Qualitative Comparative Analysis for Qualitative Field Research

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1 Introduction

Qualitative Comparative Analysis (QCA) is a methodology that uses Boolean algebra and fuzzy sets to implement the principles and processes of comparison used by scholars engaged in the qualitative study of social phenomena. Typically, qualitatively-oriented researchers examine only a few cases at a time because their analyses are both extensive—addressing many aspects of the cases—and integrative—examining how the different parts of each case fit together. By formalizing aspects of qualitative analysis, QCA makes it possible to bring the empirical intensity of qualitative research to studies that embrace more than a handful of cases—research situations that typically would call for the use of variable-oriented, quantitative methods. This formalization does not supplant traditional case-oriented, qualitative analysis but supports it by providing a set of interrelated classification techniques for identifying the characteristics of cases, constructing empirical taxonomies, and distinguishing among types of cases associated with the presence or absence of an outcome.

In QCA, the researcher first constructs a data matrix that represents each case as a configuration of descriptive characteristics ("conditions") and an outcome of interest. The cases are compared with one another to identify their similarities and differences, which are then used to develop an empirical taxonomy ("truth table") that describes the different types of cases. This process of developing a truth table is valuable in and of itself, as it permits the researcher to explore the diversity that characterizes the cases under investigation. Indeed, QCA is often best thought of as "diversity-oriented research." Typically, the analyst then proceeds to a third stage of simplifying the truth table, which parallels the minimization of switching circuits (Ragin 1987). This minimization procedure uses computer algorithms to distinguish between logically-irrelevant and potentially-explanatory conditions in order to identify how combinations of conditions ("recipes") are associated with presence and/or absence of the outcome.

This introduction to QCA is written for field researchers working with rich, case-based data who want to make cross-case comparisons without sacrificing within-case depth. We first provides an overview of its key features, and how they complement conventional qualitative approaches. Next, we describe what QCA is not, focusing on how it differs from conventional quantitative analysis. A discussion of the different types of QCA applications follows. We conclude with a demonstration of applying QCA to field research.

2 QCA's Key Features

While it is tempting to treat QCA strictly as a data analysis technique, the method embraces several key elements that together define it as a multi-method approach (Rihoux and Ragin 2009). These key elements also distinguish QCA from other methods:

QCA bridges qualitative and quantitative analysis. Most aspects of QCA require familiarity with the cases, the usual domain of qualitative analysis. This case knowledge is used to identify potentially-relevant explanatory conditions, for calibrating crisp- and fuzzy-set membership scores, and to resolve "contradictions" (cases of the same type but with different outcomes). At the same time, QCA is capable of pinpointing decisive cross-case patterns, the usual domain of quantitative analysis. QCA's examination of cross-case patterns respects the diversity of cases and their heterogeneity with regard to their different causally relevant conditions by comparing cases as configurations. QCA is inherently multi-method, as researchers must shape their analytic strategies in accordance with their understandings of their cases.

QCA is ideal for intermediate-N research designs but can also be used for small- and and large-N analysis. QCA can be usefully applied to research designs involving 10–50 cases. In this range, there are often too many cases for researchers to keep all the comparative case knowledge "in their heads," but too few cases for most conventional statistical techniques. When the number of cases is modest, QCA provides a bridge between case-oriented analysis and variable-oriented analysis. Yet QCA can also be used for small-N (< 10 cases) and large-N (> 50 cases). While such applications require some changes to how QCA is applied, the method's advantages for unraveling causal complexity remain.

QCA makes explicit the use of set-analytic methods in qualitative inquiry. QCA is grounded in the analysis of set relations, not statistical correlations. Although the nomenclature of set theory is not often used in qualitative research, the underlying model of qualitative inquiry is fundamentally set-theoretic (Goertz and Mahoney 2012). Qualitative researchers develop their in-depth case knowledge and nuanced causal explanations by examining the characteristics that cases do and do not share (i.e., the degree to which cases belong to the same "type"). Furthermore, the analysis of necessary and sufficient causes, which are frequently of interest to qualitative researchers, is also how QCA models causation; necessity is indicated when the outcome is a subset of the cause and sufficiency, when the cause is a subset of the outcome. In this way, QCA does not challenge the logic of qualitative inquiry but simply makes it explicit.

QCA provides powerful tools for the analysis of causal complexity. Set analytic methods are well-suited to the study of complex causal processes and QCA is designed to detect both conjunctural causation (the ways in which conditions combine to produce an outcome) and equifinality (the existence multiple causal pathways to the same result). Because of this sensitivity to multiple conjunctural causation (Ragin 1987), QCA may be used to study "INUS" conditions—individual conditions that are *insufficient* but *necessary* parts of causal recipes that are, themselves, *unnecessary* but *sufficient* to realize an outcome (Mackie 1974).

In line with the qualitative approach (and in contrast to conventional quantitative analysis), QCA assumes neither additivity nor linearity and does not privilege parsimonious explanations. Designed with the expectation that causal complexity is the norm, the method defaults to retaining case detail and empirical diversity. Indeed, QCA has no notion of an "average" or "typical" case. While QCA can be used to derive parsimonious explanations, this is left to the discretion of the researcher.

QCA uses a method of incremental elimination. Central to QCA is the process of constructing and minimizing truth tables. This minimization process identifies and eliminates logically-irrelevant conditions. When two cases differ by only a single condition, yet exhibit the same outcome, that condition can be eliminated from consideration as is logically irrelevant to explaining the presence (or absence) of the outcome within the context defined by the remaining conditions. This contextual sensitivity is characteristic of QCA: it is often the case that conditions are only relevant in the presence of or when combined with certain other conditions. The process of pairing cases proceeds in a bottom-up manner until no further simplifications are possible. The method of elimination is superior to both Mill's (1967) method of agreement and his indirect method of difference because the focus is on eliminating conditions in a context-specific manner.

QCA supports case-oriented counterfactual analysis. An important feature of QCA is its ability to draw upon the researcher's theoretical and substantive knowledge in order to conduct "what if" scenarios and engage in counterfactual analysis. This allows QCA researchers to emulate the practice of conducting thought experiments that is common to many forms of qualitative research. The truth table is used for this. As discussed, the truth table is an empirical taxonomy that lists all of the different types of cases present in the data matrix. It also lists all of the different types of cases that are *not* present. These "remainders" are available for use as counterfactual cases: the researcher is able to selectively incorporate them into the minimization process in order to explore if and how the results change when these cases are treated as if they exist. The researcher can also input any theoretical and/or substantive expectations into the software, which is then used to perform a counterfactual analysis.

3 What QCA is Not

Qualitative researchers are sometimes put off by QCA's formality; its use of software that takes a numerical data matrix as input and produces mathematical formulas as output can remind one of conventional statistical analysis. These researchers are often concerned that the use of software will distance them from their cases and interfere with developing the in-depth case knowledge that is valued in qualitative inquiry. Others are concerned that the use of formal (Boolean) syntax will strip the analysis of semantic meaning by exchanging nuanced explanations for shallow mathematical formulas.

Fortunately, there is nothing inherent to the QCA methodology that is antagonistic to conventional qualitative processes and practices. While it is true that case knowledge is often limited in large-N QCA applications, this is simply because the analysis of large data sets naturally impedes the possibility knowing one's individual cases. When working with small- and medium-N data, QCA supports the researcher's efforts to develop in-depth case knowledge by automating many of the most common tasks of case comparison. This ensures that all comparisons are performed while relieving the researcher of the repetitive work, freeing the researcher to focus on the cases themselves. Likewise, the use of formal syntax in no way precludes the production of rich narratives. Indeed, as has been repeatedly emphasized by all of the major methodological QCA monographs (Kahwati and Kane 2019; Mello 2021; Oana et al. 2021; Ragin 1987, 2000, 2008; Rihoux and Ragin 2009; Rutten 2024; Schneider and Wagemann 2012), the Boolean expressions produced by QCA must be theoretically and substantively interpreted. QCA will reveal the different combinations of conditions that are associated with the presence or absence of an outcome; it cannot tell you why.

This is because, although QCA is most often used in causal investigations, the technique itself is descriptive. QCA does not infer population characteristics from a sample of observations; likewise, it cannot be used to establish causation by isolating or inferring causal effects. Rather, QCA is used to study the configurational diversity found within a set of cases, regardless of whether those cases were selected at random, purposively, by convenience, or representatively. While using QCA assists the researcher in identifying and unraveling the sources of causal complexity, causal inference and interpretation are possible only at the case level. For this reason, QCA is often used alongside individual case studies (Rihoux and Lobe 2009; Schneider and Rohlfing 2013; Rihoux et al. 2013; Thomann and Maggetti 2020).

