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Schneider and Wagemann's proposed Enhanced Standard Analysis for Ragin's Qualitative Comparative Analysis: some unresolved problems and some suggestions for addressing them[1]

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Abstract

Ragin's (2008) Qualitative Comparative Analysis (QCA) provides a way of undertaking case-based configurational analysis, focusing on necessary and sufficient conditions. QCA is increasingly used to undertake systematic set-theoretic analyses of small qualitative datasets and, occasionally, to analyse survey datasets. Ragin has discussed the problems caused by the "limited diversity" characteristic of social scientific data, and demonstrated how counterfactual analysis can alleviate these. The Standard Analysis module of his fsQCA software (Ragin 2008) incorporates this counterfactual reasoning approach. Schneider and Wagemann (2012, 2013) argue that there are problems with Ragin's approach and propose an Enhanced Standard Analysis. They focus on the ways in which, during a QCA, necessary conditions can become "hidden" during the analysis of "truth tables" characterised by limited diversity. Our paper, having introduced the necessary background, argues that their proposed solutions introduce new problems, some of a logical kind, and must be treated with care.

Keywords

Qualitative Comparative Analysis (QCA), necessary conditions, limited diversity, set theoretic methods, counterfactual analysis.

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Introduction

Qualitative Comparative Analysis (QCA), developed by Charles Ragin (1987, 2000, 2006, 2008), is a configurational method which analyses the necessary and sufficient conditions for an outcome, or its absence, to occur. Put simply, to establish the sufficiency of a condition, or a combination of conditions, for some outcome, it assesses whether the set of cases with the condition is a subset of the set of cases with the outcome. To establish necessity, it assesses whether the set of cases with the outcome is a subset of the set of cases with the condition. The question of whether QCA establishes causal claims or, less ambitiously, provides complex descriptions and/or predictive claims, continues to be debated. For the purposes of this paper, we can, we think, put this question to one side (see Cooper and Glaesser 2012a for one view). Ragin has also developed methods for using QCA, with both crisp and fuzzy sets[2], in contexts where sufficiency and necessity might be only approximated to, and for using counterfactual analysis to alleviate the problems arising from "limited diversity" in populations of cases (Ragin 2000, 2008). With the term "limited diversity", Ragin draws our attention to a problem that commonly arises in non-experimental social research, especially but not only where our samples are small: the social world, or the section of it from which we gain our data, often fails to supply us with information on all the possible combinations of the putatively causal factors picked out by our theoretical models of the production of some outcome.

QCA is now widely used and there is an increasing demand for texts detailing how it should be employed. An important addition to this literature is Schneider and Wagemann (2012). Their book discusses problems that, it claims, characterise QCA's "Standard Analysis" (see Ragin 2008: chapter 9) procedure and develops an "Enhanced Standard Analysis" (ESA). One key claim is that ESA offers a better way of dealing with the problem of limited diversity than Ragin's Standard Analysis. This claim is repeated in Schneider and Wagemann (2013). Arguments employing "necessary conditions" play a crucial role in developing this ESA. For this reason, we develop our critical arguments by focusing on Schneider and Wagemann's discussion of "hidden necessary conditions". We point to some serious problems, exemplified in their discussion of the work of Stokke (2004, 2007). We argue it would be unsafe to follow the authors' ESA without considering some of its unintended paradoxical effects. We will deal first with their claims concerning "hidden necessary conditions due to incoherent counterfactuals" (Schneider and Wagemann 2012: 221) and, secondly, with those concerning "hidden necessary conditions due to inconsistent truth table rows" (225).

We try, in considering Schneider and Wagemann's claims concerning the sources of hidden necessary conditions, to take a more general approach than they have, not only because we believe this reveals what seem to be serious problems in their analysis, but also because we wish to encourage users of QCA to think in a more general way about the problems they address. We know that, in the past, many researchers using conventional approaches have tended towards rule-following (for example, in the often inappropriate, and merely ritualistic, use of significance testing). We don't want to see something similar happen to set theoretic approaches. They need to be used self-critically. The careful reader of Schneider and Wagemann's work will find ideas and suggestions that could be useful in this regard, such as their suggestions, in their presentation of "Theory-guided Enhanced Standard Analysis", for

[2] By crisp sets, sometimes called standard or conventional sets, we refer to sets where a case has either zero or full membership, scored algebraically by 0 or 1 respectively. In fuzzy sets, a case can also have partial membership, with scores running from 0 (full non-membership) to 1 (full membership). A membership of 0.5 indicates maximum ambiguity of membership (see Ragin 2000; Smithson and Verkuilen 2006).

the use of counterfactuals that Ragin's Standard Analysis procedure might rule out. However, at this stage of development of set theoretic approaches, users of QCA need, we believe, to take a cautious and critical stance towards recommendations for "good" or "best practice" of the sort offered by Schneider and Wagemann.

There are a few notational conventions that we must introduce. If we have a condition or outcome indicated by X, then we will indicate its absence by ~X. However, in quoting and discussing others' work, we will also make use of an alternative notation where upper case, X, indicates the presence of a condition and lower case, x, its absence or negation. We will sometimes use an asterisk, *, as in X*Y, to indicate set intersection, i.e. the conjunction of two (or more) conditions. In some quotes from other authors, however, we also use X**.**Y, following their use of the dot for intersection. Where it does not lead to any confusion we and others also abbreviate X*Y or X.Y to XY. All of X*Y, X.Y and XY therefore indicate the intersection of X and Y. A plus sign, +, as in X+Y, will indicate logical OR, i.e. that either X or Y or both are present. We will use X => O to indicate that X is sufficient for the outcome O to occur.

In order to address the problems in Schneider and Wagemann's use of necessary conditions, we need first to introduce a general problem they aim to address, that of "limited diversity" in datasets and the use of counterfactual analysis to address this. We draw on Ragin and Sonnett's (2005, 2008) treatment and then move on to discuss Schneider and Wagemann's (2012) own claims.

Ragin and Sonnett on Limited Diversity and Counterfactual Cases

Ragin and Sonnett (2005, 2008) note that naturally occurring social phenomena are profoundly limited in their diversity, and that such limited diversity severely complicates their analysis, demonstrating this with reference to the simple hypothetical truth table shown in Table 1. Their focus is on the possible consequences of strong unions (U) and/or strong left parties (L) for the existence of a generous welfare state (G).

Table 1: Simple Example of the Impact of Limited Diversity (Table 8.1 from Ragin and Sonnett 2008: 148)

Strong unions(U)	**Strong left parties (L)**	**Generous welfare state (G)**	**N**
Yes	Yes	Yes	6
Yes	No	No	8
No	No	No	5
No	Yes	?	0

They note that inspection of the table shows a perfect correlation between L and G, offering a simple parsimonious explanation, where parsimony refers to employing fewer causal conditions. This, they note, explains all the observed variance in the outcome. When L is present, so is G. When L is absent, so is G. However, there are no cases combining the absence of strong unions with the presence of a strong left party. They argue that an alternative case-oriented explanation might, given the evidence, favour the claim that the combination of strong unions and strong left parties explains the presence of a generous welfare state. They then claim that which answer is correct depends on the outcome that would be observed for the missing type of case (row 4 of Table 1):

> At a more formal level, which answer is correct depends on the outcome that would be observed for cases exhibiting the presence of strong left parties combined with the absence of strong unions—that is, if such cases could be found. If these cases displayed generous welfare states, then the conclusion would be that having strong left parties, by itself, causes generous welfare states. If these cases failed to display generous welfare states, then the conclusion would be that it is the combination of strong left parties and strong unions that explains generous welfare states. If relevant cases combining strong left parties and weak unions could not be identified, then researchers must speculate: What would happen in such cases? Would generous welfare states emerge? To answer these questions, researchers must rely on their substantive and theoretical knowledge, which in turn would provide the basis for deciding between the two explanations, the parsimonious (single cause) account versus the more complex (combined causes) account. In short, *the choice of explanations is theory and knowledge dependent*. (Ragin and Sonnett 2008: 149, emphasis in original).

