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Set-theoretic Multimethod Research: The Role of Test Corridors and Conjunctions for Case Selection

Carsten Q. Schneider[1] and Ingo Rohlfing[2]
[1]Department of Political Science, Central European University (CEU)
[2]Cologne Center for Comparative Politics, Universität zu Köln

Abstract: *Set-theoretic multimethod research (SMMR) using Qualitative Comparative Analysis (QCA) formalizes the choice of cases based on a truth table analysis. We make three recommendations for improving SMMR. First, current standards can lead to faulty case selection if causal inference on a conjunction is the goal. Case selection needs to take into account that the non-members of a conjunction might be empirically diverse and that only selected types of non-members are ideal for causal inference. Second, we formally show that cases with similar fuzzy-set memberships in a term and the outcome are the superior choice for process tracing. They minimize the expected membership in the mechanism and make it most difficult to pass a hypothesis test. Third, we propose formulas that comply with all SMMR principles and identify the best pairs of cases for analysis. We illustrate our arguments with a study of the effectiveness of sanctions against authoritarian regimes.*

Keywords: causal mechanism, mixed methods, multimethod research, Qualitative Comparative Analysis, process tracing

Introduction[1]

Qualitative Comparative Analysis (QCA) is traditionally portrayed as a case-based method (Marx et al. 2014). One element of its case-based nature that has been discussed since QCA's inception is the use of case knowledge before a truth table analysis (Ragin 1987: chapters 5, 6). it is only recently, though, that discussions have started on how to use the results from a truth table analysis for follow-up case studies.[2] This combination of QCA and case studies has been labeled *set-theoretic multimethod research* (Goertz and Mahoney 2012: chap. 1;

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[2] We use 'process tracing' and 'case studies' as synonyms.

Rohlfing and Schneider 2018).[3] SMMR capitalizes on the fact that QCA and case studies can be anchored in set theory (Goertz and Mahoney 2012: chap. 1; Rohlfing and Schneider 2018). The existing work on SMMR offers a set of guidelines that allow empirical researchers to perform an integrated analysis of a truth table and of individual cases via process tracing (see below). In this paper, we show that some of these recommendations can produce faulty case selection and inferences. We expose the current pitfalls and propose updated guidelines to equip SMMR researchers with valid tools for their studies.

First, we show that *conjunctions* (also called configurations) have multiple implications for the choice of typical and individually irrelevant (iir) cases that are not fully accounted for in the current literature. iir cases are those cases that are neither a member of any term in the minimized solution nor of the outcome, where a "term" can be a single condition or a configuration. With regard to conjunctions, it has been ignored that iir cases might be empirically diverse. Simple logic shows that a conjunction with c conjuncts (individual conditions) can have iir cases that are of 2^c-1 empirical variants. There is only one way to be a member of a configuration and 2^c-1 ways of being a non-member. We explain that the ideal comparison of a typical and iir case mathces cases that establish a qualitative difference in the outcome and just *one* conjunct (see Mikkelsen 2015). From this it follows that only one specific iir case of all 2^c-1 possible cases should be chosen for a comparison that focuses on one specific conjunct. We capture this argument in the *unique non-membership principle*. We further argue that the analysis of conjunctions requires compliance with a second new principle that we introduce. Given the research interest in the relationship between a specific conjunct and the mechanism linking the conjunct to the outcome in a typical and iir case, we show that both types should have their minimum membership in this conjunct. We summarize this argument in the *attribution principle*.

Second, empirical researchers are confronted with conflicting advice on how to choose typical cases in fuzzy-set QCA (fsQCA). Schneider and Rohlfing (2013) argue that choosing cases with higher membership in a term is better because this makes a typical case more similar to the ideal case that is a full member of the term and the outcome. Based on the idea of fuzzy-set process tracing (Mikkelsen 2017), we formally demonstrate the benefits of minimizing the difference between a case's membership in a term and the outcome. We formulate the *corridor principle*. It states that the inferential value of a within-case analysis increases, the smaller the difference is between a typical case's membership in the outcome and the conjunct of interest. The corridor principle also applies to iir cases when it is matched with a typical case in order to gather evidence on a mechanism. These three new principles complement the existing ones in the SMMR literature and allow empirical researchers to choose the most appropriate cases for process tracing when their solution includes conjunctions - which is almost always the case in applied QCA.

Third, we present formulas that formalize the SMMR principles and use each cases' set membership values for identifying the best pair for comparative process tracing.[4] We start our discussion of SMMR with a brief introduction of a running empirical example on the effectiveness of sanctions against authoritarian regimes (Grauvogel and von Soest 2014).

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[3] SMMR is similar in spirit to nested analysis (Lieberman 2005) and the work built on it (for example, Seawright 2016; Weller and Barnes 2014). In this subfield of multimethod research, the implicit or explicit understanding of causation is counterfactual and formalized in a potential outcomes framework. This work is important, but has little to offer for the implementation of SMMR because set-relational research and QCA have not (yet) been convincingly formalized in a potential outcomes framework.

[4] The formulas are implemented in the R package SetMethods (Oana and Schneider 2018).

The Empirical Example: Persistence of Authoritarian Regimes

The empirical example in this paper is an fsQCA study by Grauvogel and von Soest, (2014) on the persistence of authoritarian regimes in spite of sanctions imposed by Western countries. The study's aim is to determine the conditions under which international sanctions fail to instigate the breakdown of autocratic regimes. The analysis is based on 120 cases of sanctions imposed on non-democratic regimes by the European Union (EU), United Nations (UN), or the United States of America (USA) between 1990 and 2011. The outcome is defined as the persistence of the autocratic regime (set PERSISTENCE). It is operationalized as the lack of an upward movement on a democracy scale within five years after the start of the sanctions. Five conditions are specified: pronounced use of legitimation claims by the autocratic regime (CLAIMS); high comprehensiveness of sanctions imposed (COMPREHENSIVENESS); high vulnerability of the autocratic regime (VULNERABILITY); strong linkages with the West (LINKAGE); and extensive use of repression (REPRESSION).

Grauvogel and von Soest are interested in the intermediate solution which includes the five sufficient terms presented in table 1.[5] It is exemplary for empirical QCA research: each term is a conjunction; the terms have less-than-perfect consistency; solution coverage shows that a share of the cases' membership in the outcome is not covered by their membership in the solution. In the following section, we focus on SMMR based on sufficient terms for an outcome. As the running example indicates, this is the most common research interest in applied QCA.[6]

Set-Theoretic MMR: Case Types and Comparisons

SMMR is built on the idea that causal analysis is strengthened when it integrates a truth table analysis with follow-up case studies of purposefully selected cases.[7] QCA has always emphasized the importance of case knowledge before a solution is derived from the truth table (Ragin 1987: chapters 5, 6). The discussion of which cases to choose for process tracing on the basis of a truth table analysis has started only in recent years, though (Schneider and Rohlfing 2013).

In SMMR, the classification of cases as a specific type (typical, deviant etc.) integrates the qualitative distinction between members and non-members of the outcome, Y, a solution, S, and, depending on the case type, a term, T. For ease of discussion and because this is most common in applied QCA, in the following we always assume that T is a conjunction.[8] When an empirical study uses fuzzy sets, the *differences in kind* that are established by distinguishing between members and non-members is complemented by

[5] For our purposes, the debate about which type of solution and algorithm is superior (Baumgartner 2015) is not important. Our case selection guidelines are universal in this respect.

[6] None of our arguments depends on whether the QCA solution is sufficient and necessary or only sufficient (Thiem 2014: 492-498). For SMMR based on necessity claims at the cross-case level, see Rohlfing and Schneider (2013).

[7] The truth table analysis and process tracing should be implemented according to highest standards that we do not address in detail and take for granted in this paper. SMMR can also start with a within-case analysis followed by a truth table analysis (Beach and Rohlfing 2018). This strategy creates different case selection challenges than the ones we address here.

[8] This comes without loss of generality for the corridor principle that we introduce below. It applies to conditions and conjunctions.

