Confronting Theories Based on Necessary Relations: Making the Best of QCA Possibilities

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Abstract

Current standard practices put sufficiency at the core of Qualitative Comparative Analysis (QCA), while the analysis of necessity is limited to the test for necessary conditions. Here, we argue that the possibilities of QCA in the latter domain are much greater. In particular, it can be used to empirically confront theories centered on necessary relations and that involved various conditions. A new operation, labeled the "systematic necessity assessment," is therefore introduced. To show its added value, a published QCA study that confronts theories centered on necessary relations but using the regular minimization is replicated.

Introduction

More than 20 years ago, Most and Starr (1989), followed by Goertz and Starr (2003), called upon their peers to be more rigorous in the analysis of necessary conditions, all types of research design considered. They argued that despite the existence in political science of many theories based on necessary relations, researchers rarely use appropriate techniques to empirically test them. The reason for this gap, lies in the absence of an adequate tool-kit. With the exception of the quantitative models developed by Braumoeller and Goertz (2000) and by Clark, Gilligan, and Golder (2006), mainstream quantitative methods unravel symmetric causal relations that cannot grasp the particularity of necessary relations. Qualitative Comparative Analysis (QCA) in contrast, Goertz and Starr argued (2003, 13), could potentially overcome these shortcomings and complete the tool-kit in this respect, thanks to its set-theoretic logic.

For many years, however, QCA developers did not seem to have attached great importance to this possibility. As a matter of fact, the development of the method was mainly concerned with the other type of asymmetrical causal relation, namely sufficiency. Today, despite the recent rise of specific operations to evaluate the necessary character of individual conditions, the analysis of necessary relations is still falling behind. To fill this gap, this article proposes a new operation, labeled as the "systematic necessity assessment"[1] that fully exploits QCA's possibilities in this domain, and that produces useful answers to research questions addressing competing theories centered on necessary relations. In particular, it allows identifying how some of these conditions are combined, sometimes in unexpected ways, to form SUIN conditions (sufficient but unnecessary part of a configuration that is insufficient but necessary for the outcome). The article is structured in four parts, first, the current standard practices concerning necessity in QCA are described; second, in mirroring the minimization, the systematic necessity assessment is presented together with the central concepts of SUIN conditions; third, a stepwise procedure to perform this operation is described in a didactical way; and finally, a published QCA analysis is replicated to show its added value.

Necessity and QCA

Thanks to its set-theoretic feature, QCA is well-equipped for the analysis of necessary conditions. One of its strengths indeed resides in its ability to deal with causal complexity and more particularly with asymmetrical causality such as necessary relations. Formally speaking, necessity applies to conditions that are present in every case disclosing the outcome. Yet, and this is where the asymmetry appears, it does not say anything for the cases not disclosing it. Those cases are thus irrelevant for the necessary relation as the outcome may be present or absent without hindering the necessity feature of the conditions. Put in terms of set-theoretic logic, it amounts to saying that the outcome is a subset of the necessary condition (Ragin 2008, 13–28).

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Nevertheless, despite QCA's ability to deal with asymmetrical causal relations, necessity did not occupy a central position in Ragin's seminal work introducing csQCA (Ragin 1987). *The Comparative Method* indeed focused on the "minimization," which aims to "[reduce] the long description of the truth table, to the shortest possible expression—the minimal formula, which is the list of the prime implicants—that unveils the regularities in the data" (Rihoux and Lobe 2009, 225). Typically, the minimal formula is composed of various paths, which are often composed of several conditions joined by the logical AND, leading to the outcome. In this sense, those paths are sufficient conditions and take the substantive meaning of being the most relevant explanation of the outcome (Ragin 1987, 121–3). In this context, necessity was considered as a mere by-product of the minimization. The idea was that a single condition that is present in every path of the minimal formula can be considered as necessary for the outcome (Ragin 1987, 99–101). More recent works have shown that this property only holds in the absence of limited diversity and of inconsistent truth table rows (Schneider and Wagemann 2012, 217–21).