They describe the activity of assessing plausible outcomes for missing cases as counterfactual analysis[3]. For the purposes of QCA, with its basis in Boolean algebra, a row like the fourth row of Table 1 is a remainder, "a combination of causal conditions that lacks empirical instances" (Ragin 2008: 155). The solution derived in a QCA of Table 1 focusing on what combinations of conditions are sufficient for the existence of a generous welfare state will vary depending on what counterfactual assumptions are made about the outcome that might be associated with the missing combination of conditions. If this row is excluded from the process of Boolean minimisation[4], then we obtain U*L => G, i.e. the combination of strong unions and strong left parties is sufficient for a generous welfare state. On the other hand, a more parsimonious solution can be obtained here by deciding to allocate the outcome to the missing combination. In this case, the more parsimonious solution would be simply L => G, and is based on the *simplifying assumption* that the missing combination would be sufficient for the outcome G, i.e. that ~U*L => G. This assumption, combined with the empirical finding that U*L => G (from row 1) allows us to argue that it makes no difference to the outcome whether U is present or not, and therefore we are able to derive the solution L => G via Boolean minimisation[5]. As Ragin and Sonnett note (2008: 157) this counterfactual claim makes a very strong assumption, one that many researchers would find implausible. The key point though is that explanations hinge on such counterfactual decisions, even if researchers are not always aware of this. The complex solution itself here, U*L => G, effectively depends, for example, on the assumption that, were any cases of ~U*L to be found, they would *not* have the outcome. The truth of the sufficiency claim that U*L=>G is, of course, not affected by the decision on ~U*L, only the possibility of producing a more parsimonious solution for G.

The crucial point made by Ragin here concerns, we think, the role of theory. Schneider and Wagemann also stress the importance of drawing on theory in many places in their book,

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[3]An introduction to the role of counterfactual analysis in the quantitative and qualitative research traditions can be found in Goertz and Mahoney (2012). See also Thomson (2011) for a related discussion concentrating on QCA.

[4] A researcher might exclude it simply because it has no cases. An analysis would then proceed without any reference to counterfactual analysis.

[5] Boolean minimisation is a key feature of QCA. In general, the idea is to remove redundant conditions by making pairwise comparisons of the sort made here. Through repeated application of the procedure the solution of a truth table can be expressed in a simpler form. Cooper and Glaesser (2012a) argue this may sometimes lead us away from underlying causal mechanisms.

especially when they argue for privileging theory over considerations of parsimony when making choices concerning which logical remainders ought to be used in constructing a solution (e.g. their summary on page 217). However, as we shall see in the next section of this paper, in their discussion of hidden necessary conditions, they often refer primarily to the **empirical** evidence available in making their decisions about such matters as which conditions are **necessary** or not. As an illustration of the approach they take in chapter 9 of their book, we can note three things about the dataset in Table 1. We use the language they use (see their page 222):

Statement N1: U "empirically qualifies as a necessary condition" for G

Statement N2: L "empirically qualifies as a necessary condition" for G

Statement N3: ~L "empirically qualifies as a necessary condition" for ~G

Now, were N1 to be taken seriously, i.e. if we were to accept it as an adequate warrant for the necessity of U for G, then it would follow logically that ~U is sufficient for ~G. We can see the dataset does not allow us to test this claim properly. We lack one of the two truth table rows we need for a *complete* test to be made. A parallel argument applies to statement N3.

We will later explore the implications of this problem for Schneider and Wagemannn's treatment of the Stokke dataset on shaming in the context of fish stocks conservation.

Ragin (2008) develops this discussion of counterfactual analysis further, focusing on the distinction between easy and difficult counterfactuals, and the three solutions that different decisions about remainders can generate in QCA's Standard Analysis: complex, intermediate and parsimonious. We will return to the differentiating features of the three types of solutions below in the context of Ragin's discussion of Stokke's (2004, 2007) study, but we need briefly to explain Ragin's distinction between easy and difficult counterfactuals in order for what follows to be comprehensible. Imagine a QCA focusing on the outcome O and the potentially causal conditions A, B, C and D. Imagine also that the truth table has cases for the row ABC~D but none for the row ABCD, i.e. that ABCD is a remainder. Ragin (2008) argues that, if we have good theoretical reasons for believing that the presence of D, rather than its absence, should contribute to the outcome, then, given that ABC~D is associated with the outcome, we could argue that ABCD would be, since here ~D is replaced by D. ABCD is therefore an *easy* counterfactual. Then, since we now have ABC~D empirically associated with the outcome and ABCD counterfactually so, we can argue that whether D is or is not present makes no relevant difference, and combine these two terms to give the minimised term ABC. By contrast, had we had cases for ABCD, but not for ABC~D, and had still believed that it was the presence of D that was conducive to the outcome, we would not have had good reasons for allowing the remainder ABC~D to be associated with the outcome. ABC~D is a *difficult* or hard counterfactual and we would not want to see it used to enable ABCD to be minimised to ABC unless there were compelling theoretical arguments. The role of such decisions in generating the Standard Analysis's three types of solution will become clearer below where we turn to introducing the three types of solution: complex, intermediate and parsimonious. We do this in the context of Stokke's (2004, 2007) work on resource management.

Ragin on Limited Diversity and Counterfactual Cases: the case of Stokke's work

Stokke's (2004, 2007) research focuses on "shaming" as a strategy for improving the impact of international regimes in the area of resource management. Here, the substance of his work is not our focus, but it is necessary to describe it briefly. He sketches ten cases taken from three regions. These concern cod stocks in the Barents Sea and the North West Atlantic and Antarctic krill stocks in the southern ocean. Shaming aims to expose fishing practices “to third parties whose opinion matters to the intended target of shaming” (Stokke 2007: 503). Stokke argues for five conditions that are likely to lead to successful shaming. These are usefully summarised by Ragin (2008: 167) in his discussion of Stokke’s work. They are:

1. Advice (**A**): Whether the shamers can substantiate their criticism with reference to explicit recommendations of the regime's scientific advisory body.
2. Commitment (**C**): Whether the target behaviour explicitly violates a conservation measure adopted by the regime's decision-making body.
3. Shadow of the future (**S**): Perceived need of the target of shaming to strike new deals under the regime—such beneficial deals are likely to be jeopardized if criticism is ignored.
4. Inconvenience (**I**): The inconvenience (to the target of shaming) of the behavioural change that the shamers are trying to prompt.
5. Reverberation (**R**): The domestic political costs to the target of shaming for not complying (i.e., for being scandalised as a culprit).

