Advance Access publication September 25, 2016

Political Analysis (2016) 24:478–484
doi:10.1093/pan/mpw024

Standards of Good Practice and the Methodology of Necessary Conditions in Qualitative Comparative Analysis

Alrik Thiem

Department of Philosophy, University of Geneva, Rue de Candolle 2/Bât. Landolt, 1211 Geneva, Switzerland

Edited by R. Michael Alvarez

The analysis of necessary conditions for some outcome of interest has long been one of the main preoccupations of scholars in all disciplines of the social sciences. In this connection, the introduction of Qualitative Comparative Analysis (QCA) in the late 1980s has revolutionized the way research on necessary conditions has been carried out. Standards of good practice for QCA have long demanded that the results of preceding tests for necessity constrain QCA's core process of Boolean minimization so as to enhance the quality of parsimonious and intermediate solutions. Schneider and Wagemann's Theory-Guided/Enhanced Standard Analysis (T/ESA) is currently being adopted by applied researchers as the new state-of-the-art procedure in this respect. In drawing on Schneider and Wagemann's own illustrative data example and a meta-analysis of thirty-six truth tables across twenty-one published studies that have adhered to current standards of good practice in QCA, I demonstrate that, once bias against compound conditions in necessity tests is accounted for, T/ESA will produce conservative solutions, and not enhanced parsimonious or intermediate ones.

1 Introduction

Tests for the necessity of conditions with respect to some outcome of interest have long been one of the main preoccupations of researchers across all disciplines of the social sciences, from economics over political science to sociology (Braumoeller and Goertz 2000; Goertz 2003; Goertz and Mahoney 2012, 12). For example, economic historians have been convinced that "one necessary condition for the creation of modern economies dependent on specialization and division of labor ... is the ability to engage in secure contracting across time and space" (North and Weingast 1989, 831); political scientists have surmised that "[t]he coherence in authority relations of a polity is a *necessary* condition for the lengthy persistence of that polity" (Lichbach 1981, 54), and sociologists have argued that "the establishment of juvenile reformatories was a necessary precondition for changes in the legal status of children" during the development phase of state juvenile codes in the United States (Sutton 1983, 529). Necessary conditions are so central to the work of social scientists that entire books have been devoted to this subject (e.g., Goertz and Starr 2003).

The significance of research on necessary conditions has received a further, major boost with the introduction of Qualitative Comparative Analysis (QCA) in the late 1980s (Ragin 1987). While scientists had previously been restricted to bifactorial designs (e.g., Lichbach 1981), QCA suddenly made it possible to bring a formal method with a sophisticated mathematical machinery imported from electrical engineering (McCluskey 1965) and analytical philosophy (Quine 1952) to bear on high-dimensional social data. The words of Alexander Hicks (1994, 99) mirror the enthusiasm at that time: "As a logical method, the Millian approach ... is too undeveloped for truly multivariate analyses.... The Boolean procedures of QCA break the Millian logjam." Even those who were to later position themselves among the staunchest critics of QCA admitted that at the time they had been "[f]ired up by Ragin's use of the Boolean approach" (Lieberson 2004, 14). Since then, QCA

Author's note: Replication data are available on the Harvard Dataverse at http://dx.doi.org/10.7910/DVN/BCQM3Y. Supplementary materials for this article are available on the *Political Analysis* Web site.

has become a family of four related variants, the number of published applications is now about twenty times as large as during the 1990s, and numerous top journals of the social sciences have published applied QCA articles (Thiem and Duşa 2013a, 2013b; Thiem 2014b).[1]

The authors of applied articles have often followed *standards of good practice* on the use of QCA (Ragin 2000; Rihoux and Ragin 2009; Schneider and Wagemann 2010), the purpose of which is to define "how to perform QCA not only in a technically correct manner, but also in a plausible and complete way" so as to "help authors, readers, and reviewers to become aware of how a given study deviates from an ideal application" (Schneider and Wagemann 2012, 275). Generally, following guidelines is helpful as it ensures a productive division of labor between those with interests in applied issues and those who occupy themselves with technical questions of causal inference.

