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Solving contradictory simplifying assumptions in QCA: presentation of a new best practice

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Abstract

One of the strongest features of *Qualitative Comparative Analysis* (QCA) is the possibility for explicit use of remainders in order to contribute to more parsimonious results. However, as a consequence of the way in which QCA procedures are currently executed, *simplifying assumptions* made about the remainders can be in contradiction with each other. As *contradictions* – the same configuration of conditions leading to different outcomes – go against the underlying principles of the methodology and make the research results invalid, researchers using QCA should control for *contradictory simplifying assumptions* (CSA) and solve them if they have emerged during the analysis. In today's literature, one way of solving CSA has been introduced and replicated by different scholars. The purpose of this paper is to introduce an alternative technique for solving CSA and to demonstrate with real-life data how our solution can be applied in practice. We believe our technique is a refinement and improvement on both the process and result level; it remains closer to the fundamental principles of QCA and the results are possibly more parsimonious. Hence, we propose it as a new best practice.

Keywords

QCA, contradictory simplifying assumptions, European Union, international environmental negotiations

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1. Introduction

This paper presents a solution for a frequently faced problem when a Qualitative Comparative Analysis (QCA) is executed, namely '*contradictory simplifying assumptions*' (CSA). One of the strongest features of QCA is the possibility for explicit use of remainders in order to contribute to more parsimonious results. These remainders are empirically empty cells in the property space. They *may* be covered by a minimal formula if this leads to a more parsimonious result. If this is the case, a *simplifying assumption* is attributed to this remainder, allowing it to be incorporated in the minimization process. It is, however, possible that such an assumption is attributed to the minimization of the 0-outcome *and* to the minimization of the 1-outcome. This is called a CSA, and it has to be solved. As contradictions – the same configuration of conditions leading to different outcomes – go against the underlying principles of the methodology and make the research results invalid, researchers using QCA should control for CSA and solve them if they have emerged during the analysis. In today's literature, one way of solving CSA has been introduced and replicated by different scholars. The purpose of this paper is to introduce an alternative technique for solving CSA and to demonstrate with real-life data how our solution can be applied in practice. We believe our technique is a new best practice, both with reference to the process and to the obtained result of the analysis, as it remains closer to the fundamental principles of QCA and the research outcomes are possibly more parsimonious.

The paper is structured as follows: in this first section, we briefly introduce QCA as a method and situate CSA within. In section 2, we present the conventional technique for solving CSA in QCA as it has appeared in the literature up to date. Subsequently, we describe the new technique for solving CSA as we propose it. In section 3, we illustrate our technique in an application to a dataset on the negotiation autonomy enjoyed by the negotiator of the European Union (EU) vis-à-vis the EU member states in the context of international environmental negotiations. In the final section, we present the conclusions.

1.1 Introducing QCA – principles and techniques

Qualitative Comparative Analysis was initially developed by Charles Ragin (1987; 2000) for the purpose of formalizing comparative case study research with small- and moderate-N datasets, by applying set-theoretic insights. Ragin initially addressed the field of comparative political science; a field which is typically confronted with the ‘many variables, few cases’ impasse. Meanwhile, researchers from a broad range of social science disciplines, working on different levels (macro, meso, micro) and with datasets of different sizes made satisfactory use of the method and contributed to its development (Ragin 1987; Ragin, Berg-Schlosser and De Meur 1996; Rihoux and De Meur 2009; Rihoux et al. 2009). Like most other small-N methodologies, QCA marries a complex view of the social world with a causes-of-effects approach: it aims for explaining the outcome of a particular case or a few cases, rather than to look for a net effect of causes over a large number of cases (effects-of-causes approach) (Bennett and Elman 2006; Mahoney and Goertz 2006). QCA has a conception of causation, referred to as *multiple conjunctional causation*. This entails that it holds a *configurational* approach to causation. Conditions are considered and assessed in the context of other relevant conditions and are not to be assessed for their net effect. QCA is also characterized by a *typological* logic: it studies social phenomena in terms of different kinds or types. More specifically, it identifies the different conjunctions of *conditions* or ‘causal paths’, leading to a certain *outcome*.

What makes QCA distinct from other case oriented methods, is the use of Boolean algebra and set-theoretical insights to formalize comparison and unravel the causal complexity (Berg-Schlosser et al. 2009). Boolean algebra allows for drawing the maximum number of systematic comparisons that can be made in terms of the presence or absence of attributes of interest, across the cases under analysis. The main advantage of using Boolean algebra is that it allows us to identify schemes of multiple conjunctional causation and as a result also to consider those conditions which alone are not sufficient or necessary as causally relevant (Schneider and Wagemann 2004).

In this paper, we focus on the original Boolean-algebraic version of QCA. As we do not consider multi value (mvQCA) or fuzzy set QCA (fsQCA)[1], we consistently use 'QCA' and not 'csQCA' ('crisp set QCA', cf. Rihoux and Ragin 2009b) as marker to refer to the Boolean application.