With *Fuzzy-Set Social Science* (2000), Ragin complemented the shortcomings of his initial method by introducing an indicator called "necessary consistency,"[2] which is valid for both csQCA and fsQCA. This measure gives the degree of necessity of a single condition—or a configuration of conditions—for the outcome. More specifically, the necessary consistency is the proportion of cases disclosing both the condition and the outcome among the cases disclosing the outcome, or in other words, the sum of the minimum values of a condition and an outcome across all the cases divided by the sum of the values of this outcome across all the cases (Ragin 2000, 203–29). Assuming Y is the outcome and X_i is the condition, it can be written as,

$$\text{Necessary consistency} = \sum (\min(X_i, Y))/\sum (Y)$$

The closer from 1 the measure it is, the more necessary consistent the condition. A necessary consistency of 0.98, for example, would mean that the necessary relations between the condition or the configuration of conditions is supported by the truth table.[3]

Ragin's book from 2000 introduced another measure, also valid for both csQCA and fsQCA, called "necessary coverage." This measure evaluates the empirical importance of already consistent necessary conditions or configurations of conditions. It refers to the proportion of cases disclosing both the condition and the outcome among cases disclosing the condition. In more formal terms, this means that the sum of the minimum values of a condition and an outcome across all the cases divided by the sum of the values of this condition across all the cases. Assuming Y is the outcome and X_i is the configuration of conditions, it can be written as,

$$\text{Coverage necessity} = \sum (\min(X_i, Y))/\sum (X_i)$$

According to this measure, a low necessary coverage of say 0.02 warns the researcher that the necessary relation may be trivial, or truistic. It would indeed mean that the condition is constant or close to being constant for the entire population, it is not relevant for explaining the outcome (Goertz 2006, 90–1). In contrast, a necessary condition with a high necessary coverage of say 0.98 is said to be relevant.[4]

In *Redesigning Social Inquiry* (2008), Ragin put together all these elements and presented a standard procedure of QCA in which necessary consistency and coverage serve as completing the results of the minimization. According to him, performing a so-called test for necessary condition, ahead of the minimization, is required to ensure that all the individual conditions that are proven to be necessary, and nontrivial, for the outcome are present in minimal formula. The existence of limited diversity may indeed incorrectly exclude them from the final results. In those situations, the researcher is advised to bring them back in by hand[5] (Ragin 2008, 171).

Recently, it has been said that necessary consistency and coverage, or similar measures, are useful tools to test the empirical validity of theories based on necessary relations per se, and not only as a complement of the minimization (Dul et al. 2010; Goertz 2006). However, according to current QCA standard practices, the researcher should only test the necessary character of individual conditions or pairs of conditions when she has strong reason to assume that they act as functionally equivalent necessary conditions (Schneider and Wagemann 2012, 141–4). The tool-kit is empty when she faces such theoretical expectation for every condition. This typically happens when multiple theories centered on necessary relations are willing to be confronted. In this context, the researcher may be willing to unveil configurations of conditions, and not just pairs of conditions, that form SUIN conditions. The next section sheds light on this concept and describes how they can be identified with the use of the systematic necessity assessment introduced in this article that somehow mirrors the minimization.

Mirroring the Minimization to Identify SUIN Conditions

As described above, the minimization produces the minimal formula—that is, the most simple configuration of sufficient conditions for the outcome. The term "most simple" is here used as a synonym of "most parsimonious," or in other words, with the fewest conditions involved. According to these lines, the minimal formula

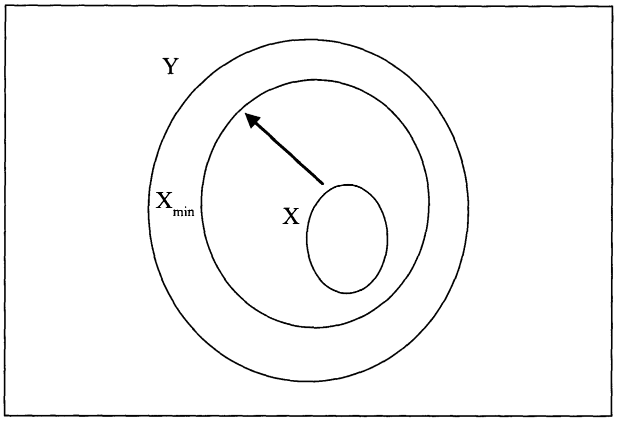

Figure 1. A sufficient set before (X) and after the minimization (X_{min}).

