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Abstract

Qualitative Comparative Analysis (QCA) relies on calibration thresholds to transform empirical information into set memberships; however, existing approaches frame threshold choices primarily as robustness concerns, leaving their systematic exploration as analytical objects largely underdeveloped. This paper introduces Threshold-Sweep QCA (TS-QCA), a methodological extension that reconceptualizes threshold settings as analytical dimensions and systematically examines how sufficiency structures vary across threshold levels.

TS-QCA implements controlled sweeps over outcome thresholds, condition thresholds, or both, systematically varying threshold values to identify threshold dependence, threshold transitions, and level-specific causal structures within a unified analytical framework. Rather than selecting a single "optimal" calibration, the approach highlights how causal configurations emerge, persist, or dissolve as threshold criteria change.

The contributions of this study are conceptual and methodological. TS-QCA is positioned relative to conventional QCA practices, robustness analyses, and recent optimization-oriented extensions, clarifying its distinct analytical question and scope. An illustrative application demonstrates how threshold sweeps can be used to describe variations in sufficiency structures, without making substantive claims or evaluative judgments.

By treating threshold dependence as substantive methodological information rather than as a secondary robustness concern, TS-QCA expands the interpretive capacity of set-theoretic analysis while remaining complementary to established QCA approaches.

Keywords: Threshold-Sweep QCA, Threshold Dependence, Calibration, Thresholds, Level-Specific Causal Structures

1 Introduction

1.1 Methodological Positioning of Threshold-Sweep Qualitative Comparative Analysis

Threshold-Sweep Qualitative Comparative Analysis (TS-QCA) advances set-theoretic methodology by redefining threshold setting in Qualitative Comparative Analysis (QCA) from a preparatory calibration choice into a primary object of methodological inquiry. Conventional QCA relies on fixed thresholds for conditions and outcomes, implicitly assuming that causal structures are invariant once calibration is set (Ragin, 2008; Schneider & Wagemann, 2012). TS-QCA relaxes this assumption by systematically sweeping thresholds across predefined ranges and explicitly examining how sufficiency relations vary across threshold levels.

Such a design enables the identification of level-specific causal structures and threshold transitions, thereby revealing patterned changes in causal configurations that cannot be captured by single-threshold analyses. Importantly, TS-QCA is neither a robustness check around an arbitrarily selected threshold nor an optimization framework seeking optimal calibration. Instead, it provides a structured analytical framework for mapping threshold-conditioned causal spaces, thereby extending QCA from static solution sets to a dynamic threshold-aware representation of causal complexity.

1.2 Distinction from Existing Approaches

Conventional robustness analysis and optimization-based approaches, such as machine-learning–enhanced QCA (mlQCA) and TS-QCA differ fundamentally in how they conceptualize the role of thresholds in set-theoretic analysis. Robustness analysis treats thresholds as fixed analytical commitments and evaluates the stability of results under local perturbations, thereby assessing sensitivity rather than generating new causal information (Skaaning, 2011; Oana & Schneider, 2024).

In contrast, mlQCA frames threshold selection as an optimization problem, with the aim of identifying a single calibration that maximizes model fit or predictive performance (Huang, 2025). TS-QCA departs from both perspectives by treating thresholds not as parameters to be stabilized or optimized but as methodological dimensions along which causal structures systematically vary. By explicitly mapping how sufficiency relations change across threshold levels, TS-QCA establishes visible level-specific causal structures and threshold transitions that are theoretically meaningful yet inaccessible within robustness- or optimization-oriented frameworks.

2 Background: Thresholds and Methodological Extensions in QCA

This chapter situates TS-QCA within the established methodological landscape of QCA. The purpose is not to provide an exhaustive review of QCA applications or a comprehensive history of methodological developments but rather to clarify how TS-QCA relates to existing approaches that address calibration, threshold choice, and sensitivity in set-theoretic analysis.

2.1 Calibration and Threshold Setting in Conventional QCA

In fuzzy-set QCA, calibration plays a foundational role by translating empirical observations into set memberships (Ragin, 2008). The process involves the specification of qualitative anchors—typically full membership, full non-membership, and a crossover point—that structure the transformation from raw values to degrees of set membership. Crisp-set QCA also requires threshold specification, typically in the form of a single cutoff point that dichotomizes a variable into membership or non-membership.

