

Fuzzy-Set Qualitative Comparative Analysis:

A Configurational Comparative
Method to Identify Multiple
Pathways to Improve Patient-Centered
Medical Home Models



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This brief focuses on using fuzzy set Qualitative Comparative Analysis (fsQCA) to evaluate patient-centered medical home (PCMH) models. It is part of a series commissioned by the Agency for Healthcare Research and Quality (AHRQ) and developed by Mathematica Policy Research under contract, with input from other nationally recognized thought leaders in research methods and PCMH models. The series is designed to expand the toolbox of methods used to evaluate and refine PCMH models. The PCMH is a primary care approach that aims to improve quality, cost, and patient and provider experience. PCMH models emphasize patient-centered, comprehensive, coordinated, accessible care, and a systematic focus on quality and safety.

I. Qualitative Comparative Analysis and Configurational Comparative Methods

Qualitative Comparative Analysis (QCA) is a powerful approach for studying PCMHs and other health services interventions (Thygeson, Solberg, Asche, et al., 2012; Kahwati, Lewis, Kane, et al., 2011). QCA was developed in political science to evaluate case studies with too few cases for standard statistical analysis and where the available data are often qualitative or a combination of qualitative and quantitative (Ragin, 1987; Rihoux and Ragin, 2009). QCA can be used to identify characteristics of the intervention, practices, patients, and practice settings that are associated with successful outcomes.

QCA differs from traditional regression analyses in that it is based on set theory and logic, not statistics, and is designed to evaluate social systems characterized by causal complexity. Consequently, QCA is a radically different approach to studying health services interventions such as medical homes. This has three important implications for investigators. First, QCA assumes there can be many pathways to the same outcome, a phenomenon known as equifinality. Second, QCA assumes each pathway can contain different combinations of explanatory characteristics. Therefore, the method looks for the effect of combinations—configurations—of necessary and sufficient explanatory characteristics,¹ rather than for the effect of each individual characteristic holding equal the other

¹ Necessary relationships occur when a characteristic, or combination of characteristics, is observed in all practices with a particular value of the outcome. That is, the presence of the outcome implies the presence of the characteristic(s). For example, a study might find that only PCMHs that use discharge planning and receive notification upon hospitalization of their patients reduce readmissions. Therefore, discharge planning and notification of hospitalization are both necessary characteristics to reduce readmissions. PCMHs that can reduce readmissions (the outcome) are a subset of the PCMHs that use discharge planning and receive hospitalization notifications (the conditions).

Sufficient relationships occur when a characteristic, or combination of characteristics, is observed in (usually) a subset of cases with a particular value of the outcome. That is, the presence of the characteristic(s) implies the presence of the outcome. Using the example above, hospitals in the area may have their own discharge planning and medication reconciliation processes, which also reduce readmissions. Therefore, each combination of characteristics (PCMH discharge planning and receipt of hospitalization notifications, or hospital discharge planning and medication reconciliation) is a sufficient condition for reducing readmissions.

Correlations are, by definition, symmetric “necessary and sufficient” relationships. The presence of the outcome implies the presence of the characteristics, and vice versa. Therefore, fsQCA can identify asymmetric types of potentially causal or explanatory relationships (necessary or sufficient) that traditional statistical methods that typically focus only on identifying correlations may overlook.

characteristics. Although traditional regression approaches may appear to be able to do this using interaction terms, they are not well suited to separately identifying necessary or sufficient characteristics (Schneider and Wagemann, 2012).

An example illustrates the first two differences. Suppose that patients rate a practice higher for two reasons. The first is that the staff are very friendly, regardless of the quality of care they deliver. The second is that the quality of care staff deliver is technically excellent, *and* the staff are at least moderately friendly, *and* the wait times for scheduled appointments average less than 30 minutes. Therefore, a set-theoretic approach is able to identify that there are two sets of patients, with different criteria (sufficient reasons) for rating the practice highly, pathways that might be missed by a traditional regression framework.