In QCA, cases are defined as configurations of *conditions* and an *outcome*. 'Conditions' and 'outcomes' are typical QCA terminology for what is traditionally respectively called 'independent' or 'explanatory' variables and 'dependent' variables.[2] QCA requires each of these variables to be dichotomized; i.e. to have two possible values: 0 and 1, meaning absence and presence of the phenomenon. Variables with a 0 value are presented in lower case, while variables taking a 1 value are presented in upper case. The k dichotomized conditions are turned into a property space of all 2^k logically possible combinations of conditions, which constitutes the theoretical blueprint for the truth table. A truth table lists (a) all logically possible combinations of the conditions, (b) the (empirically observed) outcome associated with each combination and (c) the empirical cases representing the combinations. In QCA, this is the key analytical tool for analyzing causal complexity. The goal of truth table analysis is to identify explicit connections between combinations of causal conditions and an outcome. The deterministic logic of the method (cf. Goldthorpe 1997 or Mahoney 2000) does not allow two cases to be defined by the same combination of conditions but to display a different outcome, which is called a *contradiction* in QCA terminology. It is incumbent upon the researcher to resolve as many of such contradictions as possible.[3] This is one of the key features of QCA: by

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1 csQCA and mvQCA are the only applications of the QCA family of techniques which are confronted with CSA, the subject matter of this contribution. The application of our technique to mvQCA is very similar to the one on csQCA we propose here.

2 The logic behind this different terminology is grounded in the configurational approach to causation of QCA. Within this approach, variables are interdependent and 'independent variables' are non-existent.

3 When developing new theoretical arguments, contradictions may signal an omitted variable which could differentiate between the cases involved in the contradictory combination and may thus lead to selecting additional relevant conditions. When testing theories, contradictions help disqualifying theories that are unable to discriminate correctly between cases with or without the outcome under study. Alternatively, they may indicate an unfortunate interpretation of cases or of the

seeking a solution to contradictions, researchers get a more thorough knowledge of the cases and are forced to reconsider their theoretical perspectives (Rihoux and De Meur 2009; Ragin 2005; Herrmann and Cronqvist 2006). When all contradictions in the truth table are solved, it is analysed into a *minimal formula* through Boolean algebraic minimizations that reveal the regularities in the data.[4] The goal of the QCA procedure is to represent the whole of the empirical cases in the most *parsimonious* expression of the different causal paths leading to the outcome. Both the 0 and 1 outcomes should be analyzed as we do not expect be default to find causal symmetry in social phenomena; 0-outcomes can not always be explained by the absence of the conditions associated with outcome 1 (Rihoux and De Meur 2009).

1.2. Contradictory simplifying assumptions in QCA

One of the most interesting and powerful features of QCA is the explicit use of *remainders* or empirically empty zones in the property space (also sometimes called *logical* or *theoretical cases*) to achieve more parsimonious solutions and to engage in (modest) generalization (Rihoux and Ragin 2009). Rarely all theoretically possible combinations of conditions are represented by the empirical sample of social scientific research, due to a number of reasons.[5] As a substitute for empirically absent

population. They may also signal (an) ill-chosen threshold(s) between 0 and 1 in the dichotomization of conditions and/or the outcome (Ragin 1987; Berg-Schlosser et al. 2009; Rihoux and De Meur 2009; Yamasaki and Rihoux 2009).

4 The minimization procedure is based on pairwise comparisons of the configurations (cases): 'If two Boolean expressions differ in only one causal condition yet produce the same outcome, then the causal condition that distinguishes the two expressions can be considered irrelevant and can be removed to create a simpler, combined expression' (Ragin 1987: 93).

5 First of all, remainders can result from small universes: even when the whole population of relevant cases is selected in the sample, the number of cases can still be lower than the number of combinations of conditions. Second, practical limitations during sampling (e.g. money, time, accessibility of data) can result in remainders. Third, the absence of empirical cases is often due to the limited diversity of social reality. Certain logically conceivable combinations of conditions are unrealizable in reality (e.g. the combination 'man' and 'cancer of the cervix'). Fourth, the number of remainders in a QCA analysis is also dependent on the ratio number of cases/number of conditions. The more conditions used in the analysis, the

combinations of causal conditions, comparative researchers often engage in thought experiments of *counterfactual analysis*. They imagine non-existing empirical cases and hypothesize their outcomes, using theoretical and empirical knowledge to guide their assessments. In QCA, this is done by implying remainders in the analysis. The assumptions made about the *plausible outcomes* of these empirically non-existing cases on which the resulting minimal formula depends are called *simplifying assumptions*. Because QCA uses truth tables to assess cross-case patterns, this counterfactual analysis is explicit and systematic (Rihoux and Ragin 2004).