Table 1: Intermediate Solution for PERSISTENCE (Grauvogel and von Soest 2014: 645)

term	inclusion	raw cov.	unique cov.
Comprehensiveness*CLAIMS	0.818	0.464	0.043
Linkage*CLAIMS	0.789	0.465	0.073
Repression*CLAIMS	0.782	0.403	0.053
Comprehensiveness*linkage*VULNERABILITY*repression	0.793	0.227	0.023
COMPREHENSIVENESS*LINKAGE* vulnerability*REPRESSION	0.867	0.195	0.039
solution	0.778	0.720	

differences in degree. These gradual differences follow from the partial membership values that cases can have in S, T and Y. The combination of similarities and differences in kind and degree yields the five types of cases presented in table 2. The types and their analytic value have been explained in detail elsewhere (Schneider and Rohlfing 2013, 2014; Williams and Gemperle 2017). We leave it with the definitional summary in table 2 and refer to it where necessary.

The five types of cases are constitutive for four forms of comparison. Each comparison is useful for a different analytic purpose, summarized in table 3 (see for a detailed discussion Schneider and Rohlfing 2013). In the following, we focus on the first two comparisons. Both pursue the goal of causal inference on the mechanism linking a term to the outcome. And for this, the corridor and the attribution principles are relevant.

In the following section, we show that the existing guidelines for typical-iir and typical-typical comparisons only incorporate the implications of *disjunctions* for case selection, but not the corridor and attribution principles. A disjunction is more commonly referred to as "equifinality" in the QCA literature and describes that a solution includes multiple terms that are individually sufficient. Empirical researchers should follow the *unique membership principle* (Schneider and Rohlfing 2013: 563) that calls for the choice of typical cases that are a member of only one term. Compliance with this principle avoids problems of overdetermination because it makes sure that only one term and the associated mechanism can account for the outcome (as always, assuming good data, a strong design etc.). The unique membership principle takes into account that the typical cases that are members of a disjunction might be *empirically heterogeneous*. For the solution produced by Grauvogel and von Soest (2014) with five terms T, there are 2^T-1 possible variants of membership in this disjunction. Because the logical OR operator (+) is a non-exclusive OR, a typical case can, in principle, be a member of only one single term, of any pair, triple or quadruple of terms, or of all five terms simultaneously. The unique membership principle alerts empirical researchers interested in a selected term that only one of the 2^T-1 membership types is ideal for causal inference. In the next section, we demonstrate that *conjunctions* have similar implications for selecting typical and iir cases as *disjunctions* have for typical cases.

Case Selection and Comparisons for Conjunctions

The discussion of case selection and typical-iir and typical-typical comparisons for conjunctions is based on the idea that a cause is a *difference-maker*. For a chain T ⇒ M ⇒ Y, the term T is causal for the mechanism M when the presence and absence of T makes a difference to the presence and absence of M. M is causal for the outcome when the presence and absence of M makes a difference to Y.

Table 2: Types of Cases in fsQCA of Sufficiency

Membership values		Type of case
T > .5	Y ≥ T	Typical
T > .5	Y < T	Deviant consistency in degree
T > .5	Y <.5	Deviant consistency in kind
S < .5	Y >.5	Deviant coverage
S < .5	Y <.5	Individually irrelevant

S = solution; T = term; Y = outcome

Table 3: Types and Goals of Comparisons

Comparison	Goal
Typical vs iir	Inference on mechanism
Typical vs typical	Increase confidence in general mechanism
Typical vs deviant consistency	Search for omitted conjunct
Individually irrelevant vs deviant coverage	Search for omitted conjunction

Since our paper is not a contribution to the ongoing debate on how to infer causation in QCA (for example, Baumgartner 2015), we only want to clarify the following points before we turn to the implications of conjunctions. First, a difference-making perspective on causation aligns causal inference in the truth table analysis and in the process tracing part. The two main algorithms for a truth table analysis, Quine-McCluskey (QMC and its variants, see Dusa 2018) and coincidence analysis (cna, Baumgartner 2013b; Baumgartner and Ambühl 2018), derive minimally sufficient solutions by identifying non-redundant conditions that make a difference for the outcome and that are interpreted as causal.[9] A difference-making perspective on mechanisms establishes a coherent framework for causal inference in an SMMR study, which is not a goal in itself. However, we find a common perspective more straightforward than the unnecessary combination of two different approaches to causality in the truth table and within-case analysis.[10]

Second, a difference-making account is open to multiple theories of causation. The two main candidates for QCA are a regularity theory (Baumgartner 2013a) and a counterfactual theory that, in its present state, is less developed than the regularity theory (Rohlfing and Zuber 2019).[11] As will become clear below, we prefer a counterfactual theory over the alternatives.[12] Our arguments about conjunctions and test corridors hold regardless of the causal theory and the truth table algorithm that is used.

[9] The two algorithms identify redundant and non-redundant conditions differently on a computational level. This is not relevant here.

[10] A difference-making perspective on mechanisms is in line with a large philosophical body of work (for example Dragulinescu 2017).

[11] See Schneider (2018) for further discussions on QCA and theories of causation.

[12] In our view, the main point where the differences between a counterfactual and a regularity theory matter is when unique typical cases and iir cases (negative cases) are not available for constructing the ideal comparison. A counterfactualist could ask what the outcome would be if such a unique member or iir case existed. A regularity theorist would take the lack of the ideal cases as a given and work with the cases that are available. A researcher endorsing a process view of causation (Dowe 2000), which might seem to be natural choice for process tracing (but see Rohlfing and Zuber 2019), would need to follow, instead, only our principles governing the selection of typical cases.

Taking the idea of difference-making as the premise for our discussion, implies that a term T is only causal if each of its conjuncts makes a difference to the mechanism. We explain the importance of this point and the perils of neglecting it by distinguishing between a *focal conjunct*, FC, and *complementary conjunct or conjuncts*, CC, of a term T.[13] FC is the conjunct for which we want to find out whether it makes a difference for the mechanism M. The complementary conjuncts CC represent the other conjuncts of a term T that are not of inferential interest *during a specific comparison*. Affirmative causal inference for a configuration T requires a positive difference-making inference for each conjunct, which means that we need to take each conjunct at a time as the focal conjunct and treat the others as complementary. We first discuss the importance of distinguishing between an FC and CC on an abstract level and then illustrate the arguments with the term comprehensiveness*CLAIMS from our empirical example.[14]

Figure 1 displays four different stylized constellations between the focal conjunct and the complementary conjunct. The gray shades of the markers distinguish the focal conjunct from the complementary conjunct. The marker symbol distinguishes the typical case from the iir case. The ideal scenario for a comparison of both types of cases is presented in the top-left panel. The focal conjunct is the minimum for the typical and the iir case and the iir case is a non-member of FC and a member of CC. If we find evidence that the mechanism M is present in the typical case and absent in the iir case, we can be confident that the difference in M is because of the difference in FC because this is the only conjunct that varies between the two cases and because of an additional reason we lay out next. To give a non-social science example illustrating this point: Imagine a talented cyclist (complementary conjunct) is also known to be a doper (focal conjunct) and has been successful in the past (positive outcome). If you want to know whether doping accounts for the success, for example because of an enhanced ability to recover after a race (mechanism), you need to compare a talented, successful doper to a talented, non-successful cyclist who is known not to be a doper (difference in the focal conjunct). The question then is whether the ability to recover from a race is not enhanced for the talented non-doper, which would show that doping makes a difference for the ability to recover.

In empirical research, the data might not always include a pair of cases that constitute the ideal scenario for comparison. Researchers then have to face one or more of the problems depicted in the other three panels of figure 1. In the following, we discuss each of these problems in turn. Our arguments will show that what we call *problems of attribution for iir cases* (bottom right) and the *no-difference making problem* (top right) cannot occur at the same time for a given case pair. Each of the two problems can, however, coincide with an *attribution problem for the typical case* (bottom left). We start with the problem of non-difference-making as the most severe potential problem for causal inference.