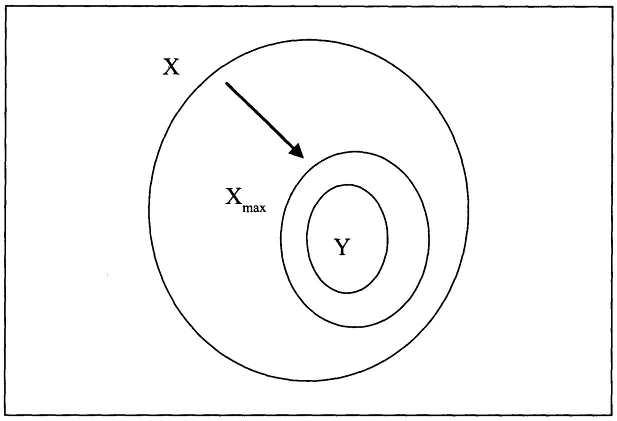

Figure 2. A necessary set before (X) and after the procedure consisting in systematizing the test for necessary conditions (X_{max}).

provides the most general explanation for the outcome in terms of sufficiency (Ragin 1987, 121–3).

The minimization is based on set-theoretic logic and Boolean algebra. It consists in deriving a "long Boolean formula" that entirely describes the truth table, and then to simplify it using the principles of formal logic. Roughly put, this amounts to excluding conditions that have different values in two cases that are exactly similar to each other concerning the outcome and the other conditions. The condition is then said to be irrelevant in the perspective of finding sufficient conditions for the outcome. When applied systematically, it produces the minimal formula[6] (Ragin 1987, 93). This operation can be expressed graphically using set theory. As sufficiency implies that the outcome is present in every case disclosing the conditions, the sufficient condition is a subset of the outcome. In this sense, the minimization corresponds to the enlargement of the set representing the initial long formula to another bigger set that is still inside the set outcome. If it goes beyond this set, it indeed loses its sufficient character (see Figure 1).

Presented this way, the principles of the minimization can be intuitively mirrored to the analysis of necessary relations. Necessary conditions are indeed supersets of the outcome (see above). An alternative operation can thus consist in the reduction of the initial set corresponding to a hypothetical long formula of necessary conditions to another smaller set that is still outside the set outcome (see Figure 2).

This operation is the "systematic necessity assessment." It produces a solution that consists in the most restrictive configuration of necessary conditions. In other words, they form the minimal requirements that a case must fulfill to disclose the outcome.[7] In particular, these requirements may be composed of several conditions joined by the logical OR, which are SUIN conditions, meaning "sufficient but unnecessary part of a configuration that is insufficient but necessary for the outcome." Just as INUS conditions (insufficient but non-redundant parts of a condition which is itself unnecessary but sufficient for the occurrence of the effect) that are typically produced by the minimization, SUIN conditions are central to characterize real-life complexity (Mahoney, Kimball, and Koivu 2009, 126). They correspond to conditions that are functionally equivalent and play the same role in the causal chain producing necessary conditions for the outcome. For example, the organization of elections for selecting public officials on one hand or the gathering of citizens' assemblies that are decisive on public affairs on the other are both SUIN conditions of democratic collective decision-making. In shedding light on how conditions can be combined to form, sometimes in unexpected ways, SUIN conditions, the new operation presented in this article gives a useful answer to the research question addressing competing theoretical explanations centered on necessary relations.