When including remainders in the analyses of both the 0 and the 1 outcome – which are done separately in QCA software –, one should watch not to include the same remainder in both calculations. Accepting the same remainder to be included in both analyses would mean agreeing with two assumptions that are contradictory. This implies creating a new logical *contradiction* (De Meur and Rihoux 2002; Rihoux and De Meur 2009), which should be solved. The careful control for CSA is crucial for any QCA to be successful, because they induce wrong conclusions, since the 1 and 0 minimal formulae both get the same explanatory status in QCA. Moreover, engaging in solving CSA may eventually generate most interesting results (Vanderborght and Yamasaki 2004; Yamasaki and Rihoux 2009).

It is argued elsewhere that researchers do not have to make the choice between either implying all remainders to the analysis or implying none. Stokke (2004, cited in Yamasaki and Rihoux 2009), for example, demonstrated that it is possible to include only a number of remainders after having examined the theoretical plausibility of the related simplifying assumptions. Ragin and Sonnet (2004) developed a systematic procedure for including only part of the remainders by distinguishing between 'easy' and 'difficult counterfactuals'. 'Easy counterfactuals' are counterfactuals in which a researcher adds a contributing cause to a configuration that is already thought to lead to the outcome. 'Difficult

more logically possible combinations of conditions are called into being and the more potential areas in the property space for which no empirical cases can be found.

counterfactuals', on the contrary, would be made when the researcher adds a cause to the analysis that is expected to go against the existing theoretical and substantive knowledge (Ragin, 2008). When only easy counterfactuals are taken into account in an analysis (and difficult ones are left out), no CSA are expected to emerge.

Thus far, one technique of solving CSA has been proposed in the literature. In what follows, we present this technique. Next, we propose an alternative technique which we believe is more in line with the general QCA principles and with we illustrate with a real-life research application.

2. Solving contradictory simplifying assumptions in QCA

2.1. Conventional technique for solving contradictory simplifying assumptions in QCA

Benoît Rihoux (2001) was the first one to bring to the fore the issue of CSA and to propose a technique for solving it. More recently, other scholars (Vanderborght and Yamasaki 2004; Skaaning 2006; Scouvart 2006; Scouvart et al. 2007) applied the same procedure, which is the only one presented in scientific literature until today and which is reproduced in the most recent comprehensive textbook on the QCA methods (Rihoux and Ragin 2009a). Yamasaki and Rihoux (2009) describe the protocol for solving CSA as follows. After having detected the presence of CSA, each remainder that constitutes such a contradiction is replaced by a *fictive case* with the same combination of conditions and an explicitly attributed outcome value (0 or 1), depending on the most *plausible outcome*. Obviously, the most plausible outcome should be substantiated based on in-depth empirical knowledge and theoretical insight. In other words: a *fictive case is added to the empirical cases* in the truth table. In the next step, both the minimization processes of the 0 and the 1 outcomes are run again on the basis of the same truth table. As it will become clear in the next section, this is where our technique differs from the existing one. If new contractions have appeared, this procedure has to be replicated in an iterative way (Rihoux 2006; Yamasaki and Rihoux 2009). For the sake of clarity, we illustrate this technique with a fictive example.

The rows of the following truth table 1 represent all 16 theoretically possible combinations of dichotomised conditions W to Z. The empirical sample of this fictive research consists of cases A to L, evenly spread over 12 combinations of conditions. Consequently, the truth table holds four remainders (indicated with R in the table). Each of the cases has a 0 or 1 score on the outcome variable; there are no contradictions.

Truth table 1. Illustration conventional technique: data from fictive example

Condition W	Condition X	Condition Y	Condition Z	Outcome O	Cases
1	0	1	0	1	A
1	0	0	0	0	B
1	0	0	1	0	C
1	1	0	1	0	D
1	1	1	0	0	E
1	1	0	0	1	F
0	1	1	0	1	G
0	1	0	0	0	H
0	1	0	1	1	I
0	0	0	1	1	J
0	0	0	0	1	K
0	0	1	0	0	L
1	1	1	1	R	-
0	0	1	1	R	-
1	0	1	1	R	-
0	0	1	1	R	-

When calculating the minimal formulae for these data, including the remainders, two remainders are implied in both results of the calculations of the 0 and the 1 outcome, thus creating CSA's, namely combinations 1011 and 0011 (marked in the truth table in grey). The technique to solve these CSA presented in the existing literature, proposes to assign to both of these combinations of conditions the most plausible outcome, based on arguments drawn from literature and empirical knowledge, and to add a corresponding fictive case to the truth table. The following table presents the new truth table, including fictive cases M and N with respective plausible outcomes 1 and 0.[6] Both the fictive cases and the plausible outcomes are presented in italic.

[6] As this example is fictive, we obviously cannot give substantial arguments for assigning these outcome scores.