Methodological research in QCA has long emphasized that calibration is a theoretically informed and substantively grounded step rather than a purely technical operation (Schneider & Wagemann, 2012). Thresholds are usually treated as fixed analytical inputs chosen prior to analysis and held constant throughout the examination of sufficient or necessary conditions.

2.2 Threshold Variation and Robustness Analysis

Concerns regarding the sensitivity of QCA results to calibration choices have motivated a stream of methodological studies on robustness analysis. In the literature, threshold variation is typically employed as a diagnostic tool to assess the stability of identified configurations (Skaaning, 2011; Oana & Schneider, 2024).

Notably, robustness analysis treats threshold variation as a means of evaluating the reliability of a given solution and not as an object of substantive or methodological inquiry in its own right. In such a context, threshold dependence is generally viewed as a potential problem that needs to be minimized or controlled.

2.3 Methodological Discussions on Threshold Choice and Sensitivity

Beyond formal robustness checks, the foundational and methodological contributions in QCA literature discuss threshold choice, sensitivity, and researcher discretion. The contributions highlight the unavoidable role of judgment in calibration and caution against mechanical or purely data-driven threshold selection while reinforcing the prevailing norm that a single substantively justified calibration should anchor the main analysis.

2.4 Optimization-Oriented Extensions and Related Approaches

More recent methodological extensions, including mlQCA, address challenges in calibration and condition selection by leveraging algorithmic search procedures. The methods aim to identify threshold combinations or condition sets that optimize predefined criteria such as consistency or predictive performance.

While such approaches expand the analytical toolkit available to QCA researchers, threshold variation functions primarily as a means toward optimization rather than as an analytical dimension to be examined in its own right.

Relatedly, software-oriented contributions have expanded the availability of advanced set-theoretic workflows in R, providing infrastructure for both applied research and methodological development (Oana & Schneider, 2018; Dușa, 2024).

2.5 Positioning TS-QCA within the Methodological Landscape

Against this background, TS-QCA is positioned as a complementary methodological approach that addresses a distinct type of question. Rather than seeking to justify a single optimal or robust threshold specification, TS-QCA treats threshold settings as an object of systematic exploration. Its contribution lies in enabling a systematic examination of how sufficient condition structures vary across threshold configurations, without presuming that one specification should ultimately be privileged.

3 Methodology

3.1 Conceptual Definition of Threshold-Sweep QCA

TS-QCA is defined as a methodological extension of QCA in which threshold settings are no longer treated as fixed analytical inputs but are explicitly repositioned as objects of systematic exploration. Conventional QCA requires researchers to select calibration thresholds prior to analysis, implicitly assuming that the resulting causal structure is substantively meaningful and sufficiently stable. TS-QCA relaxes this assumption by treating the threshold specification as a theoretically informative dimension rather than as that of a purely technical preprocessing step.

A defining characteristic of TS-QCA is its reconceptualization of threshold dependence as substantive methodological information. Rather than asking whether a single QCA solution is robust to minor perturbations, TS-QCA asks how and why sufficient condition structures emerge, transform, or disappear at different threshold levels. This shifts the analytical focus away from solution validation toward structured exploration of threshold-dependent causal patterns, thereby expanding the inferential scope of set-theoretic analysis.

3.2 Unit of Analysis: Level-Specific Causal Structures

A key methodological distinction of TS-QCA is its unit of analysis. While standard QCA considers a minimized solution at a fixed threshold as the primary analytical outcome, TS-QCA defines the unit of analysis as a level-specific causal structure embedded within a broader threshold space. Each configuration is interpreted in relation to the threshold level at which it is observed rather than as a threshold-independent causal statement.

This redefinition is necessary because threshold variation is not treated as noise or sensitivity but as an analytically meaningful dimension. By considering sets of solutions across threshold levels, TS-QCA enables identification of structural patterns, such as persistence, fragmentation, and transition of causal recipes. Methodologically, this allows researchers to distinguish between causal configurations that are contingent on narrow threshold choices and those that are characteristic of broader outcome levels, a distinction that is not readily expressed within the solution-centered framework of conventional QCA.

3.3 Analytical Procedure: Systematic Exploration of Threshold Space

The analytical procedure of TS-QCA is conceptually defined as a systematic exploration of a predefined threshold space for outcome or condition variables. For each threshold level, a standard QCA is conducted and the resulting sufficient condition structures are recorded without privileging any single solution as optimal or final. Importantly, the procedure is not designed to optimize calibration or select thresholds algorithmically but to generate a structured map of how causal configurations vary across levels.