It is also important to emphasize that QCA is not a substitute for conventional statistical analysis for small-N studies. The texts *Redesigning Social Inquiry* (Ragin 2008) and *A Tale of Two Cultures* (Goertz and Mahoney 2012) focus on the differences between set-theoretic methods such as QCA and conventional statistical methods. What is perhaps most important to appreciate is that QCA is not correlational and does not seek to compare the separate impacts of competing independent variables on a dependent variable. In fact, if one's goal is to assess individual net effects, QCA is the wrong technique to use. QCA only analyzes combinations of conditions and fundamentally assumes that it is impossible to disentangle the independent contributions of a combination's constituent components.

Any empirical technique can be used effectively or poorly. This is as true for QCA as it is for conventional quantitative and qualitative analysis. It is crucial to appreciate that QCA must not be applied mechanistically. Rather, the method is designed to facilitate "retroductive research" (Ragin 1994) by structuring a close interaction between the researchers and their data. QCA assumes a malleable analytic frame that is refined over the course of research, a perspective familiar to qualitative researchers. Practitioners new to QCA sometimes underestimate the importance of carefully reflecting upon how one's theoretical and case knowledge shapes the analytic process and interpretation of the results. QCA excels at identifying instances in which empirical reality is more complex than expected; these moments provide opportunities to better understand one's cases and refine one's theoretical model. Recent discussions of the effective application of QCA include Greckhamer et al. (2018) and Rubinson et al. (2024).

4 Types of QCA Applications

It is common to distinguish two types of QCA, crisp-set QCA (csQCA) and fuzzy-set QCA (fsQCA), with csQCA utilizing binary sets (presence/absence dichotomies) for both causal conditions and outcomes, and fsQCA utilizing sets that allow membership scores to take values between 0.0 (fully absent) and 1.0 (fully present). This distinction is largely an artifact of history: when QCA was originally introduced in *The Comparative Method* (Ragin 1987), it operated only on crisp sets. The dyadic naming schema emerged later, following the publication of *Fuzzy-Set Social Science* (Ragin 2000). The distinction between csQCA and fsQCA is somewhat overblown, as both types of sets can be used in the same analysis. In fact, it is now recognized that a crisp set is merely a particular type of fuzzy set, one restricted to two discrete values. Researchers are increasingly dispensing with the distinction in favor of the unadulterated term.[1] When deciding whether to use a crisp or fuzzy set, what is most important is retaining fidelity to the underlying measure; if a condition or outcome can be represented as a fuzzy set, it is generally preferable to not dichotomize (Ragin 2008:138–41).

QCA is used in different ways depending upon the number of cases being analyzed. Small-N applications typically address around 10 or fewer cases. In small-N applications, case knowledge plays an important role, and QCA enhances the interplay between cross-case and within-case analysis. Most QCA projects are intermediate-N applications of 11 to 50 cases. With an intermediate N, there is still a healthy dialogue between within-case and cross-case analysis but case knowledge tends to be, of necessity, uneven. Large-N applications of more than 50 cases naturally focus primarily on cross-case patterns and are used to explore questions of multiple conjunctural causation that cannot be answered with conventional statistical techniques. These analyses are often embellished with case studies of exemplary cases or of cases that stand out in some way (Rohlfing and Schneider 2013; Schneider and Rohlfing 2013).

Since the publication of *Redesigning Social Inquiry* (Ragin 2008), the method has demonstrated itself to be discipline-agnostic. Although first developed for social and policy research, QCA has now been successfully applied to research in such diverse areas as business management, comparative history, education, environmental studies, health services, legal studies, narrative analysis, organizational studies, policy evaluation, psychology, public health, and medicine. COMPASSS, the international, inter-university research consortium of QCA methodologists and practitioners, maintains a bibliographic database that, at the time of writing, lists almost 2,500 published methodological and empirical applications of QCA and related methods, representing only a portion of the full body of work, at `http://compasss.org/bibliography`.

5 Conducting QCA

Because QCA is a case-oriented methodology, researchers coming from the qualitative tradition often grasp its approach more quickly than those coming from the quantitative tradition. This accessibily reflects how QCA serves to bridge the two traditions, drawing upon the complementary strengths of each. In particular, this means that QCA is designed for examining both the similarities and differences across cases using a malleable analytic frame. That is, QCA proceeds from neither a purely inductive nor a purely deductive vantage but instead operates in between: the researcher begins with some expectation of the factors that may explain the presence and absence of an outcome but also anticipates revising this understanding throughout the analytic process, using existing knowledge to guide one's empirical investigation while remaining responsive to the emerging empirical findings. While this retroductive back-and-forth between ideas and evidence is familiar territory for qualitative researchers, it is often a new approach for many using QCA for the first time. A benefit of QCA is that it provides a framework to guide this process. The steps outlined below, however, are not meant to be followed mechanically or in strict sequence. In practice, progress on one aspect of the analysis often requires revisiting and reconsidering others—an iterative process that is more often the case than not.

5.1 Identify relevant cases and outcome and conditions of interest

Whereas qualitative researchers might start with a general question of interest and quantitative researchers, a clearly defined theory to be tested, QCA begins by identifying the outcome that one is interested in explaining. The importance of starting here is sometimes overlooked by qualitatively-oriented researchers who are often initially focused on exploring the diversity among a set of cases. But because QCA analyzes "causes of effects" (Mahoney and Goertz 2006), it is crucial to identify the effect that one is interested in explaining.[2] The next step is to identify a set of cases that are relevant to the analysis: cases that all appear to be candidates for the outcome but exhibit it to varying degrees. This criteria of outcome potentiality is a key consideration because cases where it is clearly impossible to realize the outcome do not improve one's understanding of when the outcome does or does not occur (Mahoney and Goertz 2004). Having assembled a set of relevant cases, the goal of the analysis is then straightforward: to disentangle the differences between those cases that exhibit the outcome and those that do not.[3]

Notice that QCA says nothing about how one identifies either the outcome of interest or the set of relevant cases. These are both based upon the researcher's theoretical and substantive knowledge. It is for this reason that QCA is frequently deployed as part of a larger research project, rather than as a single end of its own. That is, QCA often works well to answer a particular question or set of questions that arise in the course of broader research.

5.2 Construct the data set

Having identified the outcome of interest and the set of relevant cases, the next step is to create a data set. QCA data sets have the standard format with cases as the rows and conditions as the columns. Conditions are characteristics of cases that may be relevant to explaining the presence or absence of the outcome. Conditions differ from traditional variables in that QCA does not assume that conditions are independent of one another but, rather, describe integral aspects of cases; cases are understood to comprise combinations of conditions.

The difference between conditions and variables is most evident during the measurement process. Measuring a condition means assessing the case's *degree of membership* in a target set. A researcher measuring the variable "age," for example, must simply determine the number of years that have passed since the respondent was born. As a condition, however, the researcher must first establish an appropriate target set such as "the set of elderly people" or "the set of young people." That is, variables are nouns ("age") while conditions are adjective phrases ("elderly people").

Having identified the target set, the researcher then defines the relevant thresholds for membership. This process is referred to as "calibration" and is extensively discussed by Ragin (2008) and Ragin and Fiss (2017). A score of 1.0 indicates that a case fully belongs to the target set. Similarly, a score of 0.0 indicates that a case is fully out of the target set. For example, a researcher may decide that anyone over the age of 79 is "fully in the set of elderly people" and will be assigned a score of 1.0 while anyone under the age of 60 is "fully out of the set of elderly people" and will be assigned a score of 0.0. People between the ages of 60 and 79, then, are understood to be partially in the set of elderly people and will be assigned scores between ranging between 0.01 to 0.99.

Observe that conditions are asymmetric. A person who is "fully out of the set of elderly people" is not necessarily "young." To include this latter condition in the analysis will require defining thresholds that distinguish between fully, partially, or not belonging to the set of young people. Different calibration strategies will therefore generate different conditions. Observe also that the calibration process distinguishes between relevant and irrelevant variation. Conventional variable measurement typically retains all variation. From a set-theoretic perspective, however, not all variation matters. What is relevant when defining the set of elderly people is determining the age threshold that draws a boundary around that group of people. Within that boundary, cases are understood to be homogeneous (Rihoux and Ragin 2009) and any age differences among the set of elderly people constitutes irrelevant variation. If these differences are relevant to the analysis, the researcher should create a new condition such as "very elderly," and define rules that distinguish among those who are "fully in the set of very elderly people," "partially in the set of very elderly people," and "fully out of the set of very elderly people."

The calibration process therefore demands the application of theoretical and empirical knowledge. It is relatively straightforward to measure a variable such as age. Measuring a condition such as "degree of membership in the set of elderly people," however, requires that the researcher first determine what is meant by "elderly." This is not a trivial task and requires that the researcher draw upon his or her expertise. The benefit of this extra effort is that it allows QCA researchers to model their cases with greater nuance. Membership scores do not merely reflect quantitative variation but are also semantically meaningful, reporting both differences in degree as well as in kind.