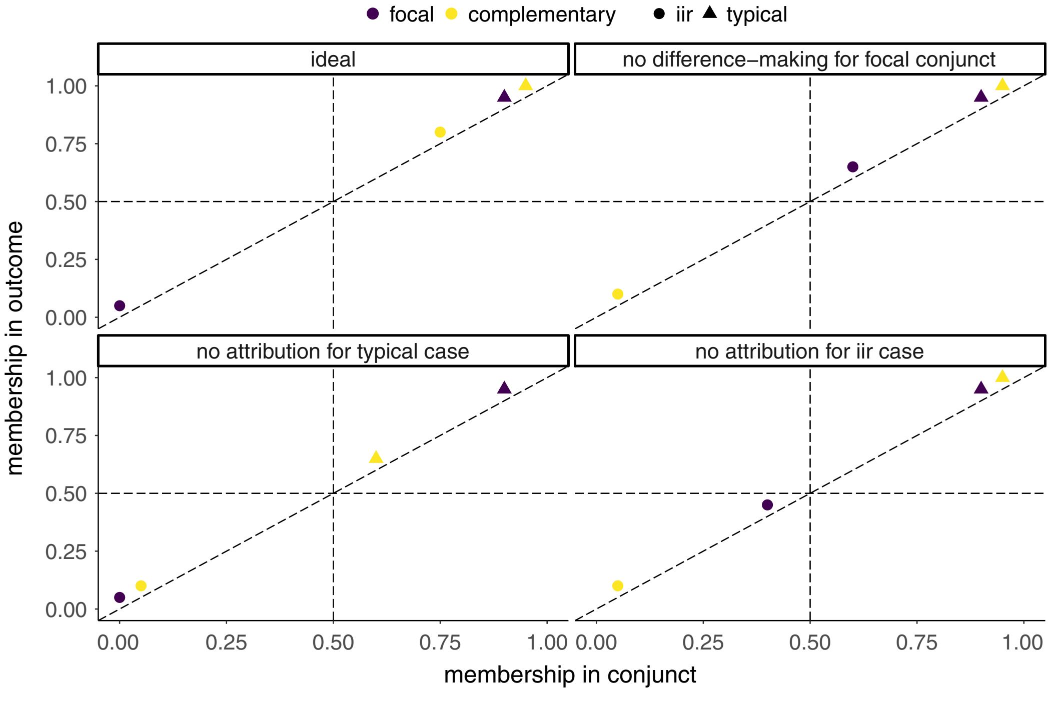
Establishing the Relevant Difference for Non-members of a Term and the Outcome

In an analysis of conjunctions such as comprehensiveness*CLAIMS, the group of iir cases is likely to be empirically diverse. It could be that it is a non-member of

[13] For the discussion of case selection, it does not matter whether CC is a single conjunct or a configuration of conjuncts.

[14] Our arguments about case selection for conjunctions and test corridors are based on formal, logical reasoning. Simulations of how case selection principles work out in repeated trials are not insightful here.

Figure 1: Four Stylized Constellations Between Typical and IIR Cases [Colour figure can be viewed at wileyonlinelibrary.com]



comprehensiveness and a member of CLAIMS; that it is a member of comprehensiveness and a non-member of CLAIMS; or that it is a non-member of both conjuncts. For a configuration with two conjuncts, this means there are three different *subtypes* of iir cases defined by different membership constellations between the conjuncts. More generally, a conjunction with c conjuncts has 2^c-1 possible non-members. The empirical heterogeneity of iir cases complicates case selection because only one subtype of iir case is ideal for causal inference for a specific focal conjunct.

Let us assume that CLAIMS is the focal conjunct in an analysis of comprehensiveness*CLAIMS. In a comparative process tracing analysis of a typical and an iir case, we want to determine whether CLAIMS makes a difference for the operation of the mechanism. Grauvogel and von Soest (2014: 644) propose three mechanisms through which legitimation claims seem to exert their impact on the outcome PERSISTENCE: (1) bolstering of in-group cohesion; (2) delegitimation of criticism of the incumbent as criticism of the nation; and (3) conviction of the population that the ruler is legitimate. The case selection goal is to compare a typical case with an iir case that is identical to the typical case except for its membership in CLAIMS. In short, with the focal conjunct being CLAIMS, we are looking for an iir case that is a member of comprehensiveness*claims to be matched with a typical case for comprehensiveness*CLAIMS.

A comparison of a typical case with an iir case that is a member of COMPREHENSIVENESS*claims would be suboptimal because both conjuncts differ compared to the typical case. If the mechanism is not present in the iir case that is a member of COMPREHENSIVENESS*claims, we cannot tell whether it is because of the difference in CLAIMS, or in comprehensiveness, or both together because the comparison is indeterminate (Lijphart 1971). Obviously, the choice of an irr case that is a member of COMPREHENSIVENESS*CLAIMS is non-sensical because there would be no difference to the typical case in the focal conjunct CLAIMS.

An empirical researcher can easily avoid the pitfall of choosing the wrong subtype of iir case by following the *unique non-membership principle*.

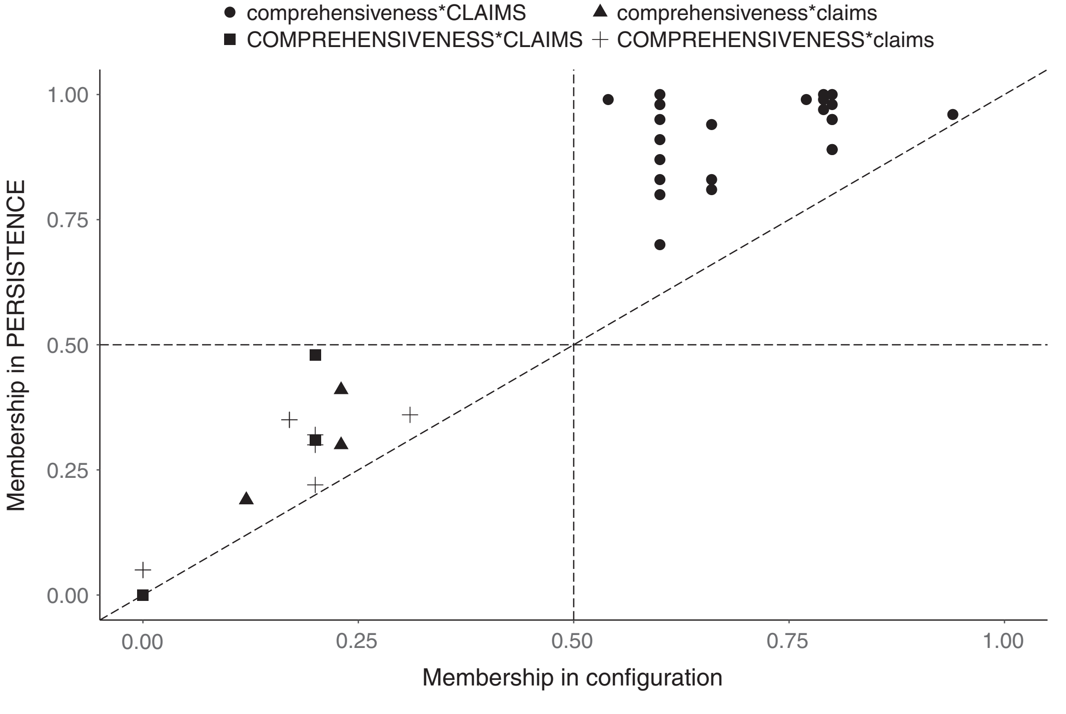
Principle of unique non-membership: An iir case should be a non-member of the focal conjunct and a member of the complementary conjuncts.

Figure 2 illustrates the problem of empirical diversity among the iir cases in our empirical example. All three iir subtypes for the term comprehensiveness*CLAIMS exist in the data. If we take CLAIMS as the focal conjunct, only four out of the 17 iir cases are members of comprehensiveness*claims. If, in turn, comprehensiveness is the focal conjunct, five iir cases are members of COMPREHENSIVENESS*CLAIMS and available for comparison with a typical case. Eight of the 17 iir cases are members of COMPREHENSIVENESS*claims and should not be selected for any comparison with a typical case as long as the superior subtype of iir case is empirically available.

Attributing Membership in Mechanism for Typical Cases and Non-members of a Term and the Outcome

A second complication of typical-iir comparisons derives from a second source of empirical heterogeneity that pertains to typical cases and iir cases. In addition to difference

Figure 2: Subtypes of Non-members of comprehensiveness*CLAIMS



making, a goal of such a comparison is to attribute the case membership in the mechanism M to the case's membership in the focal conjunct.[15] For illustration, let us again imagine that we are studying the conjunct comprehensiveness*CLAIMS and that CLAIMS is the focal conjunct. With regard to the mechanism (see above), we study the bolstering of ingroup cohesion (henceforth COHESION) as a potential link between the term and the outcome.