Stokke’s outcome measure is successful shaming. Stokke’s ten cases of “shaming” set out in a truth table ready for QCA to be applied are shown in Table 2. In such tables, a 1 is used to indicate the presence of a condition or of the outcome, and a 0 their absence. We have added a column to show the absence of the outcome, ~SUCCESS, since we need this later.

Table 2: Truth table, adapted from Stokke (2007) to include ~SUCCESS as an outcome

A	C	S	I	R	SUCCESS	~SUCCESS	n
0	0	0	**1**	0	0	**1**	2
1	0	0	0	0	**1**	0	2
1	0	0	**1**	0	0	**1**	1
1	0	0	**1**	1	0	**1**	1
1	0	1	1	1	**1**	0	1
1	1	1	0	0	**1**	0	1
1	1	1	**1**	0	0	**1**	1
1	1	1	1	1	**1**	0	1

With five conditions, a fully populated truth table will have 2^5, or 32, rows. It is therefore important to note that Table 2 includes only eight of the possible 32 combinations of the presence or absence of the five conditions. The unsimplified solution of this truth table that uses only the empirical information is given by Stokke (2007), who uses the upper / lower case notation, as Equation 1:

Equation 1: A.c.S.I.R + A.C.S.I.R + A.C.S.i.r + A.c.s.i.r => SUCCESS

This can be reduced, by Boolean minimisation of the first two terms, to the “complex” solution that is reported by fsQCA:

Equation 2: A.S.I.R + A.C.S.i.r + A.c.s.i.r => SUCCESS

Stokke also lists alternative solutions that depend on different *simplifying assumptions* being made about the remainders, i.e. the 24 logically possible rows without any cases that do not appear in Table 2. Such assumptions, as noted earlier, allow the analyst to derive a more parsimonious solution, by allocating either the outcome or its absence to all or some of the missing rows in Table 2. Stokke also considers solutions for the absence of his outcome of successful shaming.

Ragin (2008), using Stokke's truth table to discuss and illustrate counterfactual analysis, notes that the *complex* solution shown in Equation 2 above effectively sets all the remainders to "false", i.e. assumes that, were the missing configurations to be in the truth table, they would have the outcome ~SUCCESS. Ragin also derives the *parsimonious* solution of this truth table, i.e. the solution that is generated when the QCA software is allowed to allocate either the outcome SUCCESS or its negation ~SUCCESS to each remainder row guided only by the criterion of parsimony (i.e. by the desire to reduce the number of causal conditions appearing in the solution). Ragin, it is important to note, stresses, in his general treatment of these types of solution, that neither of these two extreme options seem attractive. The complex solution may be needlessly complex, in so far as it does not use available easy counterfactuals, while the parsimonious solution may be "unrealistically parsimonious due to the incorporation of difficult counterfactuals" (2008: 163). The parsimonious solution is:

Equation 3: ~I + S*R => SUCCESS

where the + indicates logical OR. Ragin explains that the complex and the parsimonious solutions can be seen as the end points of a range of solutions all of which stand in sub- or superset relations with one another. These end points are shown in Figure 1.

Figure 1 (from Ragin 2008)

A·~C·~S·~I·~R +	
A·C·S·~I·~R +	~I +
A·S·I·R	S·R

The left-hand complex solution here is a subset of the right-hand parsimonious solution, this following from the fact that the parsimonious solution includes all of the rows with the outcome from the complex solution as well as some additional remainder rows that have been allocated the solution counterfactually. Ragin notes that other solutions along the complexity/parsimony continuum are possible. Such *intermediate* solutions are determined by which subsets of the remainders that are used to generate the parsimonious solution are incorporated in this revised solution (Ragin 2008:165). As he explains, any available intermediate solutions, given the way they are generated, must be supersets of the complex solution and subsets of the parsimonious solution[6]. As we explained earlier, which, if any, of the logically available intermediate solutions is to be preferred to the complex solution hinges

[6]Schneider and Wagemann (2012) make much of the fact that the Standard Analysis constrains intermediate solutions to fall somewhere on this continuum, i.e. it rules out the use of counterfactuals that are not already incorporated into the parsimonious solution. This is an important issue but not, we think, one relevant to the arguments we make in this paper.

on decisions about easy and hard counterfactuals, i.e. about which remainders should be incorporated into the solution. Ragin (2008: 168-171) uses counterfactual reasoning to determine which remainders should be allowed into an intermediate solution. He decides, for example, looking at the term ASIR from Figure 1 above, that AS~IR would also be likely to produce successful shaming, given that "the fact that it is inconvenient (I) for the targets of shaming to change their behaviour does *not* promote successful shaming". He therefore argues that the condition I can be dropped from ASIR by allocating the remainder AS~IR the outcome, and minimising these two to ASR, since whether we have I or ~I will make no difference to the outcome. By using such reasoning[7] he finally produces the intermediate solution:

Equation 4: A~I + ASR => SUCCESS

It is important to note, given our later discussion of what Schneider and Wagemann (2012) argue about necessary conditions, that Ragin refers (2008: 171) to necessary conditions in discussing this solution. He notes that Stokke (2004) includes condition A in his results, adding A back into Equation 3 to give Equation 4, having tested for its necessity prior to his undertaking sufficiency tests, as recommended in Ragin (2000). The key point in relation to our later discussion of their comments on Ragin's Standard Analysis is that Schneider and Wagemann deem condition A an "empirical necessary condition" since, in Table 2, SUCCESS never occurs without A also being present.

Ragin summarises his discussion of counterfactuals in general, and Stokke's truth table in particular, thus:

> Many researchers who use QCA either incorporate as many simplifying assumptions (counterfactuals) as possible or they avoid them altogether. They should instead strike a balance between complexity and parsimony, using substantive and theoretical knowledge to conduct thought experiments .... QCA can be used to derive the two ends of the complexity/parsimony continuum. Intermediate solutions can be constructed anywhere along this continuum, as long as the subset principle is maintained (that is, solutions closer to the complexity end of the continuum must be subsets of solutions closer to the parsimony end). An optimal intermediate solution can be obtained by removing individual causal conditions that are inconsistent with existing knowledge from combinations in the complex solution, while maintaining the subset relation with the most parsimonious solution. (Ragin 2008: 171-172)

Importantly, the fsQCA software, as part of its Standard Analysis, makes available the three solutions. To generate an intermediate solution the researcher is asked to choose whether, for each condition, the condition should be assumed to contribute to the outcome, when it is present, when it is absent, or when it is "present or absent". We now consider some of Schneider and Wagemann's concerns about this Standard Analysis procedure, concentrating on their discussion of hidden necessary conditions.

Schneider and Wagemann on Stokke and their ESA

Schneider and Wagemann (2012) argue that the Standard Analysis embedded in the fsQCA package (Ragin, Drass and Davey 2006) has weaknesses. In particular, they argue that it can

[7] He also takes account of the requirement that any term in the intermediate solution must contain the conditions specified in the term of the parsimonious solution of which it is a subset (Ragin 2008: 165-6).

yield solution formulas that are based on “untenable counterfactual claims” (2012: 167). Because, they argue, the standard procedure chooses parsimony as the criterion for selecting eligible remainders, “impossible remainders” can be selected, leading to “untenable assumptions” (176). In addition, some remainders that are not considered might actually have provided grounds for good counterfactual claims (177). They also argue that “incoherent counterfactuals” can be used in solutions if the implications of statements – already derived – about necessary conditions for the outcome are ignored.