5.3 Necessity Testing

QCA is best know for its use of truth tables for identifying sufficient conditions. But testing for necessary conditions is equally important. When a condition (or combination of conditions) is necessary for an outcome, then instances of the outcome constitutes a subset of instances of cause. For example, HIV infection is a necessary condition for AIDS. That is: people with AIDS form a subset of people infected with HIV. Identifying such necessary conditions is important because they offer a "front line" for preventing (or enabling) an outcome. If HIV transmission can be blocked—through condoms, PrEP, PEP, or other means—then AIDS cannot develop.

Necessary conditions need not be perfect and it is perfectly reasonable to state that a condition is "almost always necessary." A prior history of smoking is almost always necessary for the development of lung cancer, with only a small proportion of cases due to other causes. A strong record of publishing is almost always necessary for tenure because there are some academics who receive tenure without one. Nevertheless, we advise children not to smoke and junior faculty to publish a lot. This is because we know that it is highly unlikely for someone to contract lung cancer if they have not smoked or be granted tenure when they do not publish.

The empirical relationship between a necessary condition and associated outcome is assessed through two goodness-of-fit measures. *Consistency* measures the strength of the superset/subset relationship and ranges between 0.0 and 1.0. When the outcome is a perfect subset of necessary condition, consistency equals 1.0. As the relationship diverges, consistency drops. Strictly speaking, only a consistency score of 1.0 indicates that a condition is "always necessary" with scores greater than 0.9 indicating that a condition is "almost always necessary." As a rule, consistency scores less than 0.9 indicate the absence of a necessity relationship.

Coverage also ranges between 0.0 and 1.0 but instead measures a necessary condition's empirical importance. A coverage score of 1.0 indicates that every case that exhibits the necessary condition also exhibits the outcome. Coverage is usually less than 1.0, which indicates that there are instances where the necessary condition is present but the outcome is absent. The relationship between HIV and AIDS provides an example. In the past, everyone who contracted HIV eventually developed AIDS—a coverage score of 1.0. As treatment has improved, coverage has declined: fewer and fewer people who contract HIV (the necessary condition) now develop AIDS.

Note that a low coverage score does not imply that a necessary condition is unimportant. Just because relatively few children exposed to SARS-CoV-2 (the necessary condition) will contract COVID-19 (the outcome) does not mean that the causal relationship is unimportant. Because of this, it is important to assess consistency prior to assessing coverage. Consistency establishes whether a relationship of necessity exists at all while coverage measures how prominent the relationship is.

5.4 Construct the truth table and resolve contradictions

A sufficiency analysis proceeds in two steps. The first step involves using the QCA software to construct a truth table. As discussed above, a truth table is empirical taxonomy derived from the raw data matrix. A truth table consists of 2^N rows, where N represents the number of explanatory conditions and each row of the truth table represents a logically-possible combination of conditions; each truth table row ("configuration") defines a specific *type* of case. Consistency is computed for each configuration. Here, a consistency score of 1.0 indicates that a particular combination of conditions is always associated with the presence of the outcome; lower consistency scores are produced when cases of a given type do not exhibit the outcome, with a consistency score of 0.0 indicating that the outcome is never seen among cases of that type. When analyzing aggregate entities, scores of less than 0.80 indicate substantial inconsistency and should be interpreted as identifying a configuration that does not consistently produce the outcome. This rule is relaxed when analyzing individuals, who are inherently more variable than aggregate entities. For individual-level data, we recommend a consistency threshold of at least 0.75. These recommendations are minimum thresholds; depending upon the project, the researcher may wish to employ stricter standards. Particularly for small-N studies of aggregate phenomena it is not unusual to employ a consistency threshold of 0.90, 0.95, or even 1.0.

When a configuration's consistency is less than 1.0 (and greater than 0.0), this indicates that, for the given type, some cases exhibit the outcome and some do not. In QCA, this is referred to as a "contradictory configuration" or, simply, a "contradiction."[4] The presence of a contradiction raises an important question: Given that these cases are descriptively similar (i.e., share the same combination of conditions), why do they differ with regard to the presence of the outcome? An underlying assumption of QCA is that similar cases should act similarly; the presence of contradictions, then, is an opportunity for further investigation (Rubinson 2013). Random variation of cases is of course one possible answer to this question, one that means a configuration is "almost always sufficient." Another possibility is measurement error: it could be that the inconsistent cases have been misclassified and actually belong to a different type. The presence of contradictions might also indicate an underspecified model in which one or more explanatory conditions have been omitted. The researcher is therefore encouraged to return to their case studies and consider these different possibilities in order to distinguish those cases that realized the outcome from those that did not. It is here that the retroductive aspect of QCA is most explicit as the process of arriving at a contradiction-free truth table requires closely engaging with both one's cases and theory in order to determine those combinations of conditions that are consistently associated with the occurrence of the outcome.

5.5 Minimize the truth table

Once all contradictions have been resolved—whether by improving the model specification, correcting errors in measurement, and/or accepting the presence of less-than-perfect consistency—it becomes possible to interpret each configuration as describing a different explanation of the presence (or absence) of the outcome. Yet it may also be that there exist minor variations among the configurations that are irrelevant. The truth table minimization process identifies and eliminates these irrelevant conditions.

The minimization procedure is a straightforward extension of Mill's (1967) well-known methods of agreement and difference. The QCA software compares two configurations, both of which consistently exhibit the outcome. When the configurations are identical except for a single condition, that condition must be irrelevant—within that combination of conditions—to explaining the outcome's presence. That is: if two configurations differ only in that one possesses a characteristic that the other does not then, logically, that characteristic is irrelevant to explaining the outcome. The QCA software repeatedly compares each configuration to every other configuration until all logically-irrelevant conditions have been eliminated.

QCA researchers commonly refer to the minimized configurations as "pathways" or "recipes" as a way of highlighting their equifinal nature—that there are multiple ways of realizing the same outcome. This "complex" solution may be further simplified by incorporating truth table rows that lack empirical instances ("remainders") into the minimization procedure as simplifying assumptions. Using all remainders (regardless of their theoretical plausibility) will produce the simplest-possible recipes, collectively referred to as the "parsimonious" solution. An "intermediate" solution that selectively incorporates remainders, based upon theoretical and empirical expectations specified by the researcher, often produces a result that best balances the detail of complex solution with the abstractness of the parsimonious solution.

Whether to use remainders as simplifying assumptions is ultimately the researcher's decision. It is standard practice, however, to report the parsimonious and at least one other solution. The parsimonious solution, although often overly simplistic, valuably reports those conditions that are integral to each recipe and cannot be minimized away. The intermediate solution is generally preferred when prior theoretical or empirical work exists that provides expectations regarding the effect of the conditions upon the presence or absence of the outcome; the complex solution is generally preferred when such background knowledge is absent.

5.6 Assess and interpret the results

As a descriptive technique, QCA highlights cross-case regularities, with the minimization procedure serving to remove irrelevant conditions. A key task for the researcher, then, is to evaluate the resulting solution. Do the recipes make sense theoretically? In what ways do they support or challenge existing theory? QCA identifies cross-case regularities that must be causally interpreted. What causal mechanisms do these recipes imply?

Do the results make sense empirically? For small- and medium-N studies, it is important to examine the cases that are associated with each recipe. If there are cases associated with more than one recipe, does this suggest that the recipes may be variants of one another, sharing the same mechanism? How similar or different are the recipes from one another? Does the way in which cases are grouped within and distributed across recipes reveal anything novel or unexpected?

It is essential to return to one's cases in order to study casual processes and establish causation. In many ways, the most important step of any QCA analysis is evaluating how well the results connect to the cases. Empirical results never "speak for themselves" and must always be interpreted. In QCA, it is crucial that the researcher explore why particular combinations of conditions are associated with the presence of the outcome. It is for this reason that, as noted above, QCA is often coupled with in-depth case analysis, which researchers use to study the causal mechanism(s) underlying the QCA results.

5.7 Repeat the analysis for the negation of the outcome

Unlike conventional statistical techniques, QCA is not symmetrical. The absence of an outcome is not necessarily explained by simply inverting the explanation of its presence. Indeed, it is usually the case that the causal processes that prevent an outcome are distinct from those that produce it. It may also be that investigating the outcome's absence produces more compelling results, that the conditions being studied do a better job of explaining failure than success. For both of these reasons, a separate analysis of the negation of the outcome is needed.