The remaining question is how to perform the systematic necessity assessment. Unlike the minimization that consists in simplifying the long formula, the goal here is to find the most restrictive necessary configuration of conditions. The principle of formal logic cannot be applied then. Therefore, the only possibility to perform this operation is to systematically apply the test of necessary conditions described above to every configuration of conditions. The next section is dedicated to a detailed description of the procedure to follow.

A Step-Wise Procedure

To perform the systematic necessity assessment, the necessary consistency and coverage of each configuration of conditions must be calculated. Depending on the number of conditions involved, this operation may be very fastidious. With two conditions ($X_{1,2}$), for instance, the two measures need to be calculated for eight configurations (see Table 1). This number increases dramatically with

Table 1. List of Configurations of Conditions with Two Conditions.

$X_1 + X_2$	$\sim X_1 + X_2$	$X_1 + \sim X_2$	$\sim X_1 + \sim X_2$
X_1	X_2	$\sim X_1$	$\sim X_2$

Table 2. Hypothetical Fuzzy Table.

Outcome	X_1	X_2	X_3
1	1	1	1
1	1	0.75	1
1	1	1	0.25
1	1	0.25	1
1	0.9	1	1
0	1	0.25	1
0	1	1	0.25
0	0.1	0	0

the number of conditions. Formally speaking, assuming a number of conditions k, the total number of configurations follows the equation.[8]

$$((3^k-1)/2) + 2^k$$

Fortunately, various QCA software packages can help in this task as they provide some sort of automated computation of necessary consistency and coverage—namely, the QCA package in R (Dusa and Thiem 2012), KirqST (Reichert and Rubinson 2012), and to some extent FS/QCA (Ragin and Davey 2012).[9] The present stepwise procedure describes, in a way we hope to be didactical, how to proceed with these calculations. Assuming three conditions, X_1, X_2, and X_3, for which the presence is theoretically linked to the presence of the outcome, and the hypothetical fuzzy table presented in Table 2, the steps are the following:

1. The necessary consistency of the least restrictive set needs to be calculated. This pretest establishes whether at least one configuration of conditions that is necessary for the outcome is present. Because any necessary condition is also a superset of the outcome (see above), if the least restrictive set is not necessary, no other set would ever be necessary. This set is the configuration of all the conditions joined by the logical OR. In our example, this would be $X_1 + X_2 + X_3$. According to the truth table presented above, its necessary consistency is of 1. It is thus worth continuing with other steps.
2. The second step consists in calculating the necessary consistency of each individual condition—that is, X_1, X_2, and X_3—separately. In our example the necessary consistency is a high for X_1 (0.98) and low for the other conditions (0.8 and 0.85, respectively).
3. The third step consists in calculating the necessary consistency of pairs of conditions, joined by the logical OR, at the exception of those that include an individual condition that was shown to be necessary at the preceding step. In our example, these are $X_2 + X_3$, which shows a necessary consistency of 1. It is worth noting that there is no need to join another condition to already consistent necessary condition such as X_1 as it would simply enlarge a set, which is already large enough to be a subset of the outcome.
4. The necessary consistent individual condition and configurations of conditions—that is, X_1 and $X_2 + X_3$—form the most restrictive necessary configurations of conditions. As mentioned above, they could be interpreted as the various criteria any case should fulfill to disclose the outcome. They thus give a useful answer for researches confronting multiple theories centered on necessary relations, as they identify both the conditions that are individually necessary for the outcome, and those that are SUIN conditions. It should be noted that if there were more than three conditions, the procedure should be continued in joining a third condition to the configurations of two conditions that were not shown to be necessary at the preceding step, and so on.
5. However, the necessary coverage of these criteria needs to be calculated to make sure none of them is trivial. There is no need to calculate the necessary coverage for other configurations, as the measure only makes sense for necessary consistent configurations. In our example, the necessary coverage is of 0.7 for X_1 and of 0.71 for $X_2 + X_3$, which indicates that they are both relevant.