Truth table 2. Illustration conventional technique: fictive cases M and N added

Condition W	Condition X	Condition Y	Condition Z	Outcome O	Cases
1	0	1	0	1	A
1	0	0	0	0	B
1	0	0	1	0	C
1	1	0	1	0	D
1	1	1	0	0	E
1	1	0	0	1	F
0	1	1	0	1	G
0	1	0	0	0	H
0	1	0	1	1	I
0	0	0	1	1	J
0	0	0	0	1	K
0	0	1	0	0	L
1	0	1	1	*1*	*M*
0	0	1	1	*0*	*N*
1	1	1	1	R	-
0	0	1	1	R	-

The minimization of this truth table 2 leads to valid minimal formulae, since the same simplifying assumptions are not used in both minimization processes. Hence, CSA are now avoided.

2.2. Our evaluation of the conventional technique

We have some points of criticism with reference to the conventional technique. In this procedure, combinations of conditions that have the status of a remainder lose this status during the analysis. In stead, they get the same status as the combinations represented by empirical cases. In other words, the fictive cases added to the truth table are treated just like the empirical cases in the minimization processes after the CSA are solved according to this technique. Therefore, the clear distinction between what is empirically observed and what is empirically empty is transgressed during the analysis. In the past, the practice of including remainders in the QCA procedure has been criticized for surpassing the empirically observable world and thus introducing (too much) speculation in scientific practice. This critique has been put aside as not pertinent, as implying the remainders in the analysis is a punctual intervention for the purpose of parsimony, which does not touch the empirical data. Researchers do not blow life into these fictive cases; they are not treated as if they were real cases (De Meur, Rihoux and Yamasaki 2009).

In this process of solving CSA, the previous critique, however, becomes all the more pertinent. Even though creating fictive cases and adding them to the truth table remains a heuristic intervention, the remainders lose their empirically empty status and start to function as real cases in the truth table and during the minimization procedures. As a consequence, the original remainders do not only lose their empirically empty status, but also their specific function as remainder in calculating a possibly more parsimonious solution. An additional unfortunate repercussion of this procedure is the fact that QCA software will not display the fictive cases as simplifying assumptions in the output, as the fictive cases are considered to be empirical cases. A researcher should not let him- or herself be distracted during the process of analysis, but a software output with an incomplete list of simplifying assumptions can be mystifying; or could at least be considered as not so elegant.

2.3. Proposal new technique for solving CSA in QCA

We propose a new technique for solving CSA in QCA which we believe to be better than the conventional one, both on the level of the process of the analysis as with reference to the result. Our technique is not completely different to the conventional one, since it also works with fictive cases to which plausible outcomes are attributed. However, we refine the further steps after the creation of the fictive cases.

The first phase of our technique is the same as in the conventional technique. Here, CSA are detected and possible outcomes for the remainders, which were used for both minimizations, are studied trough counterfactual thinking. After arguing for and deciding on the most plausible outcome of the contradictory configuration(s) in question, we propose not to create a fictive case to add to the empirical cases, but to explicitly assign *the plausible outcome* to the configuration, *only in the minimization process of the non-plausible outcome,* so where these remainders should *not* be included. As the QCA software only considers the 0-outcome configurations and (if requested) the remainders and not the 1-outcome configurations when analysing the 0-outcome and vice versa, the researcher can *sideline* the remainder during the analyses of the undesirable outcome of the remainder. This way, the remainder functions as such in the most appropriate analysis and is simply not considered as a possible remainder in the analysis of the inappropriate outcome. This implies the construction of two different truth tables – one for the 0 and one for the 1 minimization. In the truth table used for the minimization of the 0-outcomes, only the fictive cases with a plausible 1-outcome are included next to the empirical cases. Likewise, in the truth table used for the minimization of the 1-outcomes, only the fictive cases with a plausible 0-outcome are included next to the empirical cases.

To illustrate this technique, we use the same fictive example as in section 2.1. Hence, the truth table representing the data and the involved CSA's is truth table 1 (cf. supra). The most plausible outcome for configuration 1011 remains 1; the most plausible outcome for configuration 0011 is 0. First, we create truth table 3a for the analysis of the 0 outcomes. In this table, configuration 0011 is kept as a remainder and can therefore function as a remainder. This means that if including this configuration in the analysis of the 0 outcome makes the result more parsimonious, the QCA software can imply it. As we do not want remainder 1011 to be virtually assigned the 0 outcome (as we want to avoid CSA and we consider the most plausible outcome to be 1), it is added to the truth table as a fictive case with outcome 1. Consequently, this configuration will simply not be considered during the analysis and will therefore function nor as an empirical case, nor as a remainder. Second, the inverse happens in truth table 3b: configuration 1011 is now kept as a remainder; configuration 0011 is assigned the 0 outcome and is therefore sidelined in the analysis of the 1-outcome.