An analysis of the negated outcome is also important because it allows the researcher to compare positive and negative cases to one another. How similar or different are the recipes that produced the outcome from those that did not? In what ways are these similarities and differences consistent or inconsistent with existing theory and case knowledge? Such comparisons help one to better understand the conditions that enable or inhibit the operation of causal mechanisms.

At the same time, researchers should be aware that analyzing the negation of the outcome does not always yield meaningful results. In large-N applications, cases lacking the outcome may be so heterogeneous that no clear patterns emerge, particularly when case selection has not been carefully bounded. By contrast, in small- and medium-N studies where data sets are constructed more deliberately, analysis of the absence of the outcome remains both informative and an expected practice, offering researchers a richer understanding of the causal processes at work.

6 An Empirical Example: Migrant Crossing Intentions

In this section, we provide an example of QCA using a subset of interview data from the first wave of the *Migrant Border Crossing Study (MBCS)*. The *MBCS* was designed to gather qualitative and quantitative data on unauthorized Mexican migrants' border crossing, apprehension, and repatriation experiences (Martínez et al. 2017; Slack et al. 2018). The study also examined the factors that shape Mexican migrants' future crossing intentions post-repatriation. Between 2007 and 2009, Martínez and colleagues interviewed a random sample of 415 recently repatriated unauthorized Mexican migrants in Nogales, Sonora. In order to be eligible to participate in the study, potential respondents must have attempted an unauthorized border crossing along the Arizona-Sonora border, been apprehended by any U.S. authority, and repatriated to Mexico. To reduce retrospective bias, each of these events had to have occurred within six months of participating in the study. As part of the first *MBCS*, female-identifying researcher team members oversampled and interviewed 49 women. Table 1 presents the calibrated data. Due to missing data, the original data set of 49 respondents was reduced to 39. Our QCA focuses on the future crossing intentions of these women.

[Table 1 about here]

6.1 Calibrations

At the beginning of the *MBCS* interview, respondents were asked whether they were planning to attempt another crossing or not. The interviewer posed a slightly different question at the end of the interview, asking it if was possible that the respondent would attempt another crossing. We used both responses to construct a three-value fuzzy set reflecting a respondent's intent to pursue another attempt. Of the 39 respondents included in the final data set, 12 indicated their intent to cross again, 19 that they would not, and 8 were ambivalent.

Based upon existing literature (Amuedo-Dorantes and Pozo 2014; Molina 2013; Hagan et al. 2008; Martínez et al. 2018; Martínez 2016; Massey and Espinosa 1997), we focused our analysis on four key areas: the number of times the respondent had previously crossed the border, the degree to which her life was already embedded within the U.S., her socioeconomic situation, and the difficulty of the most recent crossing attempt. The calibrations and associated justifications are discussed below and summarized in Table 2.

[Table 2 about here.]

Number of Prior Crossings Prior unauthorized migration experience is positively associated with subsequent unauthorized migration trips (Massey and Espinosa 1997; Massey et al. 2003). Drawing upon this extant literature, the *MBCS* interviews, and the researchers' domain expertise regarding the knowledge that migrants gain from repeated crossings, we applied the "direct method" of calibration (Ragin 2008) and used the respondent's total lifetime number of crossings to calibrate her degree of membership the set of "women with substantial experience crossing the border".

Social Embeddedness Social embeddedness measures the respondent's connections within and integration into U.S. society. Previous research shows that individuals with family in the U.S. or who have previously lived there themselves are more likely to attempt crossing (Hagan et al. 2008; Martínez et al. 2018; Massey and Espinosa 1997; Massey et al. 2003). Degree of membership in the set of respondents strongly embedded in the U.S. was calibrated using the following rules:

1.0 = Respondent is a permanent U.S. settler; she identifies the U.S. as her home *and* has lived in the U.S. for 6 or more years.

0.8 = Respondent either (a) has lived in the U.S. for at least 2 years or (b) has lived in the U.S. *and* has family at her intended destination.

0.6 = Respondent either (a) has previously lived in the U.S. or (b) has family at her intended destination, but not both.

0.0 = None of the above.

Socioeconomic Status Weak job prospects at home is a significant factor contributing to migration from Mexico to the United States (Massey et al. 1993, 2003, 2009). Socioeconomic status was measured using two conditions, a crisp-set indicating whether the respondent reported being employed immediately prior to being repatriated and a fuzzy-set measuring the degree to which the respondent had at least a high school education or equivalent.

While the interviews also inquired as to the respondent's income, many respondents did not or could not answer this question or provided an unclear response. This condition was therefore excluded from the analysis because it would require dropping an additional seven cases from the analysis. Although QCA is not restricted by sample size, it remains important to have a suitably diverse data set. Ultimately, it is up to the researcher to decide whether the inclusion of an additional condition is worth limiting the diversity of the analysis. In this instance, we determined that the additional precision did not outweigh the information lost.

Difficulty of Crossing The *MBCS* delves deeply into the details of the respondent's most recent crossing experience and its aftermath, inquiring into many aspects related to the difficulties and dangers of crossing, including the length of the journey, who (if anyone) they traveled with, and violence experienced (e.g., being robbed during the journey or assaulted by a border patrol officer following apprehension). Unlike the conditions previously discussed, the extant literature is mixed as to the effect that a difficult crossing has on migration intentions. While it might be expected that a long and dangerous crossing experience will dissuade people from the attempt—indeed, this is the explicit justification of the United States' "Prevention through Deterrence" border enforcement strategy (Cornelius 2001; Martínez et al. 2014)—prior research on this issue has produced conflicting results. Martínez et al. (2018) found no statistical association between the length of the journey and future crossing intentions. On the other hand, Molina (2013:22) found that individuals undertaking a lengthy journey were more committed to crossing than those for whom the crossing would be less difficult. Here, we use two measures of crossing difficulty. The first is the length of the crossing, with a short crossing being defined as one that took 1 day or less and a not-short crossing taking more than 4 days. The second measure is a crisp-set, used to indicate whether the respondent was accosted by bandits during their journey.

Observe that we employed a variety of strategies when calibrating the data. Some conditions were calibrated as continuous fuzzy sets, covering the full 0.0–1.0 range. Other conditions were calibrated as discrete fuzzy sets, limited to three or four values. And some were calibrated as dichotomous crisp sets. Researchers new to QCA sometimes believe that all conditions must be calibrated identically, or that calibrations must be symmetric with an equal number of values above and below the crossover point of 0.5. Neither of these are true and it is perfectly appropriate to mix calibration strategies within an analysis. What matters is that the calibration of each condition maintains fidelity to the underlying measure. We recommend calibrating to continuous fuzzy sets whenever possible because continuous fuzzy sets retain the most information and nuance. But when the underlying measure is discrete or dichotomous, it is perfectly appropriate to deploy a discrete or dichotomous calibration.

6.2 Analysis and Results

6.2.1 Women Who Intend to Cross Again

We first conducted a necessity test that examined whether any individual conditions or combinations of conditions were required for intending to re-migrate. None reached the required threshold of 0.9 consistency; the closest was `Embedded` with a consistency score of 0.85 and a coverage score of 0.70. The high consistency and coverage scores for `Embedded`, despite not meeting the necessity threshold, points to the importance of social embeddedness in explaining re-migration intentions, which would emerge as an essential component of the sufficiency recipes.

For the sufficiency analysis, we first examined the three sets of explanatory conditions for which we had clear directional expectations: previous crossing experience, social embeddedness, and socioeconomic status. We initially omitted the conditions related to crossing difficulty because their expected effect on the outcome was unknown.

This analysis produced a simple and straightforward truth table (Table 3) possessing one configuration consistently associated with the presence of the outcome. With only one positive truth table row, there is nothing to further simplify and the sufficiency solution therefore consists of a single recipe, which is consistent with the expectations from the literature. The very high consistency score of 0.99 indicates that all respondents belonging to this group intended to cross again:

$$\texttt{educated*employed*EMBEDDED*EXPERIENCED} \xrightarrow{\texttt{s}} \texttt{INTENDS} \qquad (1)$$
$$(scon = 0.99, scov = 0.27, ucov = 0.27)$$

In QCA notation, a multiplication symbol means "and" while an addition symbol means "or." Uppercase indicates the presence of a condition and lowercase, its absence.[5] The superscripted arrow indicates that the combination of conditions on the left is sufficient for realizing the outcome. Women who are uneducated and unemployed—suggesting that they have limited job prospects at home—and are strongly attached to the United States and already have substantial crossing experience all stated that they planned to cross again. The coverage scores, however, indicate that this group only accounts for a small fraction of women that intended to cross again. And, indeed, only 6 of the 39 respondents in the data set have strong membership in this set of conditions.

[Table 3 about here.]