Imagine we choose to study EU sanctions against Algeria starting in 1992 (typical case *EU_DZA*_92). The case has a membership of 0.6 in comprehensiveness*CLAIMS, which means we would expect to find that the membership of the case in the mechanism COHESION should be equal to or larger than 0.6 because the relationship comprehensiveness*CLAIMS ⇒ COHESION should be consistent. Imagine, in the empirical analysis, we then find that membership in the mechanism is 0.7. The relationship between the term and the mechanism would be consistent, but we have what we call an *attribution problem*. The membership of *EU_DZA*_92 in the focal conjunct CLAIMS is 0.96 and in the complementary conjunct comprehensiveness 0.6. This means we can attribute the case membership of 0.7 in COHESION to the membership in the complementary conjunct because it is less than 0.7 and not to the membership in the focal conjunct because the case's membership in it is higher than 0.96. Empirically, it is possible that the membership in COHESION is more than 0.96 for the case of *EU_DZA*_92. It would be better than the previous constellation, but still not ideal because we could attribute the membership in the mechanism to the focal conjunct *and* the complementary conjunct.

The example shows that the attribution of membership in the mechanism to the case membership in the focal conjunct is only guaranteed when membership in the focal conjunct is not larger than membership in the complementary conjunct. A look at the five unique typical cases for comprehensiveness*CLAIMS shows that only the case of EU sanctions against Syria in 1987 (*EU_SYR*_87) meets this requirement if the focal conjunct is CLAIMS. It has a membership of 0.77 in CLAIMS and of 0.8 in comprehensiveness, which allows for the attribution of the case membership in the mechanism (as long as it is not less than 0.77 because it would render the relationship comprehensiveness*CLAIMS ⇒ COHESION inconsistent). We summarize and generalize this example in what we call the *attribution principle*. The principle extends to iir cases because the goal of attributing the case membership in a mechanism to the membership in the focal conjunct is identical for typical and iir cases.

Attribution principle: The typical and iir case should have their minimum membership in the focal conjunct.

In figure 3, we present the idea of attribution for the conjuncts of comprehensiveness*CLAIMS for typical cases and iir cases in our data. The different shades of the markers indicate whether the case in question holds its minimum membership in the focal conjunct CLAIMS or comprehensiveness. The typical and iir cases are empirically diverse and hold their minimum in different conjuncts. Of all 23 typical cases for the term comprehensiveness*CLAIMS, 14 cases have their minimum in

CLAIMS and nine in comprehensiveness. From the 17 iir cases, eight cases have a minimum membership in CLAIMS and nine cases in comprehensiveness.

For this conjunction, it is possible to select pairs of typical and iir cases that meet the attribution principle regardless of whether CLAIMS or comprehensiveness is the focal conjunct. In general, it is always possible to meet the attribution principle for at least one conjunct because one conjunct necessarily represents the minimum for a specific configuration. Empirically, it might be that the same case meets the attribution principle for multiple conjuncts. This happens when one case has its minimum membership value in two or more conjuncts, which, however, is not the case for the term comprehensiveness*CLAIMS in our example.

A Rank Order of Comparisons for the Analysis of Mechanisms

The best comparison of a typical case and an iir case satisfies the unique non-membership principle and the attribution principle for typical and iir cases. The worst of all comparisons satisfies neither of the three criteria. For applied QCA studies in which the ideal pair of a typical and iir case does not exist, we offer guidance by rank-ordering all eight possible scenarios according to their suitability for the analysis of mechanisms. The rank order asks, first, whether the iir case is a unique non-member of the focal conjunct FC. Second, when the iir case does not meet the unique non-membership principle, we check whether the case is at least a non-member of FC. Third, we ask whether a typical case meets the attribution principle and, fourth, whether the iir case satisfies it.

Figure 3: Attribution of Mechanism Membership for comprehensiveness and CLAIMS

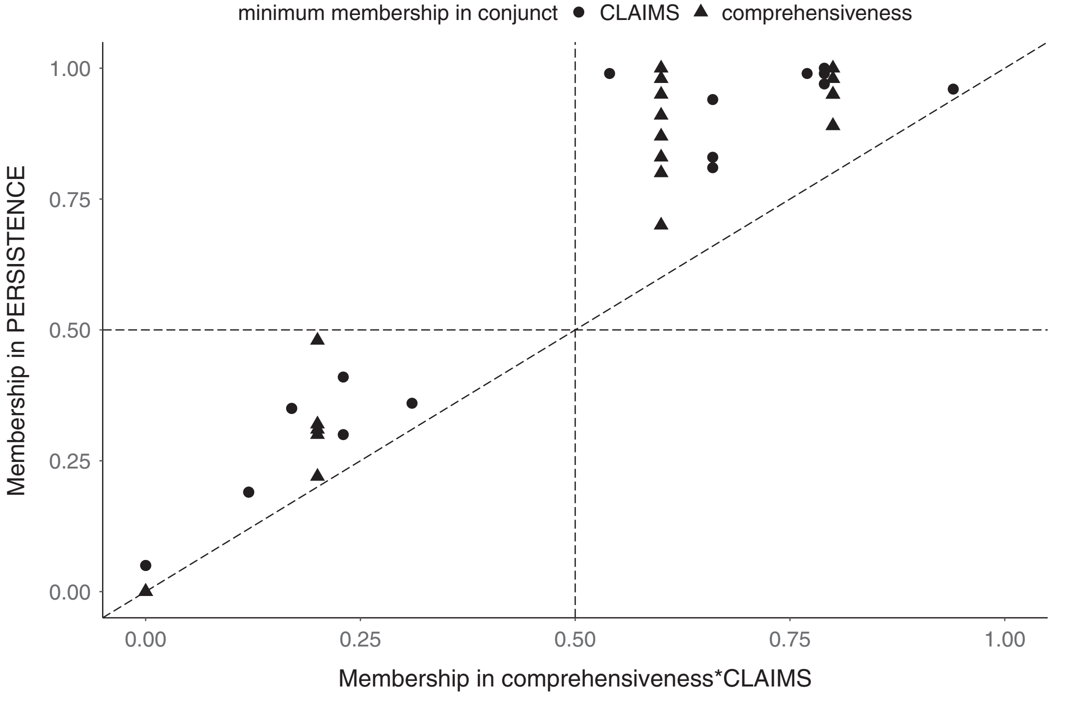


Table 4: Rank Order of Possible Membership Constellations Between Focal (FC) and Complementary Conjunct (CC) in Comparison of Typical and IIR Cases

			attribution	
rank	iir unique non-member	iir non-member	typical	iir
1	✓	✓	✓	✓
2	✓	✓	x	✓
3	x	✓	✓	✓
4	x	✓	✓	x
4	x	✓	x	✓
6	x	✓	x	x
7	x	x	✓	x
8	x	x	x	x

The ranking of case pairs is based on a hierarchy of these four criteria (table 4). The most important criterion is that the iir case is a unique non-member of FC because we want to infer whether a difference in FC makes a difference to the mechanism M. If this is not fulfilled, the second best constellation involves an iir case that is at least a non-member of FC. The two worst pairs of cases involve iir cases that are members of FC and, by implication, unique non-members of the complementary conjunct. Conditional on the type of membership for the iir case, attribution for typical and iir cases is of equal importance. This explains why we assign a shared fourth rank: the limitations to causal inference are the same regardless of whether attribution is impossible for one type of case or the other.

The rank order of constellations of comparisons is the basis for case selection in empirical research. In a first step, each pair of typical and iir cases is assigned to one of the eight ranks. Pairs of cases assigned to a given rank are superior to all pairs belonging to a lower rank. A pair from a lower rank should only be chosen if the higher ranks are empty. *Within each rank*, all pairs of cases are qualitatively identical. When the truth table analysis only involves crisp or multivalue sets, table 4 exhausts all methodological criteria and researchers are free to choose case pairs from the best available rank randomly or based on substantive importance (Schneider and Rohlfing 2013). When fuzzy sets are used, the additional information captured by fuzzy sets can be used to further distinguish among case pairs in the same rank.[16]

For the comparison of two typical cases, only minor modifications of these arguments are required. The unique non-membership principle is not applicable in this setting because typical cases, by definition, are members of the focal conjunct and the complementary conjunct. The attribution principle remains as the only relevant guideline and reduces the number of possible constellations to four (table 5). We assign a tied second rank to two comparisons because there is no genuine reason why attribution for one typical case is better than for the other.

Test Corridors in Case Selection

Two cases that have the same rank in tables 4 or 5 are qualitatively identical and equally suitable choices from the perspective of the underlying principles. In a crisp-set and

[16] See our discussion of corridors and formula-based case selection.