To show the added value of the systematic necessity assessment as a strategy for confronting multiple theories centered on necessary relations in QCA, the next section replicates a published study that originally used regular QCA's practices to achieve this goal and compare its results with those obtained through this operation.

Table 3. Bochsler's Parsimonous Minimal Formula.

Paths	Raw coverage	Unique coverage
Special	0.54	0.34
Legal × Average	0.6	0.17
Concentration × Legal × National	0.43	0.03
Concentration × No ban × Majoritarian	0.06	0.03
Solution coverage		1
Solution consistency		0.74

Frequency threshold = 1; consistency threshold = 0.33

Table 4. The Results Obtained through the Systematization of the Test of Necessary Conditions.

Sets	Necessary consistency	Necessary coverage
No ban	1	0.3
Concentration + legal	0.94	0.38
Concentration + average	0.97	0.37
Concentration + national	1	0.35

Frequency threshold: 1; Consistency threshold = 0.94 (=33 up to the 35 cases that show the presence of the outcome); only the configurations of conditions that pass the consistency threshold are disclosed.

Replicating a Published QCA Application

In a recently published study, csQCA has been used to examine the success of ethnic minority parties in postcommunist countries (Bochsler 2011). It was hypothesized that four institutional barriers could prevent the partisan representation of ethnic minorities in national postcommunist parliaments: (a) the presence of critical mass of voters to pass several thresholds: legal, effective (being at the national or at the district level), and natural resulting from the existence of a majoritarian formula, (b) the degree of geographical concentration of ethnic minorities, (c) the absence of a legal ban of the parties defending minorities' interests, and (d) the absence of reserved seats in parliament for those minorities (Bochsler 2011, 217). Necessary relations between these four conditions and the outcome were thus expected such as "not being banned" or "being concentrated and having enough voters to pass the national effective threshold" are necessary conditions for the election of parties defending ethnic minorities (Bochsler 2011, 228–9). One can say that the goal was therefore to confront multiple theories centered on necessary relations.

To do so, the author used a regular minimization with a very low consistency threshold—that is, 0.33—arguing that "contradicting configurations can be treated jointly with the configurations with positive outcomes [as even if] the necessary conditions for the success of an ethnic minority party are fulfilled, . . . this does not always mean that such a party will be created" (Bochsler 2011, 230). Although correct, this strategy is suboptimal. As pointed above, the minimization is indeed made for unveiling the most relevant configuration of sufficient conditions for the outcome.

Table 3 reports the obtained parsimonious minimal formula. It shows the existence of four paths leading to the election of parties defending ethnic minorities' interests. Each of them consists of a configuration of one to three conditions. The author interprets the results in stating that "the hypothesized effect of [the condition] concentration is particularly relevant for the explanation of the outcomes" (Bochsler 2011, 232–3). According to the author, this should be combined with a critical mass of potential voters to pass some sort of thresholds of representation. However, when looking at the parsimonious minimal formula, it appears that many other conditions intervene, sometimes in a way contradicting the author's theoretical expectations.

The results obtained through the application of the systematic necessity assessment to the same data,[10] and reported in Table 4, are rather different. They show four requirements any case should fulfill to disclose the outcome. First, the individual condition of not being banned from the electoral competition is necessary for a party representing ethnic minorities to be elected. With a necessary coverage of 0.3, this condition is not of great empirical relevance though. It indeed only concerns 8 minority parties, in Bulgaria and Albania, out of 123 in total. Second, another necessary condition is formed by the union of the geographical concentration of the ethnic minorities and the presence of a critical mass of voters to pass the legal threshold. One of these two conditions must be present for a case to disclose the outcome. In other words, they constitute SUIN conditions. Third, similar aggregated necessary conditions are formed by the union of the geographical concentration of the ethnic minority and the presence of a critical mass of voters to pass the effective threshold at the national level, or, and that forms a fourth requirement, at the district level. The last three necessary conditions also disclose a rather low necessary coverage, ranging from 0.35 to 0.40, which in turn result from the lack of variation of the different conditions involved.