Truth table 3a. Illustration new technique: minimization of 0-outcomes after CSA have been identified

Condition W	Condition X	Condition Y	Condition Z	Outcome O	Cases
1	0	1	0	1	A
1	0	0	0	0	B
1	0	0	1	0	C
1	1	0	1	0	D
1	1	1	0	0	E
1	1	0	0	1	F
0	1	1	0	1	G
0	1	0	0	0	H
0	1	0	1	1	I
0	0	0	1	1	J
0	0	0	0	1	K
0	0	1	0	0	L
1	0	1	1	*1*	*M*
0	0	1	1	R	-
1	1	1	1	R	-
0	0	1	1	R	-

Truth table 3b. Illustration new technique: minimization of 1-outcomes after CSA have been identified

Condition W	Condition X	Condition Y	Condition Z	Outcome O	Cases
1	0	1	0	1	A
1	0	0	0	0	B
1	0	0	1	0	C
1	1	0	1	0	D
1	1	1	0	0	E
1	1	0	0	1	F
0	1	1	0	1	G
0	1	0	0	0	H
0	1	0	1	1	I
0	0	0	1	1	J
0	0	0	0	1	K
0	0	1	0	0	L
1	0	1	1	R	-
0	0	1	1	*0*	*N*
1	1	1	1	R	-
0	0	1	1	R	-

2.4. Comparison and best practice

In contrast with the conventional technique, the new technique we propose to solve CSA respects the distinction between empirically empty and empirically represented combinations of conditions. The function and the strength of the remainder as a tool for developing theoretical generalizations is strictly maintained. This is because of the fact that we do not interfere in the analysis where they should function as remainder, but in the analysis where we do *not* want them to be considered. As all

remainders are treated as such by the QCA software, all simplifying assumptions used in the Boolean minimizations are listed in the output. For these reasons, we believe our procedure to be closer to the general principles of QCA and therefore to be better than the conventional one.
Moreover, it is not only better on process level, but also with respect to the outcome. In the conventional technique, the remainders involved in CSA lose their status: they are assigned a fixed outcome and become a fictive – as if empirical – case. Therefore, when calculating Boolean minimizations, they *should* be included. In the new technique, remainders *could* be included in the analysis *if including them makes the results more parsimonious*. In the example we present in section 3, we show that the results indeed sometimes differ according to the technique used. Moreover, they always differ in the sense that the minimal formulae obtained by our technique are more parsimonious than the minimal formulae obtained by the conventional technique. This can be explained as follows: the more remainders QCA software can include in the analysis, the more possibilities the software iterations have for calculating the most parsimonious result. In other words, in case the two techniques lead to different results, our technique will always be the more parsimonious one as more remainders are at play. Consequently, we defend our procedure as the new best practice for solving CSA in QCA.

To conclude the theoretical discussion of this contribution – and before continuing with the illustration of the new technique in a ‘real life’ research example – it is fair to state that certain limitations of the conventional technique for solving CSA remain present in our technique. One of the main difficulties in solving CSA is the attribution of the most plausible outcome to the configurations that are involved in the contradictions (the fictive cases). The most plausible outcome should be defined on the basis on in-depth case knowledge and theoretical insights, but rarely do they point in one clear direction. Hence, it is and remains important to assign the plausible outcomes in a very careful and well-considered way. Yet, the simplifying assumptions made by including remainders in an analysis should always be a point of careful attention during a QCA analysis.

3. Application of our technique to a real-life dataset

3.1. Explaining the negotiation autonomy of an EU negotiator

In this section, our technique as outlined in the previous section is applied to a specific research project where we were confronted with this methodological problem. The aim of the project and the qualitative comparative analysis was to identify the conditions under which an EU negotiator – i.e. a political actor participating in international negotiations on behalf of the European Union, e.g. the European Commission or the Council Presidency – enjoyed a high degree of negotiation autonomy vis-à-vis the member states he or she represents around the international negotiation table. In other words, the research aim was to find out which causal paths lead to a situation in which the EU negotiator enjoys a large room of manoeuvre vis-à-vis the member states to negotiate international environmental agreements with third countries.

The research design consisted of one outcome variable, eight condition variables and 13 cases. Since a discussion of its substantive significance falls outside the scope of this paper, the research design is presented here in a brief and technical manner. [7] The *outcome variable* is the degree of negotiation autonomy of the EU negotiator (<aut>). The following *condition variables* were selected in a theory-driven way: the degree of preference homogeneity among the member states (<prefprin>); the degree of preference homogeneity between the EU negotiator and the member states (<prefpa>); the level of politicization (<polit>); the information asymmetry in favour of the EU negotiator (<infag>); the information asymmetry in favour of the member states (<infprin>); the external compellingness (<extcomp>); the degree of institutional density (<instdens>); and the action capacity of the Presidency (<actcap>). The analysis was conducted with 13 cases: (stages of) EU decision-making processes regarding international environmental negotiations in which various EU negotiators

[7] More substantive discussions about the negotiation autonomy of the EU negotiator in international environmental negotiations and the conditions affecting this autonomy can be found in the following publications: (Delreux 2008; Delreux 2009a; Delreux 2009b).

represented the member states: *CCD*, *AEWA*, *KYOTO_1*, *KYOTO_2*, *ARHUS_1*, *ARHUS_2*, *PIC*, *CART_1*, *CART_2*, *STOCPOP_1*, *STOCPOP_2*, *SEA_1*, and *SEA_2*. In truth table 4, the dichotomized values on each variable for each of the cases are presented.