Table 5: Rank Order of Possible Membership Constellations Between Focal (FC) and Complementary Conjuncts (CC) in Comparison of Two Typical Cases

	attribution	
rank	typical 1	typical 2
1	✓	✓
2	✓	x
2	x	✓
4	x	x

multivalue QCA study, the methodological principles that should guide case selection have been exhausted and the actual choice of a case can be made randomly or based on substantive importance of a case. In fuzzy-set QCA (fsQCA), in contrast, empirical researchers should additionally leverage the information about the partial set membership of typical and iir cases in fuzzy sets to choose the best available cases.

Schneider and Rohlfing (2014) recommend choosing cases that, first, have the smallest possible difference in their membership in the term and the outcome and, second, have the highest possible membership in the term. The preference for high membership in the term derives from the idea that full membership in the term and the outcome is the *empirical* ideal type of a typical case. The higher the membership of a typical case in a term, the closer it is to the ideal type. For iir cases, the smaller its membership in the term and the outcome, the more similar it is to the empirical ideal type of an iir case. This reasoning is intuitive, but it is a plain empirical argument and it does not tell us what the added value is of choosing a case that has similar membership in the term and the outcome. We use set theory to develop a simple, formal argument that shows why typical and iir cases with identical membership in the focal conjunct FC and outcome Y are superior to cases with dissimilar membership values.[17] We refer to this as the *test corridor principle*.

> Test Corridor Principle: Choose typical and iir cases with membership scores in the focal conjunct FC and outcome Y that are as similar as possible.

We start with the discussion of typical cases and first take a *crisp-set* view on mechanisms. We add the implications of partial membership values in fuzzy sets and iir cases in the next step. The simplest formalization of a causal argument involving a focal conjunct, a mechanism and the outcome looks as follows: $FC \Rightarrow M \Rightarrow Y$.[18] A test of a hypothesis on the mechanism M can be formalized by specifying the membership values of a typical case in M that would pass a hypothesis test. With crisp sets, we know that a typical case's membership in FC and Y is 1. We *expect* this case's membership in the mechanism M to be 1 as well because only then are both parts of the sequence $FC \Rightarrow M \Rightarrow Y$ empirically consistent. The presence of the focal conjunct in combination with the

[17] Following the discussion of case selection for conjunctions above, we discuss corridors constituted by the focal conjunct and the outcome. For the discussion of the corridor, it does not matter whether the FC is minimum-scoring or not because this only determines whether attribution is possible.

[18] Our arguments generalize to the decomposition of a mechanism into a sequence of intermediate steps each of which is sufficient for the next one (for example, $FC \Rightarrow I_1 \Rightarrow I_2 \Rightarrow I_3 \Rightarrow Y$ (Machamer et al. 2000; Mikkelsen 2017). For ease of discussion, we refer to a composite mechanism M. We use relations of implication here (sufficiency) instead of equivalence (necessity and sufficiency) to allow for the possibility of multiple terms bringing about the mechanism and for multiple mechanisms producing the outcome.

absence of the mechanism would show us that something is wrong with our theoretical argument. Similarly, we would have to conclude that something is off when we observe the presence of the mechanism in combination with the absence of the outcome.

The formalization might seem trivial for crisp sets, but is important to understand because it forms the basis for understanding why typical cases with similar fuzzy-set membership values in the focal conjunct and the outcome are superior choices. For the illustration of this argument, we again use the conjunction comprehensiveness*CLAIMS, comprehensiveness as the focal conjunct and COHESION as the mechanism.[19] Imagine we choose the EU sanctions against Turkey in 1995 (*EU_TUR_95*) as a typical case for process tracing. The case has a membership of 0.6 in comprehensiveness and of 0.91 in the outcome PERSISTENCE. These two fuzzy-set membership values constitute the *corridor* within which we expect the membership value for *COHESION* to be. Membership of 0.6 in comprehensiveness is the *floor* for the expected membership in COHENSION because if it was less than 0.6, the relationship comprehensiveness*CLAIMS ⇒ COHESION would be inconsistent (Mikkelsen 2017). The membership value of 0.91 in PERSISTENCE constitutes the *ceiling* of the case membership in COHESION because the relation COHESION ⇒ PERSISTENCE would be inconsistent if membership in the mechanism was larger than 0.91. Taken together, any membership in COHESION that is not in the corridor of 0.6-0.91 would render one sequence of the chain comprehensiveness*CLAIMS ⇒ COHESION ⇒ PERSISTENCE inconsistent.[20]

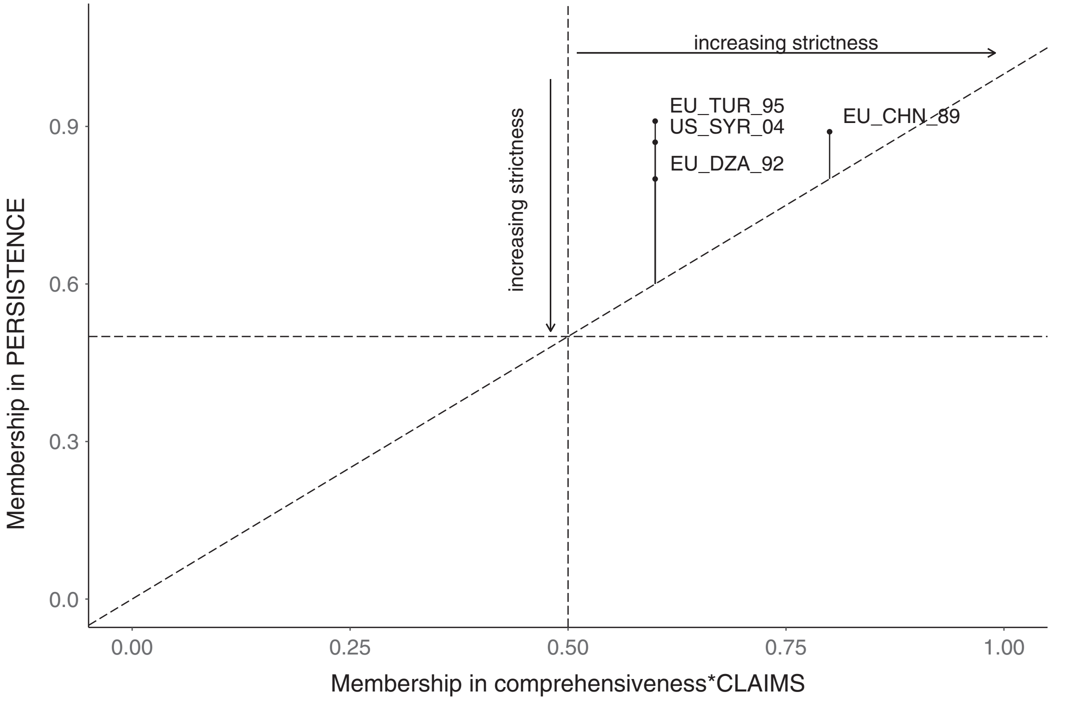
The size of the membership corridor for the mechanism represents the degree of *test strictness* of the process tracing analysis. The smaller the corridor, the smaller the range of fuzzy-set membership values of the mechanism that preserve the consistency of the chain. The smaller the range of membership values in the mechanism that can be inside the corridor, the higher test strictness because it becomes more and more difficult to pass the test. In general, more difficult tests are to be preferred over easier ones (King et al. 1994: chapter 1). A corridor of size 0 maximizes strictness because the only possible membership in COHESION that passes the test is the case's membership in comprehensiveness and PERSISTENCE. A case with membership of 0.51 in comprehensiveness and of 1 in the outcome minimizes strictness because the range of membership values that pass the test is as large as it can be for a typical case.[21]

The idea of corridors is also beneficial in *exploratory* process tracing where no expectation about potential mechanisms exist prior to engaging with within-case evidence. Also in exploratory process tracing the membership in the mechanism that is to be discovered should be within the corridor constituted by comprehensiveness and PERSISTENCE. The smaller the corridor of the selected case, the more we should be able to narrow down the number of candidate mechanisms that fall inside the corridor and the fewer hypotheses have to be tested in a follow-up confirmatory analyses. In exploratory process tracing, compliance with the corridor principle therefore enhances research efficiency.