What is methodologically novel is the purpose of this procedure. In contrast to robustness checks, which aim to confirm the stability of a given solution, TS-QCA deliberately refrains from collapsing results into a single preferred specification. The analytical value lies in the comparison across levels, which allows researchers to describe threshold transitions and articulate how causal relevance changes as the outcome definition becomes more demanding or less demanding. Thus, the procedure operationalizes threshold dependence as an explicit object of analysis, rather than a methodological nuisance. Figure 1 provides a schematic representation of such a threshold space, illustrating how sufficiency structures can be mapped across outcome and condition threshold levels.

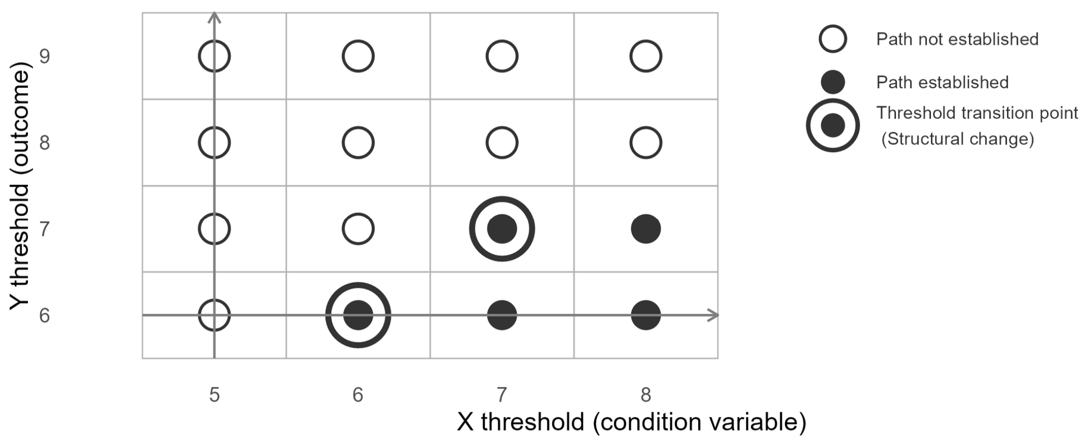

Figure 1. Schematic representation of the threshold space in Threshold-Sweep Qualitative Comparative Analysis.

Axes represent outcome and condition threshold levels, defining the threshold space over which sufficiency structures are examined.

In practice, the threshold space examined in TS-QCA is defined ex ante by the researcher based on theoretical and empirical considerations. The outcome or condition thresholds are varied over a predefined range using a fixed increment determined by the research design. At each threshold level, the same QCA procedure is applied, and the resulting sufficient condition structures are recorded in a standardized format indexed by threshold values. The aim of this procedure is not to fine-tune calibration choices, but to ensure a transparent and systematic exploration of how configurational structures vary across the specified threshold space.

3.4 Outputs and Interpretation of TS-QCA Results

The primary outputs of TS-QCA consist of sets of sufficient condition structures indexed by threshold levels, along with descriptive information about their emergence, persistence, or disappearance across the threshold space. These outputs are not interpreted as competing estimates of a single "true" causal model, but as complementary representations of level-specific causal relationships.

Interpretively, TS-QCA results support claims about where and under what threshold conditions particular causal configurations become relevant. This enables researchers to formulate nuanced statements, such as whether certain conditions are sufficient only at specific outcome levels or whether alternative pathways emerge or dominate as threshold specifications for outcomes or conditions vary. Methodologically, this output structure formalizes a distinction between causal explanation and threshold-specific description, reinforcing the role of TS-QCA as an exploratory, structure-oriented approach rather than a solution-selection technique.

4 Illustrative Application

The following chapter provides an illustrative application designed to demonstrate the methodological logic of TS-QCA, as defined in Section 3, rather than testing hypotheses or establishing substantive empirical claims. Its purpose is demonstrative and procedural: to make visible how threshold dependence, level-specific causal structures, and threshold transitions can be examined in practice once the analytical framework has been specified. Therefore, the illustrative example serves to explain the operation and interpretation of the proposed methodology, not to evaluate its empirical performance or generalizability. In this sense, Chapter 4 should be read as a structured illustration that clarifies the concepts and analytical relations introduced in the Methodology, with all substantive conclusions deliberately held in abeyance.

