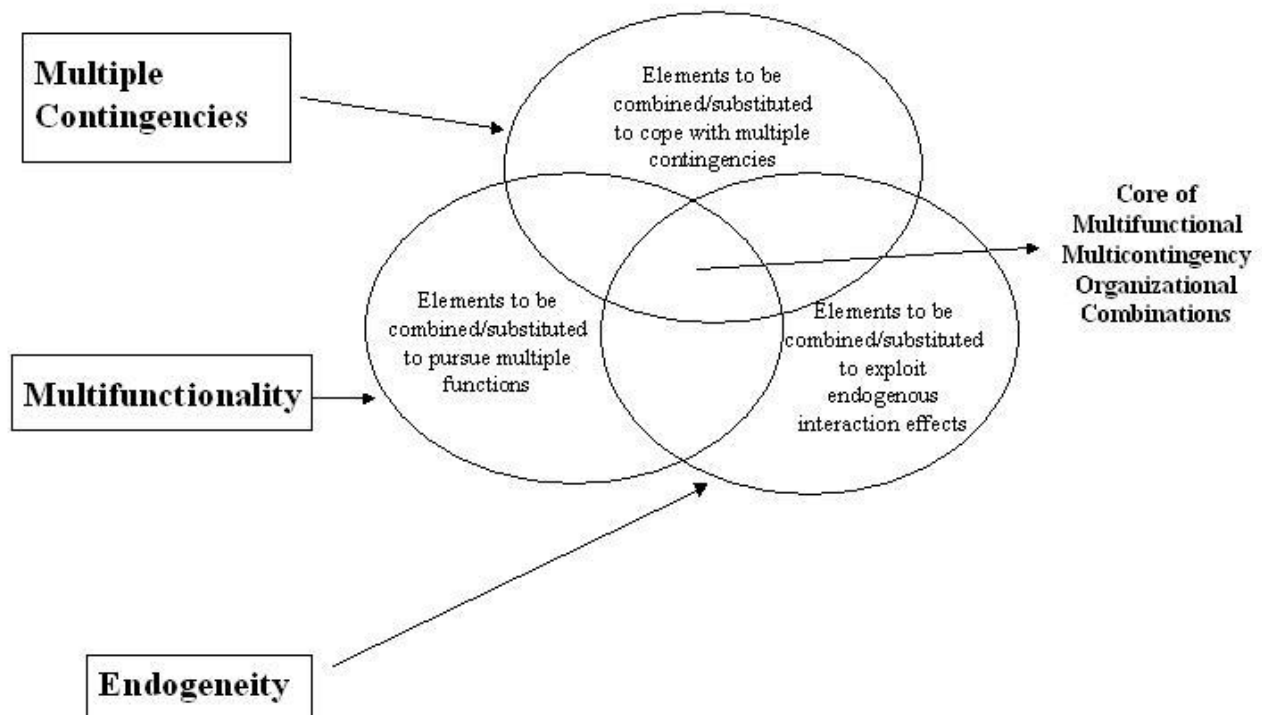


Figure 1 - Sources of Complementarities and Substituabilities

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