There is much of interest for the user of QCA in their discussion of these problems. Here, however, we will concentrate on what seems to us to be a major problem embedded in their arguments. It concerns the use they make of “empirical necessary conditions” in both their critical arguments about the Standard Analysis and in the development of their ESA. They, like Ragin in his discussion of counterfactual analysis, use Stokke’s work in their development and advocacy of their ESA.

Schneider and Wagemann on Hidden Necessary Conditions

As we have noted, “necessary conditions” play an important role in Schneider and Wagemann’s arguments. We concentrate our discussion on two of their most developed claims. These concern the ways in which necessary conditions do or do not appear in fsQCA-based analyses of sufficiency. We will concentrate in particular on their claims concerning “hidden necessary conditions” which, we argue, require a critical treatment.

They describe “the disappearance of true necessary conditions” as a fallacy that can arise “due to two, mutually non-exclusive features of the data at hand” (221). These are:

1. Hidden necessary conditions due to incoherent counterfactuals.
2. Hidden necessary conditions due to inconsistent truth table rows.

They discuss the first with reference to Stokke's (2007) dataset and the second using invented data. We raise questions about both, beginning with their discussion of Stokke’s study, and then move on to consider problems in their analysis of the consequences of “inconsistent truth table rows”. The latter will require us to consider further aspects of QCA. We will show that they appear to have mistaken a particular problem for a more fundamental one.

Hidden necessary conditions due to incoherent counterfactuals

We have Stokke’s (2007) truth table in Table 2. As already noted, of the 32 possible rows, only 8 are present with cases, leaving 24 as remainders. Schneider and Wagemann (2012: 222) note that a parsimonious solution of this truth table is “~I + SR => SUCCESS” (our earlier Equation 3)[8]. They then argue:

> From this one might be tempted to conclude that no condition is necessary, for none of them appears in both sufficient paths. However, as a glance at the truth table

[8]They add, in a footnote, that Stokke himself in his 2007 paper and Ragin and Sonnett (2005, 2008) have discussed this. It is worth noting what these authors say. Ragin and Sonnett (2005) note, “Notice, for example, that all four causal combinations in Table 3 linked to successful shaming include the presence of A, the support of the regime's scientific advisory board. This commonality, which **could** be a necessary condition for successful shaming, would not escape the attention of either a case-oriented researcher or a practitioner interested in using shaming as a tactic for stimulating compliance.” (our emphasis) Stokke himself seems to take the line that the data at hand is *compatible* with A being a necessary condition (Stokke, 2007, 507).

readily reveals, condition ADVICE (A) is present in all instances of successful shaming. It therefore empirically qualifies as a necessary condition.

The "empirically" is important here, as we shall see later, but, first, we summarise Schneider and Wagemann's argument concerning this "hidden necessary condition". They ask why it hasn't appeared in Equation 3. The answer lies, they note, in the treatment of remainders when a parsimonious solution is generated by the fsQCA software. In generating a parsimonious solution, remainders can be allocated either the outcome or its absence according to the effect of such decisions on the parsimony of the solution. They set out the sixteen remainders that have been associated with the outcome, SUCCESS, in order to generate the solution in Equation 3. Simplified algebraically, they are (Schneider and Wagemann: 223):

~A~C (~S~I~R + ~S~IR + S~I~R + S~IR + SIR) +

~AC (~S~I~R + ~S~IR + S~I~R + S~IR + SIR) +

A~C (~S~IR + S~I~R + S~IR) +

AC (~S~I~R + ~S~IR + S~IR)

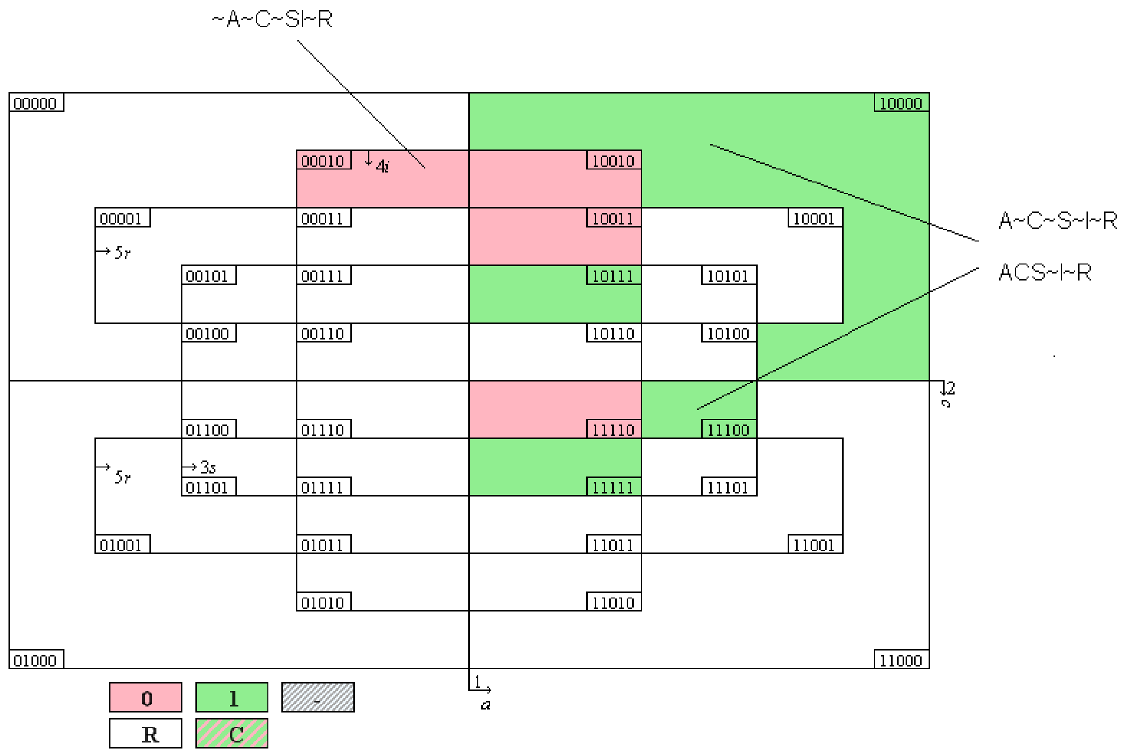
They note that ten include the absence of the "necessary" condition, A, adding, "it is because of these incoherent assumptions that the necessary condition A is deemed logically redundant and is minimised away from the parsimonious solution term" (223). The example they provide is that truth table row 2, A~C~S~I~R, after being matched with the remainder ~A~C~S~I~R, becomes ~C~S~I~R. After further minimisations involving this new term and its minimised descendants, we eventually get to the claim **~I => SUCCESS** that forms part of Equation 3. They then argue:

> This means that every single combination containing ~I either empirically implies the outcome or is assumed to imply it, regardless of whether it logically contradicts the statement that A is necessary for SUCCESS. This example suggests that the disappearance of necessary conditions from statements of sufficiency is caused by wrong-headed assumptions about logical remainders. In fact, if condition A is necessary for SUCCESS …, then this implies that there cannot be any simultaneous occurrence of ~A and SUCCESS. In other words, whenever we see a configuration containing ~A, we expect the outcome SUCCESS *not* to occur. Assuming that in the presence of ~A outcome SUCCESS occurs – as we do for the most parsimonious solution when including remainders containing ~A – contradicts our conclusion drawn from empirical observation, namely that SUCCESS occurs only when condition A is present, and that the latter should therefore be interpreted as a necessary condition. In section 8.2, we have labelled such assumptions incoherent counterfactuals. (Schneider and Wagemann 2012: 223)

Their solution to this problem is "straightforward: do not make any such incoherent assumptions" (223-4). In their "enhanced most parsimonious solution" no use will be made of "remainders containing the absence of the necessary condition" (224). They proceed to apply this suggestion to Stokke's data. This produces the solution "A~I + ASR => SUCCESS" (our earlier Equation 4). Here the "necessary" condition A appears in all terms, as they want. As part of their ESA, one must undertake analyses of necessity prior to those of sufficiency. The danger, they say, of hiding the presence of a necessary condition can be avoided if their procedure is used[9].

Now the question arises of the value and safety of their approach. There are prima facie grounds for doubt. The main one is that we appear to be getting something out of nothing, or at least out of not very much. Much hinges on the claim that A is necessary for SUCCESS, to which we now return. Is the claim well-founded? They claim, "… SUCCESS occurs only when condition A is present, and that the latter *should* therefore be interpreted as a necessary condition" (223, our italics). However, we only have 8 of the 32 possible rows from the full property space. As they note (see the quote above), were A to be a necessary condition for SUCCESS, we would be able to derive the parallel claim, by simple logic, that ~A would be sufficient for ~SUCCESS. One "empirical" check on the claim for the necessity of A for SUCCESS, then, would be to look at rows where A is absent in order to confirm that SUCCESS is also absent for these rows. In a fully populated truth table with five conditions there would be 16 rows containing the absence of A. It can be seen from Table 2 that we have just one. 15 are missing. The Venn diagram in Figure 2, drawn with the help of the TOSMANA software (Cronqvist 2007), brings the problem out very clearly.

Figure 2: the 32 configurations (sets) generated by examining SUCCESS=f(ACSIR)



Here, ones indicate the presence of a condition and zeros its absence[10] (Cronqvist 2007). The non-shaded cells are the remainders. The left hand side of Figure 2 shows the 16 configurations relevant to this test of the corollary of the necessity claim. Just one is available (~A~C~SI~R). This should make us question the soundness of the claim that A is necessary,

[9] They note that another way of avoiding the disappearance of a necessary condition, already noted by Stokke himself, and Ragin and Sonnett, is to just add it back into the Standard Analysis's parsimonious solution.
[10] The shading and cross-hatching, as the key indicates, represent sets with the outcome (1), without the outcome (0), remainders (R) or sets with contradictory outcomes (C).

unless there is very strong theoretical evidence (or evidence from other studies) that A is indeed necessary for SUCCESS, and ~A sufficient for ~SUCCESS. However, Schneider and Wagemann rely on the evidence from the eight available rows.

This opens up a critical line of argument, one that draws on their favoured criterion of “incoherence”. We can use their own approach to undermine the validity of their solution in Equation 4. Let’s look again at the truth table (Table 2), focusing on the absence of SUCCESS, i.e. ~SUCCESS . We can see that, based on the 8 existing rows, condition I is, “empirically”, a necessary condition for ~SUCCESS. Now, given this, ~I should logically be sufficient for SUCCESS. As was the case in their argument, we cannot fully test this corollary of the necessity claim. Table 2 has only two of the relevant 16 rows with I=0 (labelled A~C~S~I~R and ACS~I~R in Figure 2)[11]. Nevertheless, following Schneider and Wagemann’s own procedure, we will use this claim, derived from the eight rows, exactly as they used the claim that A is necessary, i.e. to draw new conclusions “logically” from “empirical” premises.

Here is the argument. We have shown, using their line of reasoning from “empirical” necessity claims, but focusing on the negated outcome ~SUCCESS, that ~I should be sufficient for SUCCESS. However, their recommended ESA did not generate ~I as a term in its solution (Equation 4). In their presented solution, ~I must be conjoined with A. Using their reasoning from “empirical” necessity, however, but in relation to I and ~SUCCESS rather than A and SUCCESS, we should also have had, e.g., ~A~I appearing as sufficient. This is because ~I is sufficient and therefore every configuration that is a subset of ~I should also be sufficient. ~A~I is one such configuration. But ~A~I being sufficient contradicts their claim that A is necessary. The use of their approach, arguing from “empirical necessary conditions”, leads to two contradictory claims. Their initial argument claims A is “empirically” necessary but our parallel argument, using their approach, leads to the conclusion that ~A~I is sufficient, even though it lacks A. Put another way, the remainder ~A~C~S~I~R would be ruled out by their original argument (that A is necessary for SUCCESS) but made compulsory by our new argument (that ~I is sufficient for SUCCESS, derived from I being “empirically” necessary for ~SUCCESS). This seems to be having your cake and eating it[12]. There is an alternative way of presenting this problem with their approach, which we give now.

Schneider and Wagemann say we should draw conclusions concerning remainders from the fact that, in Table 2, A is “empirically” necessary for success. To allocate remainders without A the outcome would contradict this “empirical observation”. This decision is based, we noted, on only some of the logically possible relevant configurations. This “fact” concerning necessity can be rewritten as ~A is sufficient for ~SUCCESS.

However, observation also shows that, in Table 2, I is “empirically” necessary for the negated outcome, ~SUCCESS. This means that we should, on their argument from empirical observation, rule out any remainders having the negated outcome that contradict this “fact”. Now, this “fact” implies that ~I is sufficient for ~(~SUCCESS), or that ~I is sufficient for SUCCESS.

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[11] We have twice as many as they have for their argument from the necessity of A for S, but this is still, we think, not enough.

[12] These are the 8 remainder rows that clash in relation to the 2 ESAs: acsir, acsiR, acSir, acSiR, aCsir, aCsiR, aCSir and aCSiR.

However, now we see where this argument from "empirical observation" in the face of limited diversity breaks down. We have these two "empirical" statements:

~A is sufficient for ~SUCCESS (Statement 1)
~I is sufficient for SUCCESS (Statement 2)

Now consider the remainder ~ACS~IR, a subset of both ~A and ~I.

- Statement 1 says it must have the negated outcome
- Statement 2 says it must have the outcome

The repeated use of their form of argument, from "empirical necessary conditions" - part of their ESA - produces a contradiction. More generally, drawing statements from incomplete truth tables to use subsequently as the basis for **logical** reasoning seems problematic. It is always likely to produce this type of contradiction. It goes beyond the data in a way that is unjustified. Since it is exactly when truth tables are incomplete that the procedure is "needed", we must conclude that it offers less than claimed.