4.1 Illustrative Data and Analytical Setup

The illustrative dataset consists of a small number of cases with condition and outcome variables dichotomized into crisp sets suitable for set-theoretic analysis. The specific empirical context is not of analytical interest here; it functions solely as a vehicle for demonstrating the operation of TS-QCA. All conditions and the outcome are treated in accordance with standard QCA conventions, and no claims are made regarding their substantive meaning beyond their role in the illustration.

Following the procedure defined in Section 3, a threshold space is specified for the outcome and, where relevant, for selected conditions. Rather than fixing a single threshold a priori, multiple threshold levels are examined sequentially. At each level, a standard QCA is conducted, and the resulting sufficient condition structures are recorded. No threshold level is privileged and no attempt is made to select or justify a preferred specification.

4.2 Observation of Level-Specific Causal Structures

Applying TS-QCA in this manner yields a series of sufficient condition structures indexed by threshold levels. The configurations are interpreted as level-specific causal structures, meaning each configuration is explicitly tied to the outcome level at which it appears. The illustrative results exemplify how certain configurations emerge only at higher outcome thresholds, whereas others appear at lower thresholds or persist across multiple levels.

Importantly, these observations are not interpreted as evidence of stronger or weaker causal relationships. Instead, they are interpreted as illustrating how the form and composition of sufficient conditions may vary as the outcome definition becomes more demanding or less demanding. Thus, TS-QCA enables a descriptive mapping of how causal structures are distributed across the threshold space, without collapsing them into a single solution. Figure 2 illustrates this mapping, showing how sufficient configurations vary across condition threshold levels (columns) and outcome threshold levels (rows), with threshold transitions marked where the configurational structure changes.

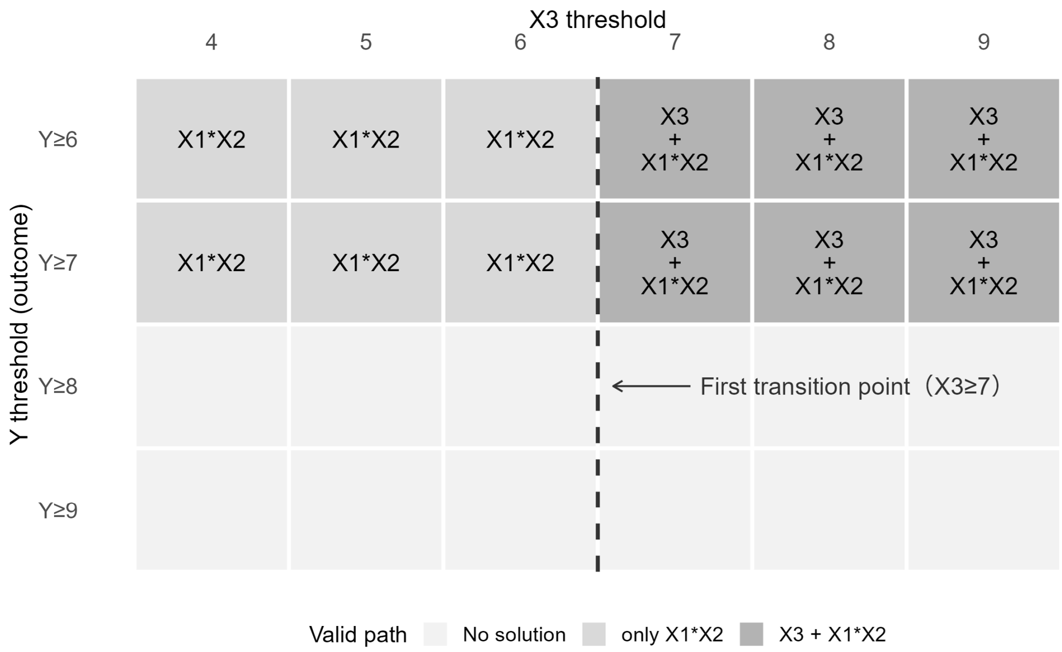

Figure 2. Mapping of level-specific causal structures across condition and outcome threshold levels. Rows represent outcome threshold levels, and columns represent condition threshold levels; changes in cell content indicate threshold transitions in sufficient condition structures. The figure is schematic and illustrative, and no substantive interpretation of the configurations is implied.

4.3 Threshold Transitions and Structural Change

As thresholds are varied incrementally, changes in causal structure can be observed at specific points. These threshold transitions take the form of the appearance, disappearance, or reconfiguration of sufficient condition structures between adjacent levels. In the illustrative application, such transitions highlight that causal configurations do not necessarily change in a smooth or monotonic manner as thresholds shift.