The third difference is that the QCA method requires the investigator to carefully convert data into measures of set membership using theoretical or substantive knowledge external to the empirical data—a process called calibration. Calibration requires that the investigator anchor the empirical data in such a way that the resulting assignment of set membership is conceptually grounded and reflects meaningful variation. Although researchers using regressions can and should think carefully about the link between their measures and the underlying concepts, the regression method does not explicitly require it, so this step is often overlooked. These three differences make QCA especially useful for explaining complex phenomena like the PCMH and how different intervention characteristics and contexts might produce different impacts.

QCA belongs to a class of analytic techniques based on set theory called Configurational Comparative Methods (CCMs). QCA is “configurational” because it allows investigators to identify combinations of (configurations) associated with an outcome of interest.² There are three types of QCA: (1) crisp-set QCA (csQCA), (2) multi-valued QCA (mvQCA), and (3) fuzzy-set QCA (fsQCA). These types differ in how the characteristics are coded. csQCA and mvQCA require characteristics to be coded as binary and multi-valued (more than two discrete values, usually three) variables, respectively, while fsQCA allows a characteristic to have any continuous value from 0 to 1. This methods brief focuses on fsQCA.

Fuzzy-Set Qualitative Comparative Analysis

The building block of fuzzy-set QCA is “fuzzy” membership of cases (such as primary care practices) in a set of cases with a given characteristic. A practice can be fully out of a set (membership = 0), a full member of the set (membership = 1), or a partial member of the set (membership between 0 and 1). In other words, practices can have continuously varying degrees of membership in a given set. The fuzzy-set approach provides flexibility for modeling the “fuzziness” implicit in concepts like “medical

² Words like “outcome” and “cause” may be used loosely to identify independent and dependent conditions in QCA; however, like statistical inference, establishing set-theoretic connections does not prove causality.

homeness” and the constituent components that characterize a PCMH.³ For example, if a medical home intervention requires NCQA certification, fsQCA is well suited to evaluating not only the presence or absence of the NCQA PCMH certification level, but also the fidelity with which it is operationalized. The fuzzy set of medical homeness may include practices that are fully in the set of medical homes (membership = 1), some that are “almost medical homes” (membership = 0.9), some that are more in than out of the set of medical homes (membership = 0.67), and so on, down to those that are fully out of the set of medical homes (membership = 0). Similarly, practices can be classified according to membership in sets defined by implementation components (such as high, medium, or low accessibility to patients); practice characteristics (such as being an independent practice or part of a larger delivery system); or patient characteristics (such as the proportion of low-, moderate-, and high-income patients).

Using membership of practices in different fuzzy sets, fsQCA can identify associations between combinations of multiple characteristics and an outcome. These associations are identified by elucidating necessary or sufficient relationships between a characteristic or combination of characteristics and an outcome. Depending on the relationships observed, these associations may be categorized as descriptive or explanatory.

Operationalizing an fsQCA Study

fsQCA is both an approach and an analytic method. The fsQCA approach includes developing a study design, with decisions about case selection and data collection that are informed by the set-theoretic perspective. This “pre-work” is valuable, but not essential to using fsQCA. Therefore, for brevity, we focus here on explaining the general steps for conducting an fsQCA analysis. Those interested in learning more about fsQCA study design and case selection should consult one of the excellent resources available (such as Berg-Schlusser and De Meur, 2009).

Step 1: Calibrate and convert each metric into a measure of set membership. After data collection, the first step in fsQCA is to construct the variables to be used in the analysis. The researcher develops a “membership function” that maps each characteristic or outcome onto the unit interval [0–1]. This step involves calibrating the data—determining the range of meaningful variation in the characteristic and what values correspond to varying levels of membership in the set of cases with that characteristic. As an example, consider how we typically calibrate the concept of temperature using the behavior of water. A thermometer may be calibrated to the freezing point (0 degrees Celsius), and boiling point (100 degrees Celsius) of water. This calibration process anchors the measurement of temperature to meaningful concepts—the points at which water undergoes distinctive phase changes. In fsQCA, this process of calibration and assigning fuzzy-set membership is explicit and requires the researcher to carefully consider what constitutes meaningful variation for each metric of interest (or variable). There are a variety of approaches to calibrate and assign a membership function (Smithson and Verkuilen, 2006). Whatever the method, every effort should be made to base the calibration on substantive knowledge, defensible theory, or empirical evidence. When this is not possible, it is acceptable to use inspection of the metric’s distribution to inform the selection of calibration breakpoints.