We now broaden the perspective on the term comprehensiveness*CLAIMS and the focal conjunct comprehensiveness and present the corridors for all four available cases. Figure 4 illustrates that test strictness, *ceteris paribus*, increases with increasing membership in the focal conjunct and decreasing membership in the outcome. The case of *EU_TUR*_95 is the worst case we could pick because it has the largest corridor. For this example, it happens that the case with the highest membership value in the focal conjunct has the smallest corridor and is the best choice for a single-case study (*EU_CHN*_89). This does not always have to be the case and might be different using different data. When two or more cases have a corridor that is of the same size and the minimum for all available cases, it is possible to use the membership level in the focal conjunct (the higher, the better) as a second-order empirical criterion for case selection.[22]

Table 6 takes a comprehensive perspective on all terms in the solution. For each term, it presents the unique typical cases, the focal conjunct in which they have their minimum, the size of the corridor and, for completeness, their membership values in the outcome and the term. The fourth term of the solution presented in table 1 is not in table 6 because it has no unique typical cases.

Figure 4: Strictness of Unique Typical Cases for Focal Conjunct comprehensiveness and Term comprehensiveness*CLAIMS



[22] This differs from the proposal by Schneider and Rohlfing (2014) that attaches more importance to the membership in the term than we do here.

Table 6: Unique Typical Cases and Corridors for Focal Conjuncts of Sufficient Terms

case	term	focal conjunct	corridor	outcome membership	term membership
EU_SYR_87	comprehensiveness*CLAIMS	CLAIMS	0.22	0.99	0.77
EU_CHN_89	comprehensiveness*CLAIMS	comprehensiveness	0.09	0.89	0.80
EU_DZA_92	comprehensiveness*CLAIMS	comprehensiveness	0.20	0.80	0.60
US_SYR_04	comprehensiveness*CLAIMS	comprehensiveness	0.27	0.87	0.60
EU_TUR_95	comprehensiveness*CLAIMS	comprehensiveness	0.31	0.91	0.60
US_PRK_50	linkage*CLAIMS	CLAIMS	0.15	0.95	0.80
US_PRK_93	linkage*CLAIMS	CLAIMS	0.15	0.95	0.80
UN_PRK_06	linkage*CLAIMS	CLAIMS	0.15	0.95	0.80
EU_RWA_94	linkage*CLAIMS	CLAIMS	0.15	0.81	0.66
US_SDN_93	linkage*CLAIMS	CLAIMS	0.15	0.86	0.71
US_FRY_91	linkage*CLAIMS	CLAIMS	0.30	0.96	0.66
US_MMR_88	linkage*CLAIMS	CLAIMS	0.30	0.89	0.59
EU_MMR_96	linkage*CLAIMS	CLAIMS	0.38	0.97	0.59
EU_SDN_94	linkage*CLAIMS	linkage	0.25	0.85	0.60
US_ZWE_02	linkage*CLAIMS	linkage	0.35	0.95	0.60
US_BLR_04	repression*CLAIMS	repression	0.19	0.99	0.80
US_MRT_08	repression*CLAIMS	repression	0.15	0.75	0.60
EU_MRT_08	repression*CLAIMS	repression	0.15	0.75	0.60
EU_GNQ_92	repression*CLAIMS	repression	0.02	0.62	0.60
US_NIC_92	repression*CLAIMS	repression	0.23	0.83	0.60
US_CUB_60	repression*CLAIMS	repression	0.34	0.94	0.60
UN_LBY_92	repression*CLAIMS	repression	0.35	0.95	0.60
US_LBY_78	repression*CLAIMS	repression	0.39	0.99	0.60
UN_IRQ_90	COMPREHENSIVENESS*LINKAGE*vulnerability*REPRESSION	LINKAGE	0.35	0.95	0.60
US_COL_96	COMPREHENSIVENESS*LINKAGE*vulnerability*REPRESSION	multiple	0.14	0.94	0.80
UN_IRN_06	COMPREHENSIVENESS*LINKAGE*vulnerability*REPRESSION	multiple	0.17	0.97	0.80
US_IRN_84	COMPREHENSIVENESS*LINKAGE*vulnerability*REPRESSION	LINKAGE	0.07	0.67	0.60
UN_IRQ_91	COMPREHENSIVENESS*LINKAGE*vulnerability*REPRESSION	LINKAGE	0.08	0.68	0.60
EU_ZWE_02	COMPREHENSIVENESS*LINKAGE*vulnerability*REPRESSION	multiple	0.35	0.95	0.60

Table 6: Continued

case	term	focal conjunct	corridor	outcome membership	term membership
US_SYR_86	COMPREHENSIVENESS* LINKAGE*vulnerability* REPRESSION	multiple	0.37	0.97	0.60

The idea of test corridors can be easily generalized from single-case studies to comparisons. The corridor principle applies to a comparison of a typical case with an iir case and of two typical cases because both focus on the analysis of mechanisms connecting a term to the outcome. The larger the corridor for one or both of the cases, the less strict the comparison becomes. We return to the question of how to make an informed choice when we present formulas that guide empirical researchers in choosing the best available pair of cases.

Regardless of whether we study one case or two cases, the idea of test corridors hinges on the possibility to determine a case's fuzzy-set membership in a mechanism. We agree with Mikkelsen (2017) that this might not be easy to achieve in practice, but that it should not be controversial in principle, for two reasons. First, fuzzy-set membership values are assigned to conditions and the outcome in the calibration stage of the truth table analysis. The mechanism M represents just another set to be calibrated in SMMR. Drawing on arguments in the case study literature (George and Bennett 2005: 49), one could even argue that a within-case analysis enhances the assignment of membership values to the mechanism set because researchers tend to have more and better empirical information about them than on the sets used in the truth table analysis. Second, if we were to study a crisp-set mechanism based on a fuzzy-set solution derived from the truth table, most tests are likely to be inconsistent. Unless the iir case is a full non-member of FC, the relation

Table 7: Criteria Guiding Case Selection for Comparisons in SMMR

form of comparison	typical-iir	typical-typical	typical-dev_{cons}	dev_{cov}-iir
purpose	causal quality of mechanism	validate mechanism	identify omitted conjunct	identify omitted conjunction
strictness	✓	✓	x	x
unique membership	✓	✓	x	implied
unique non-membership	✓	✓	x	x
attribution	✓	✓	x	x
differences in kind and degree	x	x	✓	x
deviance in kind	x	x	✓	x
max-max difference	✓	✓	x	x
max-min difference	x	x	✓	implied
diverse selection	✓	✓	✓	✓
positive outcome	✓	✓	✓	✓
truth table row membership	x	x	x	✓

FC ⇒ M would be inconsistent; and unless the typical case is a full member of Y, the sufficiency relation M ⇒ Y would be inconsistent for any value of Y. Alternatively, one could dichotomize the fuzzy sets and transfer them into crisp sets. This would come at the loss of information and precision and reduce the strictness of the analysis. We conclude that it is possible to follow the idea of test corridors and that it promises significant added value for the analysis of mechanisms based on QCA solutions.

Formula-based Case Selection for Comparisons

Case selection can quickly get challenging in fuzzy-set QCA because multiple principles have to be followed simultaneously (table 7). In this section, we propose algorithms and formulas that implement these principles to assist empirical researchers in choosing the proper cases for a comparison.[23] We broaden the perspective and develop formulas for all four possible comparisons in SMMR (table 3). The principles that feed into the formula depend on the comparison at hand because different comparisons follow different principles. Table 7 summarizes the current state on guidelines for comparisons in SMMR.