We have used Schneider and Wagemann's discussion of Stokke's truth table to raise concerns about the use of "empirical" necessary conditions as the premises for arguments. In the chapter of their book preceding this discussion, they use the same procedure in discussing other problems that they say characterise Standard Analysis. We will discuss just one more of these here: the "incoherent counterfactuals" that can arise from "contradictory assumptions". Here they use data from Lipset's (1959) study of the requisites for the survival of democracy, referring to Ragin's (2009) fuzzy set based analysis of the dataset. Ragin considers five potential causal conditions: economic development, urbanisation, literacy, industrialisation and political stability. Schneider and Wagemann (2012: 204) show that parsimonious solutions for the outcome and its negation can include some of the same logical remainders. This is clearly worrying, since in one case the remainders will have been assumed to lead to the outcome, but in the other to its negation. This arises, they argue, because the selection of remainders here is driven here solely by the goal of parsimony. They then claim that the same problem can arise even if only easy counterfactuals are employed. However, they derive their directional expectations for the easy counterfactuals for ~S (democracy not surviving) by "taking into account the finding that L (high literacy rate) and G (political stability) are necessary conditions for S". The same argument is used in Schneider and Wagemann (2013)[13]. But, as in the Stokke case, there is limited diversity: only 9 of the possible 32 truth table rows have cases. The claims concerning necessity are therefore based on very limited evidence. Furthermore, if L is necessary for S, then we should expect to find ~L being sufficient for ~S (and, indeed, this is one of their directional expectations for ~S). However,

[13] They argue:

The analysis of necessity reveals that high literacy rate (L) is an almost perfectly consistent superset for the outcome survival of democracy (S). Its consistency of 0.99 and coverage of 0.64 allow it to be interpreted as a nontrivial necessary condition (Ragin 2009b: 114). Also, the condition "politically stable countries" (G) can be interpreted as necessary for S (consistency 0.92; coverage 0.71). Hence,

$L \leftarrow S$; $G \leftarrow S$.

Declaring L and G as necessary conditions for S implies that S cannot be observed without L and G being present. This, in turn, implies that any logical remainder that contains ~L or ~G *cannot* be assumed to be sufficient for S (Schneider and Wagemann 2013: 212-213).

of the 16 rows that include ~L, just two are available in the truth table, with 14 missing[14]. This is exactly the problem we have discussed in respect of their treatment of Stokke's truth table. Our concern in mentioning this example is not with the basic claim – that incoherent counterfactuals and contradictory assumptions can occur when a QCA is performed in the context of limited diversity – but rather with the recommended use of "empirical" necessary conditions in QCAs. This, as we have shown for the case of the Stokke dataset, brings its own danger of introducing contradictions. It is important to add that the solution for the negated outcome is explicitly rejected by Ragin (2009: 117) on the grounds that "some of the simplifying assumptions that it incorporates are theoretically or empirically untenable".

Faced with limited diversity, it is possible to make valid, if not complete, *sufficiency* statements based on the evidence available. Even if new evidence comes to light, it cannot contradict the statements already derived from the truth table, only allow possible further Boolean simplification of them. Any such new solutions will be supersets of the earlier ones. This is not the case for *necessity* statements. The secure testing of necessity statements is only possible in very special circumstances, i.e. when every possible instance of the *absence* of the hypothetical necessary condition under study happens to have empirical cases.
How might we address this problem in empirical research where we have limited diversity? One way forward might appear to be to carry out a more exhaustive search for "empirical necessary conditions" during the process of addressing the limited diversity in a truth table. In the case of Stokke, as we have shown, this would involve searching for the "empirical necessity" of a range of conditions, "necessary" not just for the outcome but also for its negation. In the case of the Stokke data, following Schneider and Wagemann's procedure, one would then rule out using any remainders as simplifying assumptions that contradict either their "empirical necessary condition" or the one we added. But, as we saw, using our "empirical necessary condition" allows us to argue that ~A~I should be sufficient while theirs ruled this out, generating a logical contradiction. Since it is well-known that any statement at all can be derived from a logical contradiction, this cannot be a satisfactory way to proceed. The basic problem here arises from using logical deduction on two premises that have been chosen, inductively, on the basis of limited evidence. For us, this suggests that the procedure suggested by Schneider and Wagemann is inherently problematic, given a less than complete truth table – exactly the situation it is intended to address.

Is there a less problematic way of addressing the problem? One response is to focus less on logic applied to premises concerning "empirical necessary conditions" derived from incomplete truth tables and, instead, to focus, as Ragin (2008: 163) recommends[15], on what theory and substantive knowledge of cases can suggest concerning remainders. In the case of the Stokke dataset, for example, one would consider carefully whether it made theoretical sense to consider A to be a necessary condition. Is it possible to conceive of cases (or do they exist elsewhere) where the outcome could occur in the face of ~A? In the case of Stokke's analysis, this might be the case, i.e. one can imagine a successful case of shaming in which the shamers cannot refer to recommendations of a regime's scientific body, but where other factors compensate for the lack of this, rendering A non-necessary. Such reasoning should, of course, be combined with an examination of its consequences for the analysis. One would still want to avoid contradictory simplifying assumptions, i.e. the use of the same remainders

[14] They also include a footnote (Schneider and Wagemann 2012: 204) in which they say it is possible to generate counterfactuals that contradict the statements of necessity of L and G for S. Again, they reason here from "empirical" necessity.
[15] Schneider and Wagemann themselves often refer to the importance of case knowledge and theory, for example in developing their Theory-Guided Enhanced Standard Analysis, but, in discussing Stokke and their ESA, the stress is on logic.

in solutions for both the outcome and its negation. It may also be possible to rule out some configurations as logically impossible combinations, as in Schneider and Wagemann's example of a pregnant man. However, it is important not to claim there is some universal solution to the problems caused by limited diversity. Our own work with QCA has often used large n datasets (e.g. Cooper 2005; Cooper and Glaesser 2011a, 2012b; Glaesser and Cooper 2011, 2012, 2013). In this context case knowledge may be relatively lacking and existing theory will need to be prioritised when faced with limited diversity (which, even given large n, does occur). On the other hand, in some small n settings – those where there is little existing work – existing theory may be in short supply and case knowledge will come to the fore. All of this can be achieved while using Ragin's Standard Analysis. In addition, if the analysist wishes to include a remainder that is omitted by Standard Analysis's initial focus on parsimony, this can easily be added after theoretical reflection on the full range of truth table rows, as recommended by Schneider and Wagemann (2012, 2013). We turn now to their second key claim, that concerning "hidden necessary conditions" due to inconsistent truth table rows.

Hidden necessary conditions due to inconsistent truth table rows

Schneider and Wagemann (21012) begin their second section on "hidden necessary conditions" by noting that, unfortunately, incoherent assumptions about remainders are not the only reason for the disappearance of necessary conditions. They state that necessary conditions can disappear even from a conservative solution term (their preferred term for what we have, along with Ragin, termed a complex solution). This can arise, they say, when "inconsistent truth table rows are included in the logical minimisation that contain the absence of the necessary condition" (225). By "inconsistent" rows, they refer to rows containing cases where some achieve the outcome and some do not. They illustrate this possibility with the hypothetical example reproduced here as Table 3. They note this table "does not suffer from limited diversity" (though others might think, depending on the inadequacy of their case knowledge, that rows with just one or two cases do constitute limited diversity).