³ “Fuzziness” here refers to conceptual fuzziness (which is unavoidable in verbally mediated concepts), not lack of measurement precision. Fuzzy-set membership also is conceptually very different from probability.

Step 2: Identify strong necessary or sufficient relationships between individual characteristics and the outcome of interest. After the metrics have been calibrated and converted to measures of fuzzy-set membership, the next step is to identify characteristics that have a necessary or sufficient relationship with the outcome of interest. This makes it easier to identify key variables and is helpful in reducing the number of characteristics in the next step of the analysis.

Step 3: Identify any and all sufficient relationships between combinations of multiple characteristics and the outcome of interest. The core of the fsQCA method is fuzzy-set truth table analysis (FSTTA). This process elucidates any relationships between combinations of potentially causal or descriptive characteristics and the outcome of interest. The output of FSTTA is one or more combinations of characteristics associated with an outcome, reflecting that more than one combination can be linked to a given outcome.

II. Uses of Fuzzy Set Qualitative Comparative Analysis and the Configurational Comparative Method

QCA is beginning to gain traction in the health services literature. A recent MEDLINE search for “qualitative comparative analysis” returned 24 publications. The earliest publication was in 1995, and nearly half were published in the past 3 years. All the fsQCA studies were published in 2012 (Thygeson, Solberg, Asche, et al., 2012; Woodside and Zhang, 2012; Chuang, Dill, Morgan, et al., 2012; Eng and Woodside, 2012).

Thygeson and colleagues (2012) used fsQCA to study PCMHs and illustrated the strengths of the method, including how it may complement statistical analyses (Thygeson, Solberg, Asche, et al., 2012). They explored the relationship between primary care practice characteristics associated with PCMH capabilities (medical “homeness”) and quality outcomes, including diabetes risk factor control, preventive service delivery, and patient experience. In a sample of 21 practices certified by NCQA as Level III (high-scoring) medical homes, they identified associations between PCMH capabilities and quality outcomes that had not been evident in a prior analysis using conventional statistical methods.

The fsQCA analysis was able to identify sufficient, but not necessary, relationships that the statistical analysis overlooked, and it was less constrained by the small number of practices included in the study. The analysis first looked at why some practices had poor clinical outcomes for patients with diabetes, defined as having a higher proportion of patients who did not achieve five targeted clinical outcomes: HgbA1c less than 7; LDL cholesterol less than 100; blood pressure less than 130/80; tobacco free; and daily aspirin. They found three different types of explanations: the low-performing practices were more likely to (1) care for patients with low socioeconomic status, (2) focus on the care of women or seniors, or (3) have ineffective diabetes team care capabilities. These results suggest that having an effective clinical team may be the most important PCMH capability to improve diabetes care.

The authors also looked for constellations of characteristics linked to low delivery of preventive services. Again, they found three different explanations. Practices with low preventive service delivery were more likely to have (1) a higher proportion of patients with a high average body mass index; (2) poor information sharing and caring for women, seniors, or patients with low socioeconomic status;

or (3) weak preventive medical service management systems despite good information sharing, with a patient panel with a standard age and gender distribution. These findings suggest that improving provider-patient communication in practices serving at-risk populations, or enhancing preventive care practice systems in practices serving non-disadvantaged patients, are capabilities that practices can focus on to improve preventive service delivery. Contextual factors, such as the sociodemographic characteristics of the patient population, were strongly linked to quality outcomes and mostly dominated the effect of PCMH characteristics. The relevance of these contextual factors was not discussed in prior analyses because they were treated as control variables, and the magnitude of their influence was not assessed.