Truth table 4. Real-life data presentation: negotiation autonomy EU negotiator

prefprin	prefpa	polit	infag	infprin	inst	extcomp	actcap	aut	Cases
0	1	0	0	0	0	0	1	0	AEWA; ARHUS_2; SEA_2
0	1	0	0	0	0	1	1	0	CART_1
1	1	1	1	0	1	1	0	1	CART_2
1	1	0	0	0	0	0	1	0	CCD
0	0	1	0	1	1	1	1	1	KYOTO_1
0	0	1	1	1	0	1	0	1	KYOTO_2
1	1	0	0	0	1	1	1	1	PIC
0	1	0	0	0	0	0	0	0	SEA_1; ARHUS_1
1	1	1	0	0	1	1	1	0	STOCPOP_1
1	1	1	0	0	1	1	0	0	STOCPOP_2
								R	246 (=2^8-10) remainders

We first analysed this truth table without the inclusion of the remainders. However, the results of these analyses were not sufficiently parsimonious to provide any explanatory power. As the ratio of the number of conditions to the number of cases is rather large and as the cases were rigorously selected from their universe, guaranteeing that the remainders did not contradict existing cases in the empirical world, including the remainders was possible. The minimization processes of the 0 and 1 values of the outcome variable <aut>, in which we had to cope with the problem of CSA, were performed according to the steps discussed below. The first three steps need to be executed in every analysis where the researcher faces CSA. Steps 4 and 5 are only necessary if CSA are identified a second time. The discussion of the different steps allows the reader to follow the practical handling of our technique to solved CSA.

3.2. First step: minimizing aut=0,R and aut=1,R

On the basis of truth table 4, we ran a minimization process for both the 1-outcomes and the 0-outcomes. The simplifying assumptions used in both processes were compared, as a result of which we identified 63 CSA.[8] Hence, the minimal formulae obtained in this first step are invalid and the CSA needed to be solved. This is done in the second step.

3.3. Second step: solving the contradictory simplifying assumptions (1)

To solve the CSA, we made an assessment about which outcome (1 or 0) would be the most plausible outcome variable for the 63 different combinations of condition variables that were used as a CSA in step 1. The assessment was based on theoretical knowledge and empirical 'intimacy' with the cases (Rihoux and Ragin 2004). The former relates to theoretical insights and dynamics derived from the theoretical framework on which the selection of the variables and the development of the hypotheses was based. The latter refers to knowledge about the cases – here EU decision-making processes regarding international environmental negotiations – similar to the configurations that had to be assessed in terms of a plausible outcome. Hence, by assigning a plausible outcome to configurations of conditions generating a CSA, the CSA were converted into fictive cases. Of the 63 CSA, 15 were converted into fictive cases with a plausible 1-outcome, whereas the remaining 48 were assigned a plausible 0-outcome.

[8] The relatively large number of CSA in this real-life example relates to the low ratio of number of cases (n=13) to number of conditions (k=8). However, this ratio is justifiable because of a twofold reason. On the one hand, we selected all EU decision-making processes with regard to international negotiations leading to a multilateral environmental agreement to which the European Community and the member states are a party, negotiated between 1992 and 2004. As a result, a remainder never correspond to case existing in the empirical reality. On the other hand, including a large number of conditions in our example allows us to show the differences between the minimal formulae obtained by both techniques for solving CSA. As it will become clear below, the differences between both techniques relate to the role the remainders play in the minimization process. We can only demonstrate this with an example in which we have a lot of remainders.

After 63 such assessments were made, two separate new truth tables were constructed. On the one hand, besides the 13 empirical cases that were presented in truth table 4, truth table 5a contains the fictive cases with the plausible 1-outcome. This truth table 5a will be used for the minimization of the 0-outcomes in the next step. On the other hand, truth table 5b contains the 13 empirical cases, to which the fictive cases with the plausible 0-outcome are added. This truth table will be the basis for the minimization of the 1-outcomes in the next step. Hence, as a general rule of thumb, our technique proposes to add the fictive cases only to that truth table that will be used for the minimization of the outcome *opposite* to the plausible outcome of the fictive cases added. The fictive cases with a plausible outcome opposite to the one minimized are added to avoid that their configurations are used as a simplifying assumption. The other fictive cases may be included as a remainder if the software iterations need this to produce more parsimonious results.