An important one of these standards of good practice demands that the results of tests for the necessity of conditions with respect to the outcome being analyzed constrain the subsequent process of Boolean minimization so as to enhance the quality of the solution. Based on earlier work by Ragin (2000, 2009), Schneider and Wagemann's (2012, 197–219, 2013) Theory-Guided/Enhanced Standard Analysis (T/ESA) is currently being adopted by applied researchers as the new state-of-the-art procedure (e.g., Thomann 2015; Beyens, Lucardie, and Deschouwer 2016). However, I show in this article that T/ESA and its methodological predecessors defeat their own purpose of seeking enhanced parsimonious and intermediate solutions once bias in necessity tests is accounted for.[2]

The structure of my argument is as follows. In Section 1, I outline how the concept of necessity is currently understood in QCA and reveal this conception to be erroneous. In Section 2, I introduce the first two stages of T/ESA and demonstrate why its rationale collapses when the necessity analysis conducted prior to Boolean minimization is unbiased.[3] Sections 3 and 4 show this effect to be omnipresent in applied research by means of a meta-analysis of thirty-six truth tables across twenty-one published QCA studies that have adhered to current QCA standards of good practice on necessity tests formulated in Ragin (2000) and Schneider and Wagemann (2010, 2012).

2 Current QCA Practice in Analyzing Necessity Relations

Recall the three examples of research on necessary condition from economics, political science, and sociology in the introduction of this article. Perhaps, it was already conspicuous that all involved a causally interpreted relation between the outcome and *one* simple condition. This commonality is no result of happenstance. Necessary conditions in virtually all social-scientific research consist of atomic conditions to which causal relevance is ascribed. Neither the possibility of compound conditions nor the dissociation of the concept of necessity from that of causality is part of the current thinking on the concept of necessity.

With specific regards to the literature on QCA and related configurational methods, Schneider and Wagemann (2012), for instance, committed a logical contradiction because they could not imagine a disjunction of two atomic conditions to be a necessary condition without its disjuncts being unifiable by some *single*, higher-order concept. They wrote in relation to an empirical example in their textbook's section on necessary conditions that although "condition $\sim A + C \ldots$ passes the criterion for being a necessary condition for Y," because *Y* is demonstrably sufficient for $\sim A + C$, they "advise against interpreting $\sim A + C$ as a necessary condition" because they could not conceive any higher-order concept unifying $\sim A$ and C into "functional equivalents" (74).[4] Wagemann and Schneider (2015, 41) then tried to solve this propositional dissonance by explicitly arguing that analyses of necessity should be "performed on the basis of *isolated* [i.e., atomic] conditions and their complements" (emphasis added).

[1] See http://www.compasss.org/bibdata.htm for a bibliography of QCA publications.

[2] Another argument against T/ESA has recently been presented by Cooper and Glaesser (2016). My argument follows a different line of reasoning.

[3] I do not imply by doing so that such necessity analyses are purposeful in the context of causal inference with QCA (cf. Thiem and Baumgartner 2016), but a fundamental argument against preceding tests for necessary conditions need not be made for proving T/ESA ill conceived.

[4] To remain consistent with respect to syntax, I continue using "+" to denote the logical OR and "~" to denote the logical NOT. As is customary, the logical AND operator will be dropped if there is no risk of confusion.

That the property of causal relevance is directly ascribed to necessary conditions was most clearly demonstrated by Mahoney, Kimball, and Koivu (2009, 118), who argued that "[w]ith a set-theoretic approach, a necessary cause can be defined as: X_1 is a necessary cause of Y_1 if Y_1 is a subset of X_1." However, the formal definition of the Boolean operation of implication underlying every relation of necessity, $P \leftarrow Q \equiv P + \sim Q \equiv \sim[\sim PQ]$, neither entails anything about the structure of P, nor that some higher-order concept needs to be identified by the researcher that causally connects all disjuncts $p_1, p_2, \ldots, p_j$ of P to Q, nor that P's status as a superset of Q renders P a cause of Q (cf. Thiem and Baumgartner 2016; Thiem, Baumgartner, and Bol 2016).