csQCA also has been used to study a variety of health care topics. These include evaluating weight loss program effectiveness (Kahwati, Lewis, Kane, et al., 2011), the adoption of critical pathways and guidelines (Dy, Garg, Nyberg, et al., 2005), the impact of organizational change on sickness absence (Baltzer, Westerlund, Backhans, et al., 2011), the performance of primary care trusts in the National Health Service (Byrne, 2011), reasons for differential progress on addressing health care disparities (Blackman, Wistow, and Byrne, 2011), vaccine adoption in poor nations (Glatman-Freedman, Cohen, Nichols, et al., 2010), the influence of alcohol consumption on risky sexual activity (Schensul, Chandran, Singh, et al., 2010), and the effect of different conceptual frames on maternal fetal reduction decision making (Britt and Evans, 2007).

III. Advantages

fsQCA has many advantages when evaluating the PCMH.

Acknowledges and identifies multiple pathways to success. PCMHs are adopted in practices that are complex social systems embedded in larger complex social systems. Contextual characteristics (both external and internal) that vary in important ways across practices shape outcomes. Because fsQCA is case-oriented and set-theoretic, it is well suited to exploring and identifying important causal and constitutive relationships between PCMH components and contextual factors, and the outcomes. It is likely that there are multiple pathways or combinations of characteristics that generate successful outcomes. fsQCA is designed to identify such equifinal causal recipes. In contrast, statistical methods, such as multiple linear regression, assume the existence of a single, necessary, and sufficient, explanatory model and focus on quantifying the net effects contributed by each variable in the model.

Bridges implementation and impact findings to identify factors associated with improved outcomes. The configurational nature of the fsQCA approach is ideal for synthesizing implementation and impact findings. Because it is designed for subset analysis, it is well suited to evaluating the intervention features, context, and conditions associated with effective interventions.

Allows analysis with small samples. fsQCA can be particularly useful in revealing relationships between the outcome and explanatory variables where traditional statistical methods lack power due to small sample sizes. This makes it a promising design to evaluate PCMH interventions that typically do not include more than 50 primary care practices.

Complements statistical methods. QCA and fsQCA can also be combined with statistical methods; the two are complementary (Chuang, Dill, Morgan, et al., 2012; Glatman-Freedman, Cohen, Nichols, et al., 2010; Dixon-Woods, Agarwal, Jones, et al., 2005; Grofman and Schneider, 2009). Within a larger study, QCA can be used to answer some questions, and traditional methods can be used to answer others. Alternatively, the two can be used sequentially. For example, QCA could be used to identify relationships and generate hypotheses about sufficient combinations of characteristics linked to outcomes, and traditional methods then could be used to formally test the hypotheses.

Provides a formal method for conceptualizing and analyzing qualitative information. One of the first steps in fsQCA is to convert observations regarding a characteristic of interest into degrees of membership in “the set of cases with that characteristic.” This requires the researcher to think rigorously about the conceptualization of the characteristic and what range of variation in the characteristic is meaningful and important. This explicit conceptualization process enables the researcher to convert qualitative information into evaluation metrics that are both meaningful and useful. Many of the characteristics of PCMHs, including the concept itself, are inherently qualitative. fsQCA provides a structured method for analyzing such information.

Supports exploratory analysis and theory development. Our understanding of different PCMH models, and in particular what characteristics or capabilities are associated with the desired outcomes, is in an early stage of development. fsQCA is a “case-oriented,” rather than “variable-oriented,” analytic method. Case-oriented methods are especially useful when our understanding of a phenomenon is immature.

In addition, the fsQCA analytic process is iterative. The researcher develops a set-theoretic conceptual model, selects the cases (for example, primary care practices) to be studied, collects and analyzes the data, identifies discrepancies between the explanatory model and the results (logical contradictions), and then modifies the model in deliberate and systematic ways to better explain the data (by eliminating contradictions). In circumstances where theory is immature, this iterative method—if carefully done—is useful for theory development. This process is distinctly different from conventional statistical analysis, where, after the explanatory model and analysis plan have been determined, subsequent modifications are frowned upon because of legitimate concerns about investigator bias.