To improve the explanatory power of our analysis, we introduced additional conditions. The underlying motivation here is the recognition of equifinality: Equation 1 provides an explanation for some—but not all—of the respondents. Other respondents may be explained by other recipes. Introducing the two conditions related to the difficulty of the crossing produced a much more complex truth table (Table 4), with six rows meeting the consistency threshold of 0.8. In such a situation, QCA can produce a range of solutions of varying complexity, as discussed above. Table 5 presents the three standard solutions: a "complex" solution emphasizing case details, a "parsimonious" focusing on the core conditions of importance, and an "intermediate" solution that uses the researchers' empirical and theoretical expectations to derive a solution that seeks to balance complexity and parsimony.

[Table 4 about here.]

[Table 5 about here.]

As is common, the intermediate solution provides the most compelling results. Compared to the complex solution, the intermediate solution eliminates conditions related to socioeconomic status from some of the recipes; this suggests that employment status and level of education are indeed serving the same function and that it may be fruitful to combine them into a single condition. Compared to the intermediate solution, which produces four reasonably nuanced recipes, the parsimonious solution produces seven simplistic recipes. It is not uncommon for the parsimonious solution to generate such results; its minimization algorithm is designed to seek the simplest possible recipes without regard to their theoretical or empirical plausibility. The parsimonious solution's three recipes with 0.0 unique coverage indicate a substantial amount of redundancy across the solution: these recipes overlap entirely with one or more of the other recipes that are part of the solution. More importantly, notice that `Embedded` is eliminated from two of the parsimonious solution's recipes. Ignoring this condition does not seem reasonable, given the importance suggested by it reaching close to achieving necessity and its presence across all of the recipes of complex and intermediate solutions. The preferability of the intermediate solution can also be observed by examining the overall consistency and coverage scores of the three solutions, presented in the "Solution" rows of Table 5. The intermediate solution's overall fit equals that of the complex solution, while offering slightly simpler recipes. However, its overall consistency is far superior to that of the parsimonious solution while its coverage is only slightly worse.[6]

Figure 1 presents the intermediate solution as a Fiss configuration chart (Fiss 2011; Rubinson 2019), with large circles indicating "core" conditions that are part of the parsimonious solution and small circles indicating "contributory" conditions that are exclusive to the intermediate solution. Below, we examine each of the four sufficiency recipes and offer a brief interpretation of the findings. Because of space limitations, we do not bolster our analysis with the case knowledge gained from the qualitative interviews as would be required in order to clearly establish causation. Rather, our intent is to demonstrate how the interpretation of QCA results encourages and facilitates the case-oriented analysis of multiple conjunctural causation.

[Figure 1 about here.]

Recipe 2a: Recipe 2a is a slight modification of Recipe 1 that adds the absence of encountering bandits during the journey. The very high consistency and relatively high coverage scores indicate the importance of this recipe, which describes women who have a great deal of investment in returning to the United States, both because of their pre-existing connections as well as the economic opportunities available. Moreover, these women have a great deal of experience crossing the border and were not accosted by bandits during their previous crossing.[7]

`fzeduc*employed*EXPERIENCED*EMBEDDED*bandits` (2a)

$$(scon = 0.99, scov = 0.24, ucov = 0.19)$$

Recipe 2b: Recipe 2b exhibits strong consistency and relatively high coverage. This pathway describes women with strong pre-existing connections to the U.S. who do not have extensive crossing experience. Despite not having extensive crossing experience and enduring a relatively lengthy journey, they did not encounter bandits during their prior crossing attempt. Motivated by social embeddedness, these women generally (but not universally) planned on making a subsequent attempt.

`experienced*EMBEDDED*short*bandits` (2b)

$$(scon = 0.88, scov = 0.22, ucov = 0.13)$$

Recipe 2c: Recipe 2c offers a unique recipe that describes only a small fraction of the respondents: just two women had strong membership in this category. These women were strongly motivated to attempt another crossing because they were already embedded into U.S. society and need a job. Encountering bandits during the previous attempt was not enough to dissuade them from making another attempt, in particular because they already possess substantial crossing experience and their prior journey was short.

$$\texttt{employed*EXPERIENCED*EMBEDDED*SHORT*BANDITS} \quad (2c)$$
$$(scon = 1.0, scov = 0.07, ucov = 0.07)$$

Recipe 2d: Recipe 2d also describes a very small fraction of the respondents, with strong consistency. In many ways, this recipe is the most distinct of the four. This recipe is somewhat unusual because it describes women who possess socioeconomic resources—they are educated and employed—which would be expected to reduce the incentive to cross again. However, they are strongly embedded within the U.S., have extensive experience crossing the border and their last crossing was relatively safe—short and free of bandits.

$$\texttt{FZEDUC*EMPLOYED*FZCROSS*EMBEDDED*SHORT*bandits} \quad (2d)$$
$$(scon = 0.87, scov = 0.10, ucov = 0.06)$$

6.2.2 Women Who Do Not Intend To Cross Again (Negation of the Outcome)

Necessity testing revealed no conditions that were required for the negation of the outcome, women who did not intend to cross again. Keep in mind that the negation of the outcome includes not only women who had decided against attempting another crossing but also women who were currently undecided. A separate QCA would be needed in order to understand the conditions under which women decided to return home. Table 6 presents the truth table for the sufficiency analysis. Figure 2 presents the intermediate solution. The three sufficiency recipes tell a similar story, so are not analyzed independently. The women who had not decided to cross again all shared limited motivation for doing so: either they lacked strong pre-existing connections to the U.S. (recipe 3a), possessed socioeconomic resources at home (recipe 3b), or both (recipe 3c). Consistency was uniformly high for all three recipes, indicating that most women possessing these combinations of characteristics had not decided to cross again. Women belonging to the first two recipes not only lacked the requisite motivations for crossing again but had been accosted by bandits during their prior journey, the difference between the two groups was that the journey had been shorter for those belonging to recipe 3a. Recipe 3b is interesting as it is the only recipe across all solutions that does not include degree of social embeddedness as a contributing condition. This indicates that, for a small fraction of women, when one already possesses economic resources, the threat of undertaking another long and dangerous journey was sufficient for not having decided to cross again, regardless of their existing connection to the United States.

[Table 6 about here.]

[Figure 2 about here.]

6.2.3 The Importance of Strong Social Embeddedness

Common to all of explanations of a respondent's intent to cross again is the presence of strong social embeddedness within the U.S. Similarly, the absence of strong social embeddedness is a component of two of the recipes explaining women who did not intend to cross again. That the sufficiency recipes for the presence of the outcome all share this condition does not mean, however, that the condition is necessary; indeed, the necessity analysis revealed that it is not. Rather, `Embedded` is simply a common component of all four recipes. The importance of strong social embeddedness is evident in the qualitative interviews, with women emphasizing their need to reunite with their husbands, children, and extended family currently living in the U.S, independent of economic motivations. Despite their legal status, many of the respondents view the U.S. as their home; it is where they have lived, where their family continues to live, and where they will live again.

And yet, the overall solution coverage scores remain moderate: 0.55 and 0.49 for the presence and absence of the outcome, respectively. This indicates that these seven recipes leave unexplained a sizable fraction of the women who both do and do not intend to attempt another crossing. Of particular interest are questions related to those women who are not strongly embedded within the U.S. that nevertheless intend to cross again. What drives these women to attempt another crossing? What conditions or combinations of conditions might substitute for the affective motivation to return home and reunite with family? Also of interest are women who are strongly embedded but did not intend to cross again. Recipe 3b indicates that a difficult and dangerous crossing may be sufficient for women with existing socioeconomic resources. What are the other combinations of conditions that enjoin one's determination to re-migrate following a failed attempt?

7 Conclusion

QCA is a diversity-oriented research method, designed for the in-depth analysis of causal complexity. As illustrated by our analysis of the *MBCS* data, QCA bridges the qualitative and quantitative traditions by promoting analysis that is simultaneously case- and variable-oriented, encouraging researchers both to get to know their cases ("How are the women determined to cross again similar and different from one another?") and how conditions combine to produce an outcome ("Despite the importance of pre-existing connections to the U.S., the possession of strong social embeddedness is not sufficient by itself to facilitate a subsequent crossing attempt. What other conditions must be present?"). For qualitative researchers, QCA provides an opportunity to study a larger number of cases while preserving case holism, remaining sensitive to the presence of multiple conjunctural causation and maintaining the analytic rigor that in-depth case studies provide.

QCA complements, rather than challenges, traditional methodological approaches by allowing empirical researchers to leverage the strengths of both qualitative and quantitative research. The method may be used in both an inductive fashion for exploratory analysis and also applied deductively for hypothesis testing (Ragin and Rubinson 2009; Thomann and Maggetti 2020). Yet QCA also provides a distinctive approach to empirical research that focuses attention on the diversity embedded in one's data (Ragin and Rubinson 2009), encouraging researchers to explore contextual effects, how cases are similar and different from one another, and the various pathways by which an outcome may be reached. Fundamental to QCA's distinctiveness is that it is a set-theoretic methodology that uses Boolean algebra and fuzzy-set theory to identify superset/subset relationships among combinations of conditions.