For example, in every QCA solution that exhibits perfect consistency and coverage, the disjunction of minimally sufficient conditions for the outcome is also minimally *necessary* for that outcome, without a unifying higher-order concept being required. It is also the case that all effects are necessary for their causes, which may sound implausible to QCA researchers because of their misconception of necessary conditions as being isolated causes of given effects. Moreover, the Boolean Law of Monotonicity says that if some phenomenon P is necessary for some other phenomenon Q, where P is anything (P could, for instance, be an atomic condition, an effect, a disjunction of atomic conditions that is minimally necessary for Q, or a minimally necessary disjunction of minimally sufficient conditions of Q), then $P + \Psi$, where Ψ is anything other than P, will also always be necessary for Q (cf. Baumgartner 2008). Put differently, *necessity* is no relational property of an object that is conferred onto it by the causal interpretation of a researcher, but only by the algebraic laws that define the operation of necessity in conjunction with the data in hand. With these mere facts now put into place, the next section shows why the correction of the bias against compound conditions in tests for necessity relations prior to Boolean minimization makes T/ESA and its methodological predecessors fall apart.

3 The CONSOL Effect

The problematic part of T/ESA to be addressed consists of the procedure's first two stages. In the first stage, necessary conditions of the outcome are identified; in the second, these results are used in barring what Schneider and Wagemann (2013) called "incoherent counterfactuals of type 1"—remainders that are incompatible with the results of the first stage—from being used by the Quine–McCluskey algorithm (QMC) as simplifying assumptions.[5] According to its inventors, T/ESA, therefore, ensures that "necessary conditions do not disappear from solution terms of sufficiency due to assumptions made on logical remainders" (Schneider and Wagemann 2012, 209).

For illustrating T/ESA, Schneider and Wagemann (2013, 213) construct the truth table shown in Table 1, based on fuzzy set data initially presented in Ragin (2009, 95) on the survival of democracy in interwar European countries.

The endogenous factor measures whether democracy survived during the interwar period in the country (S). The exogenous factors include a measure of whether the country was economically developed (D), whether it was urbanized (U), whether it had a high literacy rate (L), whether it was industrialized (I), and whether it was politically stable (G). For these data, Schneider and Wagemann (2013, 212) identify and present L and G as the only two necessary conditions of S. The parsimonious solution, which the authors then report, comprises exactly one model, namely m_1 in expression (1):

$$m_1: D{\sim}I + UG \rightarrow S. \tag{1}$$

As usual, a question mark in the column "Output" in Table 1 signifies a remainder; a tick mark in the column "SA" means that this remainder has been used as a simplifying assumption in the derivation of m_1; and a tick mark in the column "IC_1" indicates that this remainder has been identified by Schneider and Wagemann (2013, 212–3) as an incoherent counterfactual of type 1. T/ESA would

[5] QMC is widely taken to be the very heart of QCA (Ragin 2008, 135; Rihoux and De Meur 2009, 33; Schneider and Wagemann 2012, 104–15).