The analytical value of identifying threshold transitions lies in their role as descriptive markers of structural change. Rather than treating such changes as instability or sensitivity, TS-QCA records them as systematic features of the threshold space. This allows researchers to describe where and how causal relevance is reorganized across threshold levels without attributing evaluative significance to any particular transition.

4.4 Interpreting Illustrative Outputs

The outputs of the illustrative application consist of sets of level-specific causal structures and their distribution across the threshold space. The figures presented in this chapter are used solely to support procedural understanding by visualizing how configurations align with threshold levels. They are not intended to summarize results, rank solutions, or support empirical inference.

In conjunction with Section 3, this illustrative application clarifies how TS-QCA operationalizes threshold dependence and how its outputs are to be interpreted. The example shows that TS-QCA produces a structured description of causal configurations across levels rather than a single substantive conclusion. Chapter 4 explicates the methodological logic of TS-QCA and prepares the ground for the conceptual discussion that follows.

5 Discussion

This chapter discusses the methodological implications of Threshold-Sweep QCA (TS-QCA) by abstracting from the illustrative application presented in Chapter 4. The analysis has deliberately refrained from interpreting observed regularities as empirical findings or substantive effects. Instead, the focus has been on clarifying the type of methodological questions TS-QCA is designed to address and how it conceptually extends the analytical scope of conventional QCA.

By reconsidering threshold settings not as fixed analytical inputs but as dimensions of systematic inquiry, TS-QCA reframes how configurational causation can be examined within a set-theoretic framework. The following discussion consolidates this reframing by articulating its key conceptual implications.

5.1 Threshold Dependence as an Explicit Analytical Dimension

A defining feature of TS-QCA is the explicit treatment of threshold dependence as the object of analysis. In standard QCA practice, calibration thresholds are typically specified and held constant, with occasional sensitivity checks to confirm the robustness of the conclusions. In this context, the variation in thresholds is treated as a potential source of analytical sensitivity.

TS-QCA departs from this orientation by shifting the analytical question. Rather than asking whether causal solutions are stable across threshold choices, TS-QCA asks how sufficiency relations are structured across systematically varied thresholds. Thus, threshold variation becomes an analytical dimension through which configurational patterns can be examined rather than a methodological problem to be minimized.

This shift has significant methodological implications for future research. It allows researchers to make explicit the dependence of set-theoretic solutions on definitional choices and describe causal structures in a threshold-aware manner, without privileging any single calibration as uniquely correct.

5.2 Methodological Implications of Level-Specific Causal Structures

A focus on threshold dependence naturally leads to the concept of level-specific causal structures. TS-QCA makes explicit the possibility that different configurations may be sufficient at different outcomes or condition levels, even when the underlying cases remain unchanged.

From a methodological standpoint, this suggests limits to the implicit assumption that a single solution set can adequately represent the causal structure of an outcome once an appropriate calibration has been selected. Instead, TS-QCA highlights that configurational causation may vary across levels defined by analytical thresholds.

Notably, this does not imply that causal relations are unstable or arbitrary. Rather, it suggests that causal sufficiency can be meaningfully described as being conditional on the strictness of threshold-based definitions. TS-QCA provides a framework for articulating such conditionality without collapsing level-specific patterns into a single aggregate solution.

5.3 Threshold Transitions as Descriptive Properties of the Analysis

Another implication of the threshold-sweep perspective is the ability to describe threshold transitions, that is, points at which the structure of sufficient configurations changes as thresholds vary. The transitions are not interpreted as empirical tipping points or substantive regime shifts. Instead, they are descriptive properties of the analytical mapping between threshold settings in calibration and the resulting sufficiency solutions.

Methodologically, threshold transitions offer a way to characterize how the space of sufficiency relations is reorganized across threshold settings. This descriptive capacity enriches set-theoretic analysis by enabling researchers to examine not only which configurations are sufficient but also how the configuration space is restructured as analytical definitions change.

Crucially, these transitions are properties of the analytical procedure, rather than claims about empirical phenomena. They serve to clarify the internal structure of configurational analysis under varying thresholds.

5.4 Distinctiveness from Robustness Analysis and Machine-Learning–Enhanced QCA

The methodological contribution of TS-QCA becomes clearer when contrasted with robustness analysis and machine-learning-based extensions, such as mlQCA. Robustness analysis typically asks whether identified solutions persist under alternative specifications, with stability serving as a criterion for credibility. In this context, variation is something to be controlled or assessed.