An especially distinctive and valuable characteristic of QCA is that it produces a range of solutions of varying complexity. Ranging from nuanced solutions that emphasize case detail to abstract ones focusing upon core conditions of relevance, QCA encourages researchers to pursue middle-range causal explanations that balance specificity and generality. This capacity for "modest generalization" (Rihoux and Ragin 2009) offers yet another counter to the all-too-common claim that qualitative research can only produce idiosyncratic explanation and must only be used for exploratory research (Abbott 2004).

There are three major components involved in conducting QCA: construction of the calibrated data set, necessity testing, and sufficiency testing. These aspects of the analysis inform one another and QCA encourages a retroductive approach to conducting social research. Indeed, it is not uncommon for one aspect of the analysis to cause the researchers to revisit another. For example, given the importance of strong social embeddedness as a motivating factor for crossing, might some degree of pre-existing connection be necessary, all or most of the time? Could very strong social embeddedness be sufficient in and of itself? Are there other forms of embeddedness that are not captured by the existing measure? To better understand the relationship between social embeddedness and future crossing intentions would necessarily involve recalibrating the existing social embeddedness measure.

QCA encourages the flexible, iterative approach to conducting empirical research that is familiar to qualitative researchers. We began the sufficiency analysis with a straightforward model of four conditions grounded in existing theory and prior research. While this model (Equation 1) was confirmed as a crucial recipe for explaining future crossing intentions, the low coverage score indicated that women were crossing for other reasons as well. We then introduced additional explanatory conditions that allowed us to identify three additional causal recipes that illustrated different ways that crossing motivations and crossing experiences can combine to drive future crossing attempts.

Given the asymmetrical nature of causation, we analyzed both the presence and absence of the outcome and identified different causal recipes for each. Reflecting the challenges entailed in uprooting one's life and making the difficult journey across the border, the explanations for those women who had not decided to cross again were more similar to one another and simpler than those for women who had decided to cross again. Nevertheless, total coverage for both of the sufficiency analyses remains moderate, indicating the need for additional research on this topic.

This article has provided a high-level overview of QCA, both as a general approach for studying the social world and as a specific methodological technique. For additional resources, we recommend exploring the COMPASSS website at `http://compasss.org`. In addition to the bibliography of QCA-related publications mentioned above and posting news of interest to the QCA community, COMPASSS hosts a working papers series, publishes a list of software for conducting QCA and maintains a calendar of upcoming conferences, workshops, and training opportunities.

Although QCA has developed its own dedicated community of methodologists and practitioners since its introduction over three decades ago, we continue to view the method primarily as an approach to and technique for supporting case-oriented research. The procedures of QCA continually encourage researchers to get to know their cases while facilitating comparisons that identify the different types of cases present, distinguish relevant conditions and combinations of conditions from irrelevant ones, and determine the patterns that facilitate and/or hinder the realization of outcomes. Sensitive to the diversity that permeates our world, QCA offers case-oriented researchers a toolkit for exploring the inherent complexity of empirical reality.

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Notes

[1]The only real problem associated with the csQCA/fsQCA nomenclature is that some researchers are under the erroneous impression that csQCA and fsQCA operate according to separate logics and, therefore, one cannot mix crisp- and fuzzy-sets in the same analysis. In fact, the QCA algorithms are agnostic regarding this and do not distinguish between the two types of sets.

[2]As previously noted, the truth table represents an empirical taxonomy and researchers interested in exploring the diversity of a data set can therefore use QCA software for this purpose; however, such projects are typically not referred to as QCA *per se* (e.g., Rubinson and Mueller 2016). As a technique, "QCA" is generally understood to involve an explanation of an outcome.

[3]As QCA is a method for exploring diversity, it is crucial that both positive and negative cases are included in the analysis. QCA cannot be applied when the outcome is always present or always absent. (QCA is equally incapable of assessing the relevance of an explanatory condition that is a constant.) Ragin (2023) introduces *generalized analytic induction*, an alternative to QCA that operates on constant outcomes.

[4]Rubinson (2013) developed a formal test for the presence of contradictions based on a configuration's ratio of consistent to inconsistent cases, implemented in the Kirq software package (Reichert and Rubinson 2014).

[5]An alternative QCA syntax indicates a condition's absence using the mathematical symbol for negation, either $\sim$ or $\neg$. See Rubinson (2019) for a complete discussion of symbolic notation for QCA.

[6]It is common for consistency and coverage to work against one another in this way: a specific recipe with high consistency often explains only a small fraction of the observations. It is the researcher's responsibility to determine where to make such a trade off, relying upon their substantive and theoretical understanding of the cases.

[7]The absence of encountering bandits does not preclude other forms of assault nor indicate that the journey was in any way safe. Crossing the border is always a frightening experience and all but two respondents reported that

their crossing experience as either “very” or “extremely” dangerous.

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A Sufficiency Results

A.1 Sufficiency Results for Outcome

```
*********************
*TRUTH TABLE ANALYSIS*
*********************

File:  //vboxsvr/cjr/projects/border_crossing/cjr2.csv
Model: intends = f(educated, employed, experienced, embedded, short, bandits)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.831397
                                                          raw       unique
                                                        coverage    coverage   consistency
                                                       ----------  ----------  ----------
employed*~experienced*embedded*~short*~bandits          0.169927    0.129153    0.8574
~educated*~employed*experienced*embedded*~bandits       0.244139    0.244139    0.989083
educated*employed*experienced*embedded*short*~bandits   0.103881    0.0631068   0.872832
educated*~employed*experienced*embedded*short*bandits   0.0684961   0.0684961   1
solution coverage: 0.545669
solution consistency: 0.937035


Cases with greater than 0.5 membership in term employed*~experienced*embedded*~short*~bandits: A115 (0.731059,0.7),
  A141 (0.731059,1)
Cases with greater than 0.5 membership in term ~educated*~employed*experienced*embedded*~bandits: A139 (0.8,1),
  A125 (0.8,1), A136 (0.8,1), A144 (0.645656,1),
  A132 (0.645656,1), A109 (0.605532,0.7)
Cases with greater than 0.5 membership in term educated*employed*experienced*embedded*short*~bandits: A119 (0.605532,0.7),
  A123 (0.6,0.7)
Cases with greater than 0.5 membership in term educated*~employed*experienced*embedded*short*bandits: A116 (0.605532,1),
  A106 (0.6,0.7)
*********************
*TRUTH TABLE ANALYSIS*
*********************

File:  //vboxsvr/cjr/projects/border_crossing/cjr2.csv
Model: intends = f(educated, employed, experienced, embedded, short, bandits)
Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.831397
                                                  raw       unique
```

```
                                              coverage    coverage   consistency
                                              ----------  ----------  ----------
~experienced*~short                          0.290688    0.158214    0.650907
~educated*~employed*embedded                  0.286786    0.210341    0.990691
~employed*embedded*bandits                    0.0795455   0.0110493   1
educated*~employed*experienced*bandits       0.074178    0.00568181  0.753203
educated*experienced*embedded*bandits         0.0854574   0           0.66769
educated*employed*embedded*short*~bandits     0.103881    0           0.872832
educated*employed*experienced*embedded*short  0.120842    0           0.677099
solution coverage: 0.625962
solution consistency: 0.77943


Cases with greater than 0.5 membership in term ~experienced*~short: A115 (0.731059,0.7),
  A141 (0.731059,1)
Cases with greater than 0.5 membership in term ~educated*~employed*embedded: A139 (0.8,1),
  A144 (0.8,1), A125 (0.8,1), A136 (0.8,1),
  A132 (0.8,1), A109 (0.605532,0.7)
Cases with greater than 0.5 membership in term ~employed*embedded*bandits: A116 (0.8,1),
  A106 (0.6,0.7)
Cases with greater than 0.5 membership in term educated*~employed*experienced*bandits: A106 (0.858149,0.7),
  A116 (0.605532,1)
Cases with greater than 0.5 membership in term educated*experienced*embedded*bandits: A116 (0.605532,1),
  A106 (0.6,0.7)
Cases with greater than 0.5 membership in term educated*employed*embedded*short*~bandits: A119 (0.605532,0.7),
  A123 (0.6,0.7)
Cases with greater than 0.5 membership in term educated*employed*experienced*embedded*short: A119 (0.605532,0.7),
  A123 (0.6,0.7)
*********************
*TRUTH TABLE ANALYSIS*
*********************

File:  //vboxsvr/cjr/projects/border_crossing/cjr2.csv
Model: intends = f(educated, employed, experienced, embedded, short, bandits)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.831397
Assumptions:
~educated (absent)
~employed (absent)
experienced (present)
embedded (present)
                                                          raw       unique
                                                        coverage    coverage   consistency
                                                       ----------  ----------  ----------
~experienced*embedded*~short*~bandits                   0.221264    0.129153    0.877265
~educated*~employed*experienced*embedded*~bandits       0.244139    0.192801    0.989083
~employed*experienced*embedded*short*bandits            0.0707759   0.0707759   1
educated*employed*experienced*embedded*short*~bandits   0.103881    0.0631068   0.872832
solution coverage: 0.547949
solution consistency: 0.93728


Cases with greater than 0.5 membership in term ~experienced*embedded*~short*~bandits: A115 (0.731059,0.7),
  A141 (0.731059,1)
Cases with greater than 0.5 membership in term ~educated*~employed*experienced*embedded*~bandits: A139 (0.8,1),
  A125 (0.8,1), A136 (0.8,1), A144 (0.645656,1),
  A132 (0.645656,1), A109 (0.605532,0.7)
Cases with greater than 0.5 membership in term ~employed*experienced*embedded*short*bandits: A116 (0.645656,1),
  A106 (0.6,0.7)
Cases with greater than 0.5 membership in term educated*employed*experienced*embedded*short*~bandits: A119 (0.605532,0.7),
  A123 (0.6,0.7)
```