Table 1 Extended truth table based on Table 1 in Schneider and Wagemann (2013, 213)

Row	*D*	*U*	*L*	*I*	*G*	Output	SA	IC_1	ID	Cases
1	1	1	1	1	1	1				BE, CZ, NL, UK
2	1	0	1	0	1	1				FI, IE
3	1	0	1	1	1	0				FR, SE
4	0	0	1	0	1	0				EE
5	0	0	1	0	0	0				HU, PL
6	1	1	1	1	0	0				DE
7	1	0	1	1	0	0				AT
8	0	0	0	0	1	0				IT, RO
9	0	0	0	0	0	0				GR, PT, ES
10	0	0	0	1	0	?		✓	1,4	
11	0	0	0	1	1	?		✓	1,3,4	
12	0	0	1	1	0	?		✓	1,4,8	
13	0	0	1	1	1	?			3,4,8	
14	0	1	0	0	0	?		✓	1,2,5	
15	0	1	0	0	1	?	✓	✓	1,2,3,5	
16	0	1	0	1	0	?		✓	1,4,5	
17	0	1	0	1	1	?	✓	✓	1,3,4,5	
18	0	1	1	0	0	?		✓	1,2,5,6	
19	0	1	1	0	1	?	✓		2,3,5,6	
20	0	1	1	1	0	?		✓	1,4,5	
21	0	1	1	1	1	?	✓		3,4,5	
22	1	0	0	0	0	?	✓	✓	1	
23	1	0	0	0	1	?	✓	✓	1	
24	1	0	0	1	0	?		✓	1	
25	1	0	0	1	1	?		✓	1	
26	1	0	1	0	0	?	✓	✓	1	
27	1	1	0	0	0	?	✓	✓	1,2	
28	1	1	0	0	1	?	✓	✓	1,2	
29	1	1	0	1	0	?		✓	1	
30	1	1	0	1	1	?	✓	✓	1	
31	1	1	1	0	0	?	✓	✓	1,2	
32	1	1	1	0	1	?	✓		2	

thus induce QMC to generate model m_2 in expression (2) after its first two stages since any remainder featuring either $\sim L$ or $\sim G$ is made unavailable to the algorithm's minimization machinery:

$$m_2: DL \sim IG + ULG \rightarrow S. \quad (2)$$

Let us see what happens once the arbitrary restriction on the complexity of necessary conditions is lifted and the bias against any conditions other than atomic ones corrected. Table 2 lists all eight minimally necessary conditions that result from an unbiased search.[6] As Schneider and Wagemann (2012, 143) proposed an inclusion cutoff of 0.9, this value is also applied here; coverage scores are provided for completeness but are no formal criterion in ascribing the status of necessity to a condition with respect to *S* according to its Boolean definition. The column "Negation" in Table 2 presents the respective logical negation of the identified condition, and the ID of this negated condition is listed in the last column of Table 2 and the column "ID" in Table 1.

It is notable that each remainder row in Table 1 has at least one ID entry, which means that no remainder is eligible for being included by QMC into the process of minimization because this would be irreconcilable with at least one statement of necessity according to T/ESA. Thus, T/ESA

[6]This and all following analyses have been carried out with the *QCApro* package (Thiem 2016a).

Table 2 Exhaustive list of minimally necessary conditions for Table 1

Condition	*Inclusion*	*Coverage*	*Negation*	*ID*
LG	0.915	0.793	$\sim L + \sim G$	1
$I + \sim U$	0.989	0.511	$\sim IU$	2
$D + \sim G$	0.912	0.579	$\sim DG$	3
$D + \sim I$	0.964	0.518	$\sim DI$	4
$D + \sim U$	0.964	0.506	$\sim DU$	5
$D + \sim L + I$	0.919	0.569	$\sim DL \sim I$	6
$D + U + I$	0.903	0.716	$\sim D \sim U \sim I$	7
$D + U + \sim L$	0.924	0.570	$\sim D \sim UL$	8

would force QMC to output model m_3 in expression (3) in its second stage:

$$m_3: D \sim UL \sim IG + DULIG \rightarrow S. \quad (3)$$

Yet, by inspecting rows 1 and 2 of Table 1, it is easy to see that m_3 corresponds to the conservative solution, without any minimization whatsoever having taken place. Instead of enhancing parsimonious and intermediate solutions, an implementation of T/ESA on the basis of an unbiased necessity analysis seems to leave but one choice for QMC, namely to generate the conservative solution. Put differently, T/ESA appears to defeat its own purpose, a phenomenon I refer to as the "CONSOL Effect" because, following an objective necessity analysis, T/ESA will force QMC to output *con*servative *sol*utions instead of enhanced parsimonious and intermediate ones.