Truth table 5a. Minimization of 0-outcomes after CSA have been identified a first time

prefprin	prefpa	polit	infag	infprin	inst	extcomp	agprin	aut	Cases
0	1	0	0	0	0	0	1	0	AEWA; ARHUS_2; SEA_2
0	1	0	0	0	0	1	1	0	CART_1
1	1	1	1	0	1	1	0	1	CART_2
1	1	0	0	0	0	0	1	0	CCD
0	0	1	0	1	1	1	1	1	KYOTO_1
0	0	1	1	1	0	1	0	1	KYOTO_2
1	1	0	0	0	1	1	1	1	PIC
0	1	0	0	0	0	0	0	0	SEA_1; ARHUS_1
1	1	1	0	0	1	1	1	0	STOCPOP_1
1	1	1	0	0	1	1	0	0	STOCPOP_2
								1	15 different fictive cases with plausible 1-outcome
								R	231 (=2^8-10-15) remainders

Truth table 5b. Minimization of 1-outcomes after CSA have been identified a first time

prefprin	prefpa	polit	infag	infprin	inst	extcomp	agprin	aut	Cases
0	1	0	0	0	0	0	1	0	AEWA; ARHUS_2; SEA_2
0	1	0	0	0	0	1	1	0	CART_1
1	1	1	1	0	1	1	0	1	CART_2
1	1	0	0	0	0	0	1	0	CCD
0	0	1	0	1	1	1	1	1	KYOTO_1
0	0	1	1	1	0	1	0	1	KYOTO_2
1	1	0	0	0	1	1	1	1	PIC
0	1	0	0	0	0	0	0	0	SEA_1; ARHUS_1
1	1	1	0	0	1	1	1	0	STOCPOP_1
1	1	1	0	0	1	1	0	0	STOCPOP_2
								0	48 different fictive cases with plausible 0-outcome
								R	198 (=2^8-10-48) remainders

3.4. Third step: minimizing aut=0,R+fictive cases and aut=1,R+fictive cases

On the basis of respectively truth tables 5a and 5b, we minimized the 0-outcomes and the 1-outcomes. Additionally, in order to compare the results obtained by our technique with the results obtained by the conventional technique, we also minimized the dataset according to the rules of the conventional technique. In table 6, we compare the results obtained by applying the new technique we propose with the results that one would obtain by using the conventional technique. Three conclusions can be drawn from this comparison. First, it is clear that the way the CSA are solved affects the minimal formulae – and thus the results of the research. Indeed, the conventional technique and the new technique we propose can lead to different results. The causal paths that differ are presented in italics in table 6. Second, the extent to which the minimal formulae differ seems to be consistent, since the minimal formulae obtained by using the new technique are more parsimonious than the minimal formulae obtained by using the conventional technique. This means that the number of causal paths explaining a particular outcome is smaller when one uses our new technique than when the conventional technique is used. Third, it seems that the minimal formulae obtained by using the new technique do not only consist of *less* causal paths, but that it is also possible that they consist of *other* causal paths than the minimal formulae resulting from the conventional technique.

Table 6. Comparison of minimal formulae obtained by conventional and new technique after having solved CSA for the first time

	Conventional technique	**Our new technique**
aut=0,R+fictive cases	infag*inst + POLIT*infag*infprin + *extcomp +* *PREFPRIN*PREFPA*inst*	infag*inst + POLIT*infag*infprin +
aut=1,R+fictive cases	polit*INST + *POLIT*INFAG +* *prefprin*INFAG*EXTCOMP +* *prefpa*INFAG*EXTCOMP +* *INFPRIN*INST*EXTCOMP*	polit*INST + *prefprin*POLIT +* *INFAG*INST*

Like in the first step, we had to verify again if the minimization processes did not make use of the same simplifying assumptions. Hence, we checked for CSA. Unfortunately, we found 24 CSA, as a result of which the results presented in table 6 are invalid. It does, however, not mean that our conclusions about the differences and the extent of parsimony between the two kinds of results do not hold. The new CSA are solved in the next step. If no CSA would have been identified in this step, the implementation of our technique ends here. Only if the researcher identifies new CSA, the next step needs to be incorporated in the procedure.

3.5. Fourth step: solving the contradictory simplifying assumptions (2)

We again apply our technique in the same way we did in the second step. This means that we added, based on our theoretical and empirical knowledge, the most plausible outcome to the configurations that were used as a simplifying assumption by both minimization processes. Two of them were assigned the plausible outcome 1, the other 22 were attributed the plausible outcome 0. The two fictive cases with a plausible 1-outcome were added to truth table 5a, resulting in truth table 7a. Similarly, the 22 fictive cases with a plausible 0-outcome were added to truth table 5b, resulting in truth table 7b. This thus implies that the fictive cases that were added to solve the CSA a first time remain in the truth table. Hence, the new truth tables contain (a) the empirical cases, (b) the fictive cases from step 2, and (c) the fictive cases from step 4. Just like in the second step, truth table 7a will be used for minimizing the 0-outcomes, whereas truth table 7b will be used for the minimization of the 1-outcomes.