In the first row, we present the rationale for the comparison. The other rows capture the criteria guiding case selection and comparisons.[24] The table illustrates that a full-scale SMMR study is demanding because an empirical researchers needs to perform multiple comparisons centered on multiple disjuncts for studies of typical and deviant cases for consistency. We follow existing recommendations (Schneider and Rohlfing 2014) and believe that a SMMR study benefits most from starting with validating *that* a mechanism is in place. Once this has been done in a comparison of a typical case and iir case and two typical cases, a basis has been established for solving the puzzles of deviant cases consistency and coverage (in that order).[25]

We now introduce the formula for each comparison and explain its rationale. For three comparisons, we present one plot illustrating that the formula identifies the best cases that are available.[26]

The ideal *comparison between a typical and iir case* involves a typical case that is a full member of the focal conjunct FC, the complementary conjunct CC and the outcome Y, and an iir case that is a full non-member of FC and Y and a full member of CC. These two cases satisfy all criteria and maximize the difference between the expected membership in the mechanism for the typical case, $M_{TYP} = 1$, and the iir case, $M_{IIR} = 0$. The maximum difference does not have a methodological rationale, but seeks to enhance the empirical contrast between the two cases. If this pair is not available in the data, we propose formula 1 for identifying the pair that comes closest to the ideal. This and the following formulas are more complex than those formulated before in work on SMMR. The increase in complexity is attributable to the larger number of criteria that the formulas have to meet.

$$\begin{aligned} \text{TYP-IIR} = & [1 - (FC_{TYP} - FC_{IIR})] && \text{large difference in focal conjunct} \\ & + [1 - (Y_{TYP} - Y_{IIR})] && \text{large difference in outcome} \\ & + |\min(CC_{TYP}) - \min(CC_{IIR})| && \text{high membership in complementary conjuncts} \\ & + 2 * |(Y_{TYP} - \min(FC_{TYP}, CC_{TYP})| && \text{strictness for typical case} \\ & + 2 * |(Y_{IIR} - \min(FC_{IIR}, CC_{IIR})| && \text{strictness for iir case} \end{aligned} \tag{1}$$

TYP: typical case; IIR: iir case; Y: outcome; FC: focal conjunct; CC: complementary conjunct

Each line in equation 1 formalizes one criterion. The formula is applied to each conjunct of a conjunction for all possible pairs of cases *within* each rank listed in table 4. Smaller formula values indicate more suitable pairs of cases. Figure 5 presents all typical and iir cases that constitute an ideal rank-1 comparison for the conjunct comprehensiveness with regard to the term comprehensiveness*CLAIMS. The two labeled cases connected by the gray line (*EU_CHN*_89 - *EU_FRY*_98}) represent the best pair for comparison according to formula 1.

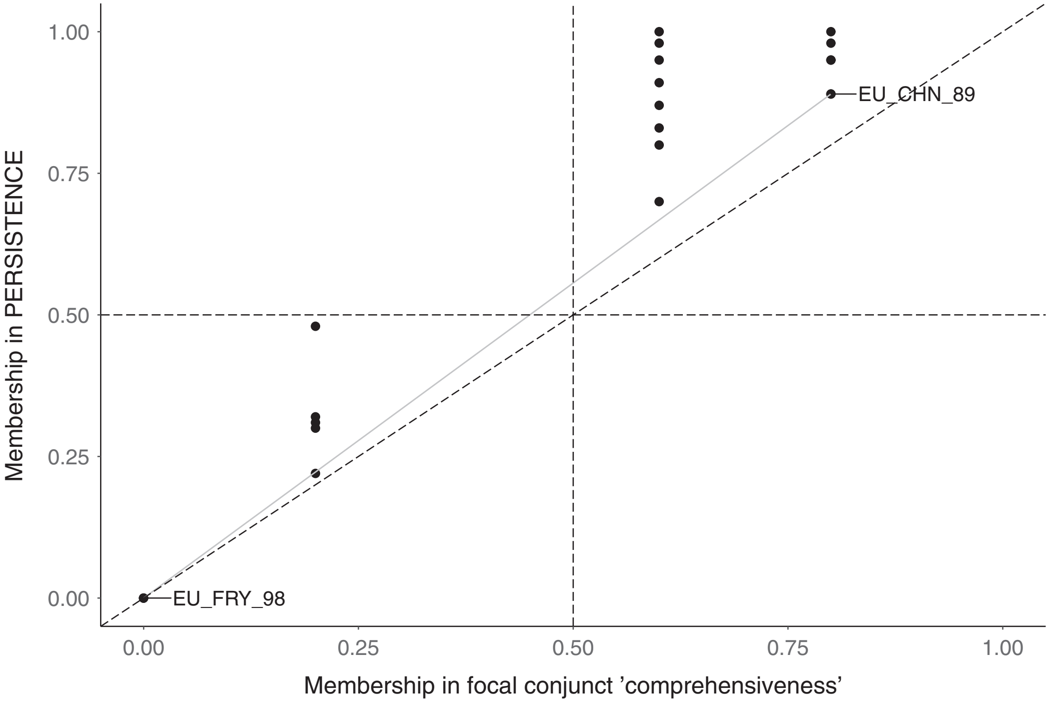
The ideal *comparison of two typical cases* is between a full member of FC, CC and Y and a just-so typical case with the smallest-possible membership[27] in FC and Y and full membership in CC. Applying formula 2 to any pair of typical cases within the ranks of table 5 allows empirical researchers to find the pair coming closest to the ideal.

$$\begin{aligned} TYP_1 - TYP_2 = & [0.5 - (FC_{TYP_1} - FC_{TYP_2})] && \text{large difference in focal conjunct} \\ & + [0.5 - (Y_{TYP_1} - Y_{TYP_2})] && \text{large difference in outcome} \\ & + |(CC_{TYP_1} - CC_{TYP_2})| && \text{small difference in complementary conjuncts} \\ & + 2 * |(Y_{TYP_1} - \min(FC_{TYP_1}, CC_{TYP_1})| && \text{strictness for typical case 1} \\ & + 2 * |(Y_{TYP_2} - \min(FC_{TYP_2}, CC_{TYP_2})| && \text{strictness for typical case 2} \end{aligned} \tag{2}$$

TYP: typical case; Y: outcome; FC: focal conjunct; CC: complementary conjunct

Figure 6 presents the unique typical cases that have their minimum membership in the focal conjunct comprehensiveness for the term comprehensiveness*CLAIMS. The formula yields *EU_CHN*_89 (sanctions of the EU against China in 1989) and *EU_DZA*_92 (sanctions by the European Union (EU) against Algeria starting in 1992) as the best pair of two typical cases. This might seem surprising because figure 6 shows that *EU_ZMB*_96 (sanctions against Zambia by the EU starting in 1996) has the same membership in the term as *EU_DZA*_92 and a smaller corridor. The choice of *EU_DZA*_92 over *EU_ZMB*_96 can be explained with the cases' membership in the complementary conjunct CLAIMS, which cannot be seen in figure 6. The case of *EU_ZMB*_96 has a membership of 0.69 in the complementary conjunct CLAIMS, whereas the case of *EU_DZA*_92 has a

Figure 5: Best Comparison of Typical and IIR Cases for Focal Conjunct comprehensiveness for Term comprehensiveness*CLAIMS



membership of 0.96. Formula 2 privileges larger differences between the focal and complementary conjuncts over smaller ones and identifies *EU_DZA*_92 as the better case for comparison with *EU_CHN*_89.

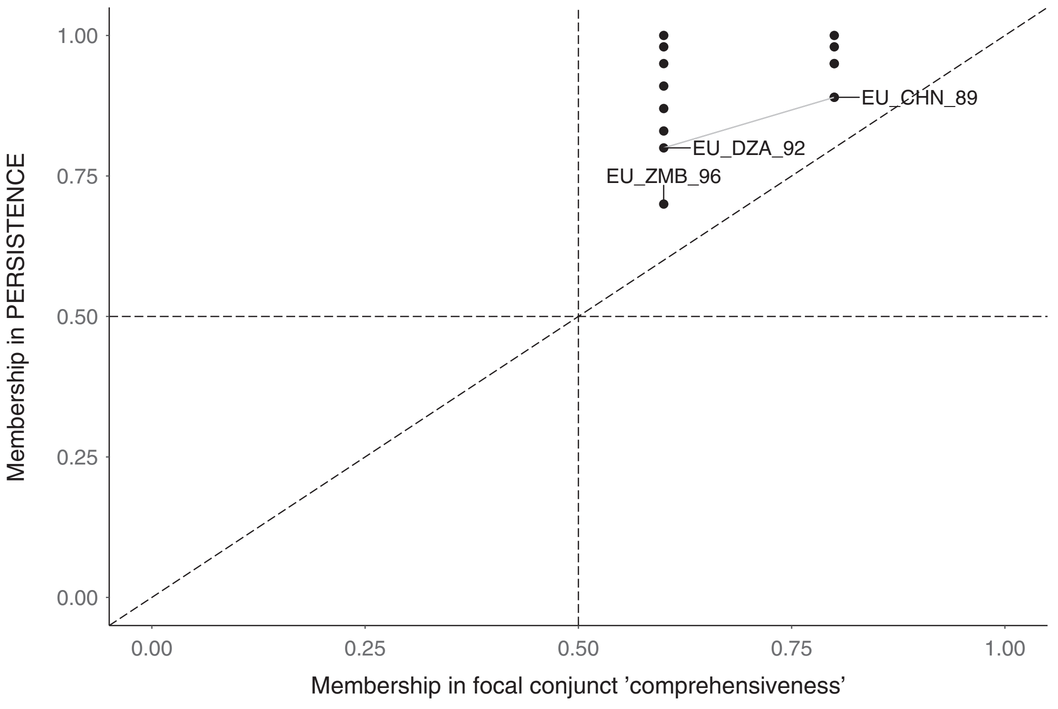
The goal of the *comparison between a typical case and a deviant case consistency* is to identify a potentially overlooked conjunct from a term and to solve the puzzle why one case is a member of the outcome whereas the other is not. The ideal comparison is between the ideal typical case and the ideal deviant case consistency with membership zero in the outcome and full membership in the term. These arguments imply that the best available pair of a typical and a deviant case consistency maximizes three criteria: a small difference in both case's membership in T; a big difference in Y; and a high membership of both in T. The principles formulated for conjunctions do not apply here because there is no known conjunct for which we want to establish that it makes a difference to the mechanism. This allows us to take the sufficient term T as a composite term and as the basis for case selection.