4 The Prevalence of the CONSOL Effect in Applied Research: A Meta-Analysis

The above example represented a single data experiment. This section now investigates how widespread the CONSOL Effect is in applied research. To this end, I have collected twenty-one data sets from published QCA articles that have conducted a necessity analysis prior to Boolean minimization as demanded by current standards of good practice.[7] The complete list of studies and all detailed results of this meta-analysis are available in the Supplementary Materials.

At their original inclusion cutoffs, ten studies present some necessary conditions, whereas eleven report to have not found any. With the exception of one study, which identified four conditions, the maximum number reported was two. Almost all studies use an inclusion cutoff for the analysis of necessity that was different from that used for the analysis of sufficiency during the stage of minimization, and some do not even report their cutoffs. I, therefore, harmonized inclusion cutoffs to the common value of 0.75, which Ragin (2008, 46), as well as Schneider and Wagemann (2012, 129), suggest for the analysis of sufficiency relations. Because of the simple fact that every statement of necessity can be turned into a logically equivalent statement of sufficiency and vice versa, this modification is permissible according to existing standards of good practice.[8] For twenty-three outcomes, this change increased the number of necessary conditions; for ten outcomes, it had a decreasing effect; and for three outcomes, it was inconsequential. I then reran QCA for each outcome, recorded the simplifying assumptions of each model of the corresponding solution, and tested whether the CONSOL Effect bit.[9]

The results allow only one conclusion: the CONSOL Effect is omnipresent. Apart from one solution for one of whose models no simplifying assumptions existed in the first place, one

[7] All data sets have been obtained from http://www.compasss.org/bibdata.htm (accessed April 26, 2016).

[8] Due to the symmetry of sufficiency and necessity, the inclusion cutoff for an analysis of necessity need not be different from that used for an analysis of sufficiency as suggested by Schneider and Wagemann (2012, 129, 143).

[9] The function *testTESA* in the *QCApro* package returns the share of simplifying assumptions that would have been used by QMC but have been barred by T/ESA (the minimization process itself is performed by the *e*QMC algorithm) (Thiem 2015; Duşa and Thiem 2015).

saturated truth table, and two outcomes for which no reanalysis was possible due to extreme model ambiguities, the meta-analysis reveals that for twenty-nine out of thirty-two outcomes, T/ESA forced QMC to bar all remainders that would have served as simplifying assumptions from being included in the minimization.[10] That alone, however, does not mean that the CONSOL Effect is absent in the case of the remaining three outcomes. In point of fact, for two outcomes, eight models out of eleven are beset; for one outcome, eight of ten models are affected; and for all eight models that are not affected, more than 92% of all remainders that would have been converted to simplifying assumptions were made inaccessible to QMC.

5 Conclusions

The analysis of necessary conditions has long been one of the main preoccupations of researchers across all disciplines of the social sciences. The introduction of QCA in the late 1980s has provided a major boost to this existing interest. When applied researchers have employed QCA, they have often relied on instructive guidelines assembled and enshrined by some methodologists in standards of good practice.

An important standard has been the identification of necessary conditions prior to Boolean minimization in order to constrain the use of simplifying assumptions by QMC. Schneider and Wagemann's T/ESA is currently being adopted as the new state of the art in this respect. I have shown in this article that when bias against compound conditions in tests of necessity relations is corrected, T/ESA and its methodological predecessors produce conservative solutions instead of enhanced parsimonious or intermediate ones. A meta-analysis of thirty-six truth tables across twenty-one published QCA articles that adhered to current standards of good practice for the analysis of necessary conditions prior to Boolean minimization has revealed that this effect pervades applied research. These results call for a thorough re-evaluation of current standards of good practice for QCA.

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