Interestingly, the results obtained through the systematic necessity assessment reflect more clearly the conclusion of the theoretical arguments made by the author of the original article. In particular, the role played by the geographical concentration of the ethnic minority that acts as a functional equivalent to the presence of a critical mass of voters to pass all kind of legal and effective thresholds that was emphasized in the original article (Bochsler 2011, 233) is clearly highlighted in Table 4.

Conclusion

Despite recent advancements in the analysis of necessary conditions in QCA, no operation has so far been developed to properly confront multiple theories based on necessary relations. The article aimed to fill this gap in presenting a new operation labeled as the "systematic necessity assessment," which offers the possibility to identify how conditions can be combined, sometimes in unexpected ways, to form SUIN conditions that constitute useful answers for researchers addressing this type of research question.

We believe the systematic necessity assessment could be valuable in other contexts. For example, it would make sense to use in combination with the regular minimization to somehow tackle the problem of limited diversity inherent to QCA. The systematic necessity assessment could serve to reduce the number of potential logical remainders to be included in the minimization, as suggested in the "enhanced standard analysis" (Schneider and Wagemann 2012, 191–209). Alternatively, according to us, this new operation could also be used to analyze data sets that contain two groups of conditions: one that is expected to be necessary for the outcome, and the other that is expected to be sufficient. In those situations, a systematic necessity analysis could be operated with the first group, while a minimization could be operated with the second, and the two results interpreted jointly. Given these diverse potential applications, the new operation presented in this article offers great potential for the development/advancement of QCA as a tool for social inquiry. It goes without saying though that it has to be tested in different studies to confirm its practical relevance.

Notes

1. The systematic necessity assessment presented in this article holds for both crisp-set QCA (csQCA) and fuzzy-set QCA (fsQCA). It is however not directly applicable to multivalue QCA (mvQCA) as this last subtechnique is not fully based on set-theoretic logic (Vink and Van Vliet 2009).
2. In his book, Ragin (2000) talked about "consistency" referring to both sufficiency and necessary consistencies. In the present article, we separate the two for the sake of clarity. The same remark applies to sufficiency and necessary coverages (see below).
3. Stating a benchmark value for necessary consistency and coverage (see below), which would always be recommended, is hazardous as many different factors such as the number of cases or the quality of the calibration should be considered (Ragin 2008, 53–4).
4. It is worth mentioning that Ragin's indicator does not capture the trivialness of necessary conditions in all situations. This issue falls beyond the scope of this article though. (For a further discussion, see Schneider and Wagemann 2012, 144–6.)
5. This idea already appeared in former contributions of the same author (Ragin 2000, 105); a strong case for the ex ante test for necessary conditions was only made in his 2008 book.
6. According to QCA current practices, the minimization sometimes demands to make assumptions on logical remainders. Depending on the number and on the type of logical remainders included, different minimal formulas are obtained (see Schneider and Wagemann 2012). Although similar concerns are also applicable to the new operation presented here, this falls beyond the scope of the present article. We therefore assume that either limited diversity is inexistent or that assumptions are made on all possible logical remainders. In this sense, the results obtained through this new operation correspond to the parsimonious minimal formula.
7. Unlike the operation proposed by Rohlfing and Schneider [this issue] that allows to achieve a similar goal, the systematic necessity assessment does not assume more case knowledge than a regular QCA.
8. When the conditions are carefully selected, it is pointless to compute the necessary consistency of the configurations of conditions that are joined with the logical AND, because it will just have the effect of lowering down this value.
9. For didactical purposes, a ready-to-run Excel sheet to perform this stepwise procedure is downloadable from the corresponding author's website (www.damienbol.eu). When the user fills the columns of the fuzzy table, the necessary consistency and coverage of all the configurations of up to three conditions are automatically computed.
10. It should be noted that compared with the original analysis, the condition accounting for the presence of reserved seats in parliament for parties representing ethnic minorities' interests has been excluded. Unlike other conditions, it obviously supposes a relationship of sufficiency with the outcome and is therefore not appropriate for this operation.