Table 3: Schneider and Wagemann's (2012) Table 9.2

	Conditions			Outcome			
Row	A	B	C	Y	Cases with Y	Cases with ~Y	Consistency for Y
1	0	0	0	0	0	1	0
2	0	0	1	1	20	0	1
3	0	1	0	0	0	39	0
4	0	1	1	0	0	15	0
5	1	0	0	1	10	0	1
6	1	0	1	1	15	0	1
7	1	1	0	1	4	1	0.8
8	1	1	1	0	0	2	0

In order to assess the validity of their argument, we need to introduce the measures of consistency with sufficiency and necessity that are employed in the fsQCA software. Given that their truth table is built on the basis of crisp sets where a case in either fully in or fully out of the set, these concepts are straightforward[16]. For strict sufficiency of a condition, or a conjunction of conditions, X for Y we need, wherever X is present, to find Y also present. This requires the subset of cases with the conditions X to be a subset of the cases with the outcome Y (shown as the left-hand side of Figure 3). For strict necessity of a condition Z for Y, on the other hand, we need, given the outcome Y, always to find the condition Z present. This requires the set of cases with the outcome Y to be a subset of the set of cases with the condition Z (shown as the left-hand side of Figure 4). In practice, subset relations in the social world are frequently not as perfect as these.

The more realistic right-hand sides of the two figures show such approximations to sufficiency (Figure 3) and necessity (Figure 4). Ragin uses, for crisp sets, a simple measure of the closeness of such relations to strict subsethood. Consider sufficiency. On the right-hand side of Figure 3, he takes the proportion of cases in X that fall within the boundaries of Y as a measure of the consistency of these data with sufficiency. Such imperfect subset relations are usually described with the terms quasi-sufficient (and, for necessity, quasi-necessary). In the case of Figure 3, the right-hand side would give us a consistency of the order of 0.8, usually taken as large enough in the literature to support a claim of quasi-sufficiency.

Figure 3: strict and quasi-sufficiency of X for Y

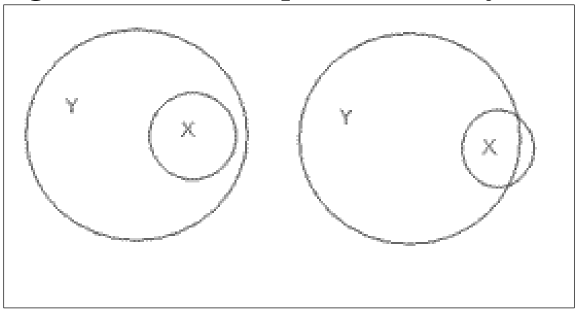
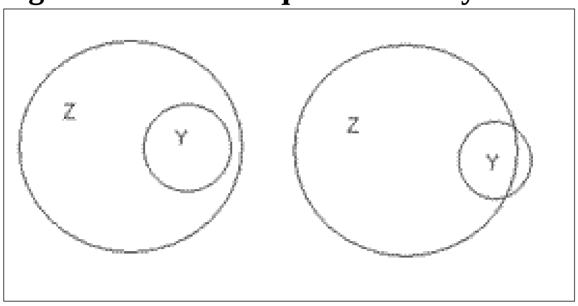


Figure 4: strict and quasi-necessity of Z for Y



After these preliminaries, we can return to Schneider and Wagemann's argument. Looking at row 7 of Table 3, it can be seen that, of these five cases that are AB~C, four have the outcome Y. This configuration is therefore quasi-sufficient for Y, with a consistency of 0.8. If we run a QCA on the truth table in Table 3 that allows row 7 to go forward (i.e. if we accept a consistency of 0.8 as adequate for quasi-sufficiency) we obtain the following minimised solution:

Equation 5: A~C + ~BC => Y

The first term, A~C, has a consistency with sufficiency of 0.93 and the second, ~BC, of 1.0.

[16] This is not the case when fuzzy sets are used (see, e.g., Ragin 2006).

As Schneider and Wagemann note, no single condition appears in both paths and one might be “tempted to conclude there is no necessary condition for Y” (226). They note, however, that separate tests for necessary conditions show ~B to be necessary for Y, with a very high consistency of 0.92[17]. They argue that, “based on the empirical evidence, we have good reasons to consider ~B to be a relevant necessary condition for Y”. They give this reason why it has disappeared:

> Why, then, is ~B not part of all sufficient paths in the conservative solution? Necessary condition ~B is logically minimized from the sufficiency solution by matching row 5 of Table 9.2 (A~B~C) with the inconsistent row 7 (AB~C) into the sufficient path A~C. ... thus, the necessary condition disappears from the sufficiency solution because both the former and the latter are not fully consistent. In other words, this is an example of a hidden necessary condition due to inconsistent subset relations. (226)

This, we think, is far from the whole story. To see why, consider a small change in the truth table, one that removes the problem of inconsistency. Assume, contrary to what we see in Table 3, that all five cases in row 7 achieve the outcome Y. What then happens when we undertake a QCA that parallels that reported by Schneider and Wagemann? On the basis of changing just one case from not having to having the outcome, we obtain the same algebraic solution as in Equation 5 (though in this case both terms are strictly sufficient, i.e. have consistencies of 1). And, once again, ~B is quasi-necessary for Y (with a consistency of 0.90). We have no inconsistent rows, but we still see the “problem” Schneider and Wagemann are addressing.

This clearly suggests that the problem of a hidden necessary condition concerning Schneider and Wagemann is not due to the inconsistency of row 7 per se. What then is its cause? A glance at the truth table shows there are quite different numbers of cases in the rows. It is instructive to undertake another analysis. If we increase the number of cases in row seven to 40, but retain the proportion in this row achieving the outcome at 0.8, we obtain the same solution for sufficiency (with the first term having a consistency of 0.84 and the second of 1), but we now find that a test for the necessity of ~B returns a consistency of only 0.58. ~B is no longer a hidden quasi-*necessary* condition. The “problem” disappears. It seems that the inconsistency of row 7 is not in itself the fundamental problem. We can remove the problem of the disappearance of ~B by reweighting so that it is no longer a necessary condition in the first place. We also showed that ~B, when it is a necessary condition, can disappear from the solution even in the absence of this inconsistency.

The fundamental problem is not due to inconsistencies per se (though these will modify the way it appears) but to the relative numbers of cases in the rows of a truth table, coupled with the manner in which the arithmetic of proportions works. Indeed we can make the problem much worse by running the analysis with just one case in row 7 – *a case which has the outcome* ; again therefore with no inconsistency characterising this row. Doing this, we obtain the solution for sufficiency in Equation 5 (with both terms having consistencies of 1) while the consistency with necessity of ~B rises to an almost perfect 0.98.

Clearly, Schneider and Wagemann have, in choosing their example, brought an important issue to our attention. They have not, however, treated it in a general enough fashion. Given limitations of space, we will merely indicate one way of thinking about this problem that can

[17] 45 of the 49 cases with the outcome Y have the condition ~B.

keep things clear in one's mind when undertaking the analysis of truth tables. This involves regarding each row as evidence for the sufficiency or otherwise of the configuration it represents, while ignoring at this stage finer details concerning the degree of consistency with sufficiency (or necessity). Assume, for the sake of argument, that the evidence for each configuration in Table 3 is considered good enough to treat the rows as warrant for the eight claims in Table 4.