A.2 Sufficiency Results for Negation of Outcome

```
*********************
*TRUTH TABLE ANALYSIS*
*********************

File:  //vboxsvr/cjr/projects/border_crossing/cjr2.csv
```

```
Model: ~intends = f(educated, employed, experienced, embedded, short, bandits)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.805892
```

	raw coverage	unique coverage	consistency
educated*employed*experienced*~embedded*~bandits	0.118806	0.0474548	0.830805
educated*~experienced*~embedded*short*bandits	0.127964	0.0375577	0.92542
~educated*~employed*experienced*~embedded*short*bandits	0.0432835	0.0400684	0.822422
~educated*employed*experienced*embedded*~short*bandits	0.103787	0.064095	0.891612
educated*employed*experienced*~embedded*short	0.201316	0	0.917288
educated*employed*~embedded*short*bandits	0.157942	0	0.993915

```
solution coverage: 0.421684
solution consistency: 0.901339


Cases with greater than 0.5 membership in term educated*employed*experienced*~embedded*~bandits: A140 (0.605532,1),
  A145 (0.605532,1)
Cases with greater than 0.5 membership in term educated*~experienced*~embedded*short*bandits: A143 (0.73,1),
  A146 (0.605532,1)
Cases with greater than 0.5 membership in term ~educated*~employed*experienced*~embedded*short*bandits: A148 (0.858149,1)
Cases with greater than 0.5 membership in term ~educated*employed*experienced*embedded*~short*bandits: A118 (0.6,1),
  A117 (0.6,1)
Cases with greater than 0.5 membership in term educated*employed*experienced*~embedded*short: A110 (0.95,1),
  A142 (0.605532,1), A145 (0.605532,1)
Cases with greater than 0.5 membership in term educated*employed*~embedded*short*bandits: A110 (0.95,1),
  A142 (0.605532,1), A146 (0.605532,1)
*********************
*TRUTH TABLE ANALYSIS*
*********************

File:  //vboxsvr/cjr/projects/border_crossing/cjr2.csv
Model: ~intends = f(educated, employed, experienced, embedded, short, bandits)
Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.805892
```

	raw coverage	unique coverage	consistency
educated*~embedded	0.371083	0.151927	0.878299
~short*bandits	0.185047	0.0429906	0.88
~embedded*bandits	0.364486	0.0983793	0.928572

```
solution coverage: 0.559403
solution consistency: 0.887356


Cases with greater than 0.5 membership in term educated*~embedded: A110 (0.979309,1),
  A143 (0.979309,1), A140 (0.605532,1), A142 (0.605532,1),
  A145 (0.605532,1), A146 (0.605532,1)
Cases with greater than 0.5 membership in term ~short*bandits: A117 (1,1),
  A118 (0.65,1)
Cases with greater than 0.5 membership in term ~embedded*bandits: A110 (1,1),
  A142 (1,1), A146 (1,1), A143 (1,1),
  A148 (1,1)
*********************
*TRUTH TABLE ANALYSIS*
*********************

File:  //vboxsvr/cjr/projects/border_crossing/cjr2.csv
Model: ~intends = f(educated, employed, experienced, embedded, short, bandits)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.805892
Assumptions:
educated (present)
employed (present)
~experienced (absent)
~embedded (absent)
```

```
                               raw       unique
                             coverage    coverage   consistency
                            ----------  ----------  ----------
educated*employed*~embedded   0.278149    0.120175    0.917043
employed*~short*bandits      0.157477    0.0639868   0.925824
~embedded*short*bandits       0.300935    0.119343    0.914773
solution coverage: 0.485129
solution consistency: 0.897336


Cases with greater than 0.5 membership in term educated*employed*~embedded: A110 (0.979309,1),
  A140 (0.605532,1), A142 (0.605532,1), A145 (0.605532,1),
  A146 (0.605532,1)
Cases with greater than 0.5 membership in term employed*~short*bandits: A117 (1,1),
  A118 (0.65,1)
Cases with greater than 0.5 membership in term ~embedded*short*bandits: A110 (0.95,1),
  A148 (0.95,1), A142 (0.73,1), A146 (0.73,1),
  A143 (0.73,1)
```

Tables

ID	Intends	Bandits	Short	Educated	Employed	Experienced	Embedded
A102	1.0	0	0.95	0.008887	1	0.952574	0.8
A103	0.7	0	0.14	0.105001	1	0.645656	0.6
A104	1.0	1	0.73	0.020691	1	0.645656	0.8
A105	0.7	1	0.73	0.783421	1	0.268941	0.8
A106	0.7	1	0.73	0.952574	0	0.858149	0.6
A107	0.0	0	0.95	0.000685	1	0.858149	0.6
A108	0.0	0	0.73	0.952574	0	0.952574	0.6
A109	0.7	0	0.35	0.394468	0	0.645656	0.8
A110	0.0	1	0.95	0.979309	1	0.985226	0.0
A112	0.0	0	0.14	0.605532	1	0.858149	0.6
A113	0.0	1	0.95	0.105001	1	0.952574	0.6
A114	0.0	1	0.73	0.605532	1	0.268941	0.6
A115	0.7	0	0.05	0.991113	1	0.268941	0.8
A116	1.0	1	0.73	0.605532	0	0.645656	0.8
A117	0.0	1	0.00	0.000685	1	0.998641	0.6
A118	0.0	1	0.35	0.105001	1	0.952574	0.6
A119	0.7	0	0.95	0.605532	1	0.952574	0.8
A121	0.0	0	0.14	0.105001	1	0.995504	0.6
A122	1.0	0	0.05	0.394468	1	0.645656	0.8
A123	0.7	0	0.73	0.605532	1	0.952574	0.6
A125	1.0	0	0.95	0.047426	0	0.952574	0.8
A128	0.0	0	0.73	0.105001	0	0.645656	0.0
A130	1.0	0	0.35	0.394468	1	0.645656	0.8
A132	1.0	0	0.35	0.000685	0	0.645656	0.8
A133	0.0	0	0.73	0.020691	1	0.268941	0.6
A134	1.0	0	0.14	0.008887	1	0.645656	0.8
A136	1.0	0	0.35	0.003791	0	0.952574	0.8
A137	0.7	1	0.73	0.008887	1	0.268941	0.6
A138	0.0	0	0.35	0.003791	0	0.645656	0.0
A139	1.0	0	0.95	0.105001	0	0.858149	0.8
A140	0.0	0	0.00	0.605532	1	0.858149	0.0
A141	1.0	0	0.05	0.105001	1	0.268941	1.0
A142	0.0	1	0.73	0.605532	1	0.858149	0.0
A143	0.0	1	0.73	0.979309	0	0.268941	0.0
A144	1.0	0	0.95	0.105001	0	0.645656	0.8
A145	0.0	0	0.95	0.605532	1	0.645656	0.0
A146	0.0	1	0.73	0.605532	1	0.268941	0.0
A147	0.0	1	0.73	0.783421	1	0.268941	0.6
A148	0.0	1	0.95	0.000685	0	0.858149	0.0

Table 1: Calibrated data for border crossing study.