IV. Limitations

fsQCA presents investigators with several challenges.

Limits to explanatory power. First, although it is well suited to studies with small samples, fsQCA analytic power has limits, just as regression analyses do. The number of possible logical combinations of characteristics grows exponentially with the number of characteristics (combinations = 2^N , where N = the number of characteristics). Consequently, there is a limiting ratio of explanatory cases-to-characteristics. Below this ratio, there is an unacceptably high likelihood of incorrectly finding “meaning,” when there is really just random variation. Researchers have developed rules of thumb for csQCA for the limiting ratio of cases-to-characteristics. Although these ratios were developed

for csQCA, it seems reasonable to assume that a similar constraint exists for fsQCA.⁴ The ratios vary according to the number of characteristics in the model. With three or four characteristics, a ratio greater than 3:1 is preferred; with five or six characteristics, the ratio should be greater than 4:1. A study of 50 cases (practices) should ideally include no more than seven characteristics in the explanatory model (Marx, 2010).

Limits to causal analysis. Like regression and other standard statistical methods, fsQCA identifies associations, not causality. In a typical analysis, fsQCA reveals configurations of characteristics associated with an outcome; it is up to the investigator, however, to hypothesize any possible causal mechanisms or temporal dependencies between the characteristics. Another CCM approach, Coincidence Analysis, has been proposed as a better method for addressing causal dependencies (Baumgartner, 2012). Alternatively, Coincidence Analysis can be reproduced using a sequence of fsQCA analyses that specify subsequent conditions as intermediate outcomes of precedent conditions. Researchers can array their possible causal conditions in hypothetical chains and conduct separate analyses for each intermediate outcome. In addition, set relationships identified by fsQCA can be used to deduce possible evolutionary relationships between cases. Thus, if all PCMHs in a set of PCMHs have characteristic X, but only some have characteristic Y, and one believes theoretically that Y comes after X, one can hypothesize that X is a characteristic of PCMHs that occurs early in the development of PCMHs, and that Y occurs later. fsQCA also can be modified to include temporality in the analysis by explicitly including characteristics that include time patterns, such as “X preceded Y,” in the analysis (Caren and Panofsky, 2005; Ragin and Strand, 2005).

Sensitivity to case selection. Results of fsQCA and other CCMs may be sensitive to which cases are included in the analysis. This is especially true for very small sample studies so the process of case selection becomes even more important (Berg-Schlusser and De Meur, 2009).

Risk of bias due to subjective decisionmaking. fsQCA requires the evaluator to make many potentially subjective decisions during the design, implementation, and iteration of the analysis; this, in turn, introduces the potential for substantial bias. The antidotes to this are absolute transparency, diligent application of substantive or theoretical knowledge in making these decisions, and careful sensitivity testing regarding all methodological choices. All potentially explanatory combinations generated by fsQCA analysis should be viewed as potentially falsifiable hypotheses to be tested with additional studies, using complementary quantitative methods when possible. This is also true of traditional regression analyses.

Analysis requires considerable time and effort. In general, the software packages that support fsQCA are not as fully functional as mainstream statistical packages, so fsQCA is relatively labor intensive compared to traditional techniques. The requirements for careful methodological diligence and the iterative nature of the analysis, coupled with a lack of tools to automate and document these processes, may make for a relatively prolonged period of analysis. Other challenges include describing and displaying fsQCA results within the word count and graphical limits common to health services research publications, and finding knowledgeable reviewers for funding requests and publications.

⁴ For technical reasons, however, fewer cases may be needed with fsQCA, because a single case can provide information about more than one configuration of characteristics.

V. Conclusion

fsQCA and other CCMs are important additions to the toolkit for evaluating the PCMH and other health services interventions. These methods are useful for carefully conceptualizing explanatory