Truth table 7a. Minimization of 0-outcomes after CSA have been identified a second time

Prefprin	prefpa	polit	infag	infprin	inst	extcomp	agprin	aut	Cases
0	1	0	0	0	0	0	1	0	AEWA; ARHUS_2; SEA_2
0	1	0	0	0	0	1	1	0	CART_1
1	1	1	1	0	1	1	0	1	CART_2
1	1	0	0	0	0	0	1	0	CCD
0	0	1	0	1	1	1	1	1	KYOTO_1
0	0	1	1	1	0	1	0	1	KYOTO_2
1	1	0	0	0	1	1	1	1	PIC
0	1	0	0	0	0	0	0	0	SEA_1; ARHUS_1
1	1	1	0	0	1	1	1	0	STOCPOP_1
1	1	1	0	0	1	1	0	0	STOCPOP_2
								1	15 different fictive cases with plausible 1-outcome (step 2)
								1	2 different fictive cases with plausible 1-outcome (step 4)
								R	229 (=2^8-10-15-2) remainders

Truth table 7b. Minimization of 1-outcomes after CSA have been identified a second time

prefprin	prefpa	polit	infag	infprin	inst	extcomp	agprin	aut	Cases
0	1	0	0	0	0	0	1	0	AEWA; ARHUS_2; SEA_2
0	1	0	0	0	0	1	1	0	CART_1
1	1	1	1	0	1	1	0	1	CART_2
1	1	0	0	0	0	0	1	0	CCD
0	0	1	0	1	1	1	1	1	KYOTO_1
0	0	1	1	1	0	1	0	1	KYOTO_2
1	1	0	0	0	1	1	1	1	PIC
0	1	0	0	0	0	0	0	0	SEA_1; ARHUS_1
1	1	1	0	0	1	1	1	0	STOCPOP_1
1	1	1	0	0	1	1	0	0	STOCPOP_2
								0	48 different fictive cases with plausible 0-outcome (step 2)
								0	22 different fictive cases with plausible 0-outcome (step 4)
								R	176 (=2^8-10-48-22) remainders

3.5. Fifth step: minimizing aut=0,R+two kinds of fictive cases and aut=1,R+ two kinds of fictive cases

Truth tables 7a and 7b were minimized. Like we did in the third step, we also applied the conventional technique to this dataset in order to be able to compare the minimal formulae obtained with our technique to those obtained with the conventional technique (see table 8). The three conclusions that emerged from this comparison in step 3 are valid here as well: (a) both techniques lead to *different results*, (b) the results contain *less causal paths* (they are more parsimonious), (c) and also *other causal paths*.

Table 8. Comparison of minimal formulae obtained by conventional and new technique after having solved CSA for the second time

	Conventional technique	**Our new technique**
aut=0,R+two kinds of fictive cases	infag*inst + *extcomp* + *PREFPRIN*PREFPA*inst* + *POLIT*infag*infprin*	infag*inst + *PREFPRIN*POLIT*infag*infprin*
aut=1,R+two kinds of fictive cases	INFPRIN*INST*EXTCOMP + *prefprin*INFAG*EXTCOMP* + *prefpa*INFAG*EXTCOMP* + *polit*INST*EXTCOMP* + *INFAG*INST*EXTCOMP*	INFPRIN*INST*EXTCOMP + *polit*INST* + *POLIT*INFAG*

The minimal formulae presented here are now valid, since no CSA were used to obtain them. Hence, this is the last step of the application of our technique. However, the QCA procedure as such does not end here, as these results still have to be interpreted in the light of the empirical data. We do not provide these interpretations in the framework of this paper, but they can be consulted elsewhere (Delreux 2009b).

4. Conclusion

Contradictory simplifying assumptions need to be eliminated from a QCA procedure as they decrease the validity of its results. We proposed a new technique to solve CSA, which refines the existing ('conventional') technique and which better fits with the general QCA approach. The main difference between both techniques is the treatment of the remainders once the most plausible outcome is attributed to the configurations that led to a CSA. The key element of our technique is that, after the creation of the fictive cases, two separate truth tables are constructed. The first truth table is only used for the minimization of the 0-outcomes, while the second only is only used for the minimization of the 1-outcomes. The former contains the empirical cases and the fictive cases with a plausible 1-outcome, the latter the empirical cases and the fictive cases with a plausible 0-outcome. Hence, only those fictive cases, which may not be used as a remainder, are added to the truth table. All the other possible configurations, including the fictive cases included in the other truth table, can then be used as a remainder if this contributes to more parsimonious result. In the conventional technique, the fictive cases function as ‘cases’, in the sense they *must* be covered by the minimal formula. In our technique, they can freely play their role as ‘remainders’ and they *might* be covered by the minimal formula if this is necessary for a more parsimonious result.

Compared to the conventional technique, the added value of our technique is twofold. On the one hand, the distinction between a configuration functioning as a ‘case’ and a configuration functioning as a ‘remainder’ is respected in our technique, whereas this distinction is blurred in the conventional technique. On the other hand, we gain parsimony in the minimal formulae, which means that the results obtained by using this technique have a stronger explanatory power than those obtained by applying the conventional technique. The fact that more configurations can function as a remainder is the reason for this increased parsimony. Because of its added value both at the level of the process and at the level of the results, we present this technique as a new best practice for solving contradictory simplifying assumptions in QCA.

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