Condition	Description	Calibration method	Calibration thresholds
Intends (Outcome)	Degree of membership in the set of women intending to cross again	Manual assignment	1.0 = Intends to cross again 0.7 = May cross again 0.0 = Does not intend to cross again
Experienced	Degree of membership in the set of women with substantial previous experience crossing the border	Direct method	1.0 = 4 prior crossings 0.5 = 1.5 prior crossings 0.0 = 0 prior crossings
Embedded	Degree of membership in the set of women with strong connections within and integration into U.S. society	Manual assignment	1.0 = Is a permanent U.S. settler and has lived in U.S. 6+ yrs 0.8 = R either (a) has lived in U.S. for 2+ yrs or (b) has lived in U.S. and has family in U.S. 0.6 = R either (a) has previously lived in U.S. or (b) has family in U.S., but not both 0.0 = None of the above
Employed	Is employed?	Crisp set	1.0 = Yes 0.0 = No
Educated	Degree of membership in the set of women who have a high-school education	Direct method	1.0 = 12 yrs of school 0.5 = 8.5 yrs of school 0.0 = 5.5 yrs of school
Short	Degree to which recent crossing attempt was short	Direct method	1.0 = Journey took 1 day 0.5 = Journey took 2.5 days 0.0 = Journey took 5 days
Bandits	Encounted bandits during journey	Crisp set	1.0 = Yes 0.0 = No

Table 2: Calibrations of Outcome and Explanatory Conditions

Row	Educated	Employed	Experienced	Embedded	N	Outcome	Consist	PRI
1	0	0	1	1	6	True	0.99	0.99
2	1	0	1	1	3	False	0.76	0.68
3	0	1	0	1	3	False	0.69	0.62
4	1	1	1	1	3	False	0.65	0.51
5	1	1	0	1	4	False	0.62	0.52
6	0	1	1	1	11	False	0.57	0.49
7	1	0	0	0	1	False	0.48	0.34
8	0	0	1	0	3	False	0.39	0.35
9	1	1	0	0	1	False	0.31	0.16
10	1	1	1	0	4	False	0.26	0.11

Note: Remainders omitted

Table 3: Initial Truth Table for *Intends to Cross Again*.

Row	Educated	Employed	Experienced	Embedded	Short	Bandits	N	Outcome	Consist	PRI
1	1	0	1	1	1	1	2	True	1.00	1.00
2	0	0	1	1	1	0	3	True	0.99	0.98
3	0	0	1	1	0	0	3	True	0.98	0.97
4	1	1	0	1	0	0	1	True	0.90	0.86
5	1	1	1	1	1	0	2	True	0.87	0.80
6	0	1	0	1	0	0	1	True	0.83	0.80
7	0	1	1	1	0	0	5	False	0.70	0.65
8	1	1	1	1	0	0	1	False	0.69	0.56
9	0	1	1	1	1	0	2	False	0.67	0.58
10	0	1	0	1	1	1	1	False	0.62	0.48
11	1	1	1	0	1	0	1	False	0.54	0.30
12	0	0	1	0	1	0	1	False	0.53	0.49
13	1	0	1	1	1	0	1	False	0.50	0.34
14	0	1	0	1	1	0	1	False	0.50	0.42
15	1	1	1	0	0	0	1	False	0.47	0.26
16	0	1	1	1	1	1	2	False	0.44	0.31
17	0	0	1	0	0	0	1	False	0.44	0.36
18	1	1	0	1	1	1	3	False	0.36	0.24
19	1	0	0	0	1	1	1	False	0.32	0.21
20	0	1	1	1	0	1	2	False	0.30	0.13
21	0	0	1	0	1	1	1	False	0.22	0.19
22	1	1	0	0	1	1	1	False	0.12	0.01
23	1	1	1	0	1	1	2	False	0.08	0.01

Note: Remainders omitted

Table 4: Revised Truth Table for *Intends to Cross Again*.

Complex Solution	Consist	Raw cov	Uniq cov
EMPLOYED * experienced * EMBEDDED * short * bandits +	0.86	0.17	0.13
educated * employed * EXPERIENCED * EMBEDDED * bandits +	0.99	0.24	0.24
EDUCATED * EMPLOYED * EXPERIENCED * EMBEDDED * SHORT * bandits +	0.87	0.10	0.06
EDUCATED * employed * EXPERIENCED * EMBEDDED * SHORT * BANDITS	1.00	0.07	0.07
Solution	0.94	0.55	n/a

Intermediate Solution	Consist	Raw cov	Uniq cov
experienced * EMBEDDED * short * bandits +	0.88	0.22	0.13
educated * employed * EXPERIENCED * EMBEDDED * bandits +	0.99	0.24	0.19
employed * EXPERIENCED * EMBEDDED * SHORT * BANDITS +	1.00	0.07	0.07
EDUCATED * EMPLOYED * EXPERIENCED * EMBEDDED * SHORT * bandits	0.87	0.10	0.06
Solution	0.94	0.55	n/a

Parsimonious Solution	Consist	Raw cov	Uniq cov
experienced * short +	0.65	0.29	0.16
educated * employed * EMBEDDED +	0.99	0.29	0.21
employed * EMBEDDED * BANDITS +	1.00	0.08	0.01
EDUCATED * employed * EXPERIENCED * BANDITS +	0.75	0.07	0.01
EDUCATED * EXPERIENCED * EMBEDDED * BANDITS +	0.67	0.09	0.00
EDUCATED * EMPLOYED * EMBEDDED * SHORT * bandits +	0.87	0.10	0.00
EDUCATED * EMPLOYED * EXPERIENCED * EMBEDDED * SHORT	0.68	0.12	0.00
Solution	0.78	0.63	n/a

Frequency threshold: 1; consistency threshold: 0.80. Directional expectations are that Experienced and Embedded will contribute to the presence of the outcome while Employed and Educated will contribute to its absence. No directional expectations are provided for Short and Bandits.

Table 5: Sufficiency Results for *Intends to Cross Again*.

Row	Educated	Employed	Experienced	Embedded	Short	Bandits	N	Outcome	Consist	PRI
1	1	1	1	0	1	1	2	True	0.99	0.99
2	1	1	0	0	1	1	1	True	0.99	0.99
3	0	1	1	1	0	1	2	True	0.89	0.87
4	0	0	1	0	1	1	1	True	0.82	0.81
5	1	0	0	0	1	1	1	True	0.81	0.79
6	1	1	1	0	0	0	1	True	0.81	0.74
7	1	1	1	0	1	0	1	True	0.81	0.70
8	1	1	0	1	1	1	3	False	0.78	0.74
9	0	1	1	1	1	1	2	False	0.75	0.69
10	1	0	1	1	1	0	1	False	0.74	0.66
11	0	0	1	0	0	0	1	False	0.68	0.64
12	0	1	0	1	1	1	1	False	0.65	0.52
13	0	1	0	1	1	0	1	False	0.64	0.58
14	1	1	1	1	0	0	1	False	0.61	0.44
15	0	0	1	0	1	0	1	False	0.55	0.51
16	0	1	1	1	1	0	2	False	0.55	0.42
17	1	1	1	1	1	0	2	False	0.49	0.20
18	0	1	1	1	0	0	5	False	0.44	0.35
19	1	1	0	1	0	0	1	False	0.35	0.12
20	0	1	0	1	0	0	1	False	0.31	0.20
21	1	0	1	1	1	1	2	False	0.25	0.00
22	0	0	1	1	0	0	3	False	0.17	0.03
23	0	0	1	1	1	0	3	False	0.10	0.02

Note: Remainders omitted

Table 6: Truth Table for *Does Not Intend to Cross Again.*

Figure Captions

Figure 1. Fiss Chart for *Intends to Cross Again*

Figure 2. Fiss Chart for *Does Not Intend to Cross Again*

Figures

	Configurations			
	2a	2b	2c	2d
Embedded	•	⬤	⬤	⬤
Experienced	⊖	•	⬤	⬤
Employed		⊝	⊖	⬤
Educated		⊖		⬤
Short trip	⊖		•	⬤
Bandits	⊝	⊝	⬤	⊖
Consistency	0.87	0.99	1.00	0.87
Raw coverage	0.22	0.24	0.07	0.10
Unique coverage	0.13	0.19	0.07	0.06

Solution consistency: 0.94

Solution coverage: 0.53

⬤ / • Core/contributory condition present

⊖ / ⊝ Core/contributory condition absent

Figure 1: Fiss Chart for *Intends to Cross Again*

	Configurations		
	3a	3b	3c
Embedded	⊖		⊖
Employed		•	•
Educated			●
Short trip	•	⊖	
Bandits	●	●	
Consistency	0.91	0.93	0.92
Raw coverage	0.30	0.16	0.29
Unique coverage	0.12	0.06	0.12

Solution consistency: 0.90

Solution coverage: 0.48

● / • Core/contributory condition present

⊖ / ⊝ Core/contributory condition absent

Figure 2: Fiss Chart for *Does Not Intend to Cross Again*