$$\begin{aligned} \text{TYP-DCON} = {} & [(1 - (T_{TYP}) + (1 - T_{DCON})] \quad \text{large membership in term} \\ & + [1 - (Y_{TYP} - Y_{DCON})] \quad \text{large difference in outcome} \\ & + |T_{TYP} - T_{DCON}| \quad \text{small difference in term} \end{aligned} \tag{3}$$

TYP: typical case; DCON: deviant case consistency; T: sufficient term

Figure 7 shows that the best comparison is between the typical case *US_VEN*_06 (US sanctions against Venezuela in 2006) and the deviant case *EU_IDN*_98 (EU sanctions

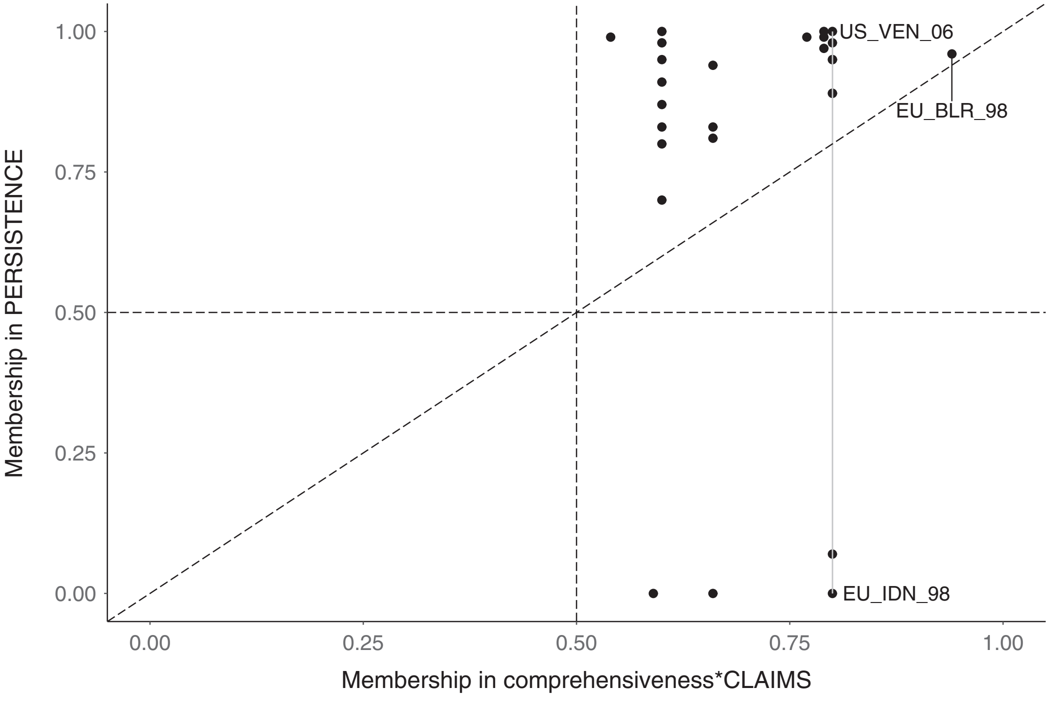
Figure 6: Best Comparison of Two Typical Cases for Focal Conjunct comprehensiveness for Term comprehensiveness*CLAIMS



against Indonesia in 1998). The two cases share the same membership in the term comprehensiveness*CLAIMS and have a maximum difference in the outcome. The plot shows that *US_VEN*_06 is preferred over a typical case that has a higher membership in the term and a very small distance to the diagonal (*EU_BLR*_98). Again, this demonstrates that eyeballing an XY-plot is inferior to applying the formulas we propose because multiple case selection criteria need to be taken into account and not all of them are visualized in an XY plot.

The *comparison of a deviant case coverage and an iir case* targets the second puzzle that one might confront in SMMR - the presence of cases that are members of the outcome without being members of any of the terms that have been identified by QCA. The goal of this comparison is to identify a term that has been omitted from the solution. The comparison of a deviant case coverage with an iir case must match cases from the same truth table row (Schneider and Rohlfing 2013). Taking a row as the basis for case selection, the logic of this comparison is identical to the comparison of a typical with a deviant case consistency: a pair of cases is qualitatively identical with regard to their membership in a term (here, a truth table row) and differs in their membership in Y. This similarity makes formula 4 structurally similar to formula 3 for the comparison of a typical case with a deviant case consistency. Because of the similarity between the two comparisons, we refrain from presenting a plot illustrating the application of formula 4 for a selected truth table row.

Figure 7: Best Comparison of a Typical Case and Deviant Case Consistency for comprehensiveness*CLAIMS



$$\begin{aligned}\text{DCOV-IIR} = &[(1-(R_{DCOV})+(1-R_{IIR})] \quad \text{large membership in truth table row}\\ &+[1-(Y_{DCOV}-Y_{IIR})] \quad \text{large difference in outcome}\\ &+|R_{DCOV}-R_{IIR}| \quad \text{small difference in truth table row}\end{aligned} \tag{4}$$

DCOV: deviant case coverage; IIR: individually irrelevant case; R: truth table row

Conclusion

In this paper, we have contributed to the advancement of SMMR in three ways. First, we have demonstrated that the analysis of conjunctions creates special challenges that need to be taken into account in the case selection stage. These challenges derive from the empirical diversity among the group of typical and iir cases and led us to formulate the principles of unique non-membership for iir cases and the attribution principle for both types. Second, we have formulated the corridor principle and shown that cases with more similar membership values in a focal conjunct and the outcome are superior choices for process tracing. Third, for fsQCA, we have proposed formulas that unify the new principles and existing ones to guide the choice of cases by empirical researchers in their SMMR studies.

Altogether, the requirements for a complete SMMR study are notable. The empirical example we have used involves a solution composed of three terms with two conjuncts and two terms with four conjuncts. The analysis of each focal conjunct of each term would require the realization of 14 single-typical case studies or comparisons. This is beyond the usual number of cases that are studied in process tracing and does not even include the possible within-case analyses on deviant cases.[28] Since the study of mechanisms benefits from its depth (Gerring 2004), QCA researchers should choose the comparisons that are most interesting from a theoretical or empirical perspective. If resource constraints prevent performing all within-case analyses, we suggest to prioritize the comparison between typical and an iir cases, especially if the researcher's primary goal is causal inference. The SMMR framework defines the ideal scenario and allows empirical researchers to assess how much their own study approaches the ideal design.

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Carsten Q. Schneider is Professor of Political Science at Central European University (CEU). His substantive research focuses on political regime change, political and social inequalities, and public speeches of heads of government in democracies and autocracies. His methodological work focuses on set-theoretic methods, in particular Qualitative Comparative Analysis (QCA). schneiderc@ceu.edu

Ingo Rohlfing is Professor of Methods of Comparative Political Research at the Cologne Center for Comparative Politics, University of Cologne. He does research on social science methods, has published the monograph Case Studies and Causal Inference and articles in Comparative Political Studies, Sociological Methods & Research, Political Analysis. i.rohlfing@uni-koeln.de