By contrast, TS-QCA does not evaluate solutions against a stability benchmark or optimization criterion. The central question concerns variation itself: how configurational structures change across thresholds. Instability is not treated as a weakness but as an informative analytical pattern.

Similarly, mlQCA often frames threshold selection as an optimization task, for example, by searching for specifications that improve predictive or fit-related criteria. TS-QCA neither pursues optimization nor aims to identify the single best specification. Its purpose is to render threshold dependence visible and interpretable within a set-theoretic logic.

These differences highlight that the TS-QCA addresses a distinct methodological question centered on the relationship between calibration choices and configurational sufficiency relations.

This perspective is consistent with broader methodological clarifications regarding the distinct logic of configurational analysis. Thiem et al. (2016) emphasize that many critiques of QCA stem from misunderstandings rooted in regression-based thinking, particularly the expectation that causal relations should be evaluated in terms of net effects or stability across specifications. TS-QCA aligns with this clarification by treating variation in sufficient configurations not as a deficiency to be corrected but as a meaningful property of set-theoretic analysis when outcome calibration definitions change. Thus, TS-QCA does not approximate QCA to regression-based models; rather, it extends configurational reasoning by making threshold dependence explicit as an analytical dimension.

5.5 Positioning TS-QCA within the QCA Methodological Landscape

Overall, the points clarify that TS-QCA is not intended to replace conventional QCA. Instead, it should be understood as a complementary extension that preserves the set-theoretic logic of configurational analysis while expanding its analytical perspective.

Conventional QCA remains appropriate for research designs that proceed with a single calibration specification and require a parsimonious representation of causal configurations. TS-QCA becomes relevant when researchers seek to examine how such representations depend on threshold choices, or when threshold dependence itself is of methodological interest.

By making this dependence explicit, TS-QCA contributes to greater transparency and conceptual clarity in configurational analysis. Its value lies not in producing alternative substantive empirical claims but in extending the methodological vocabulary with which causal complexity can be examined.

At the same time, several limitations of TS-QCA should be acknowledged. The approach is not designed to evaluate the strength, relative importance, or optimality of causal configurations, nor does it aim to produce parsimonious summaries comparable to those derived from single-threshold analyses. Moreover, while TS-QCA makes threshold dependence analytically explicit, it does not provide criteria for determining theoretically "correct" calibration choices, which remain the responsibility of the researcher. As a result, TS-QCA is best understood as a descriptive and exploratory methodological extension, rather than a substitute for effect-oriented or evaluative analytical frameworks.

6 Conclusion

This paper has introduced Threshold-Sweep QCA (TS-QCA) as a methodological extension of conventional QCA that explicitly treats threshold settings as objects of systematic inquiry. Building on the discussion in Chapter 5, the central contribution of TS-QCA lies in reframing calibration thresholds from fixed analytical inputs into explicit dimensions of systematic exploration. This reframing makes threshold dependence explicit and systematically describable within a set-theoretic framework.

Rather than aiming to produce a single solution tied to a specific threshold choice, TS-QCA enables researchers to examine how sufficient configurations vary across threshold values. It further allows the identification of level-specific causal structures and the tracing of transitions in configurational patterns as thresholds change. Thus, TS-QCA expands the analytical scope of QCA by shifting the primary methodological question from whether a solution is robust to how and where causal structures depend on threshold choices.

From a methodological standpoint, TS-QCA addresses a distinct analytical question in relation to existing approaches. Robustness analyses typically ask whether results remain stable under alternative or slightly varied calibration specifications, whereas recent machine-learning-based approaches, such as mlQCA, focus on optimizing threshold selection or condition sets.

In contrast, TS-QCA asks how causal configurations are structured across the threshold space and what this variation reveals about the underlying configurational logic. Therefore, it is not proposed as a replacement for standard QCA, robustness checks, or optimization-based methods, but as a complementary methodological perspective that can be used alongside them when researchers are interested in threshold dependence as analytically meaningful methodological information.

The scope of the present paper is intentionally limited to conceptual clarification and illustrative demonstration. Its primary aim is to establish a methodological perspective in which threshold dependence is treated as an explicit object of analysis, rather than to provide exhaustive technical or empirical elaboration.

Building on this foundation, future research may integrate TS-QCA with substantive empirical applications that examine how configurational sufficiency varies across analytically meaningful outcome calibration levels, while preserving the methodological perspective articulated in this study.

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