Table 4: eight statements concerning sufficiency

Configurations with the outcome Y	Configurations with the outcome ~Y
AB~C=>Y	ABC=>~Y
~A~BC=>Y	~A~B~C=>~Y
A~BC=>Y	~AB~C=>~Y
A~B~C=>Y	~ABC=>~Y

Looking at the truth table in this way, we see that ~B is not strictly a necessary condition for Y, since AB~C=>Y. If we were to run a QCA on the *temporary* assumption that there is just one case per row, then we will obtain a consistency with necessity for ~B for Y of 0.75, reflecting the fact it appears in three of the four rows to the left of Table 4. It can readily be seen, however, that, the higher the number of cases for the three lower rows to the left of Table 4 (~A~BC, A~BC, A~B~C) in relation to those for the row AB~C, the higher will be the reported consistency of necessity of ~B for Y, and the more serious the problem of this quasi-necessary condition being hidden in the solution for sufficiency will appear to be. If we allocate three cases each to the three lower rows on the left-hand side, leaving the row AB~C with just one, then consistency with necessity for ~B for Y is 0.90. If on the other hand, we allocate 10 cases to AB~C, while leaving the lower three rows with just one case each, then the consistency with necessity for ~B for Y falls to 0.23.

Schneider and Wagemann, apparently believing that their problem is due to inconsistent rows, propose the "imperfect remedy" of increasing thresholds for consistency. They point out that had a stricter threshold for sufficiency of 1.0 been used, then the inconsistent row AB~C would not have been allowed into the minimisation process and the "necessary condition ~B would not thus have been logically minimised away". However, as they note, were the same threshold used for testing necessity, ~B would no longer be a necessary condition!

We have shown that this problem is a more difficult one than they suggest, having its roots not so much in inconsistent rows as in the distribution of cases across rows. For this reason, even in truth tables with no contradictory (or inconsistent) rows, the problem needs to be at the forefront of a QCA-user's mind. Ragin's (2000: 105, 254) advice should, of course, be followed: perform necessary conditions tests prior to sufficiency tests[18]. In addition, we would recommend that the sort of thinking we have illustrated in respect of Table 4 can help

[18] One reviewer of this paper has pointed out that since many QCAs consider both the outcome and its negation, then, given that every sufficiency claim in respect of O, as we have noted earlier, entails a necessity claim in respect of ~O, and vice versa, this suggestion is redundant. However, this entailment is only secure in the context of strict sufficiency and strict necessity and becomes insecure when quasi-sufficiency and quasi-necessity are allowed (as they are in many QCAs).

QCA-users understand better what is going on when they analyse a truth table where the distribution of cases across the rows is uneven. Having undertaken such thought experiments, researchers should come to understand better the implications of the distribution of cases for fsQCA's sufficiency and necessity indices.

Discussion

In this paper, focusing on what Schneider and Wagemann say about hidden necessary conditions, we have found ourselves confronting some of the complexities of QCA. Our discussion of their analysis of Stokke's data showed the importance of exploring the logical consequences of apparently harmless working assumptions. The underlying problem with their approach, as we have argued in our section on "hidden necessary conditions due to incoherent counterfactuals", is perhaps the application of logic to derive conclusions from premises (for example concerning "necessary conditions") whose own status, because of limited diversity, is insecure. We have shown that elements of their recommended approach can lead to internally contradictory conclusions. Ragin (2008) has argued, in the face of limited diversity, for intermediate solutions based on the inclusion of only those logical remainders for which a good theoretical or substantive case can be made. Taken in conjunction with checks for the unintended inclusion of contradictory simplifying assumptions, this should allow the Standard Analysis to avoid *some* of the problem that can arise in applying logic in contexts of limited diversity (see, for example, the literature referred to by Yamasaki and Rihoux (2009) and their discussion of ways of avoiding the problem[19]). As it happens, in presenting their arguments for the use of "good counterfactuals" in constructing intermediate solutions that they argue the Standard Analysis would rule out, Schneider and Wagemann (2012, 2013) do focus on theoretical soundness, as recommended by Ragin (2008). Our subsequent discussion of the relation between hidden necessary conditions and inconsistent rows in truth tables shows that all the usual problems concerning the arithmetic of proportions (weighted averages, etc.) and the weighting of samples (Glaesser and Cooper 2012) need to be taken into account in carrying out and interpreting the results of a QCA, not just those arising from simple logic. QCA must be seen as a very valuable contribution to social science, but certainly not as one for those looking to avoid some careful mathematical and logical thinking. This is especially true for fuzzy set QCA, but not just for fuzzy set QCA, as our discussion has shown. This raises some more general points.

Schneider and Wagemann (2012, 2013) make considerable use of illustrative examples in developing their arguments. In principle, this is a useful strategy, especially for readers who lack a mathematical background. It does, however, carry the danger that their readers will not appreciate the importance of developing a more general understanding of the methods they employ, of what is going on "under the bonnet". Schneider and Wagemann may believe that readers can develop a more general understanding on the basis of illustrations of problems and how to address them but our discussion of their two arguments shows that there are dangers inherent in this approach.

They certainly seem to believe that the mathematical and logical demands of QCA and fsQCA are not high, writing (16-17):

[19] They note the problem is greater when there is much limited diversity. Goertz, Hak and Dul (2013), in discussing ways of analysing the boundary between regions of observations and of no observations provide us with another way of conceptualising some related issues.

> The challenge in understanding set-theoretic methods is not so much in grasping the math that is behind them. In fact, in terms of standard mathematical operations, not much more is required than simple subtraction and division of natural numbers. It is not even required to delve too deeply into the more complex intricacies of formal logic and set theory. The three rather simple logical operators (AND, OR and NOT) and the notions of subsets and supersets suffice for denoting any possible result that can be obtained using QCA.

Notwithstanding that they add, "yet understanding and correctly using set-theoretic methods is challenging" (17), we believe this claim concerning the demands of QCA to be misleading. Some aspects of QCA, especially fsQCA, can be complex and puzzling, reflecting the complexity of fuzzy set theory and fuzzy logic. It can be necessary to think long and hard about what is going on "under the bonnet" (see Cooper and Glaesser 2011b, for an example concerning the paradoxical findings that can arise when the laws of conventional logic are modified in fuzzy set QCA).

There is a growing demand for guidance on using QCA. Schneider and Wagemann's (2012) book, with its recommendations for "good practice", is therefore likely to be widely read. The book encourages its readers to follow its recommended procedures, by its use of such subheadings as the "Recipe for a good QCA", its claims concerning "Enhanced Standard Analysis", and its continual references to "best practice" (as in "we add further strategies that go beyond the current best practice approach" (151)). Our own view is that, at this stage of the development of set theoretic approaches, a less authoritative tone would be more appropriate. Ragin's own seminal work seems to us to have been characterised by a continuing search to find ever more fruitful ways of applying set-theoretic analysis to social science data. He has demonstrated, in his development of QCA, how best to respond to critics of his methods: use constructive criticism as a way to improve them. Schneider and Wagemann's ESA is presented as an improved form of QCA, especially relevant to addressing "limited diversity". We hope that this paper, in showing that their approach is not without its own problems, will contribute in some small way to the important debate about the most appropriate ways of dealing with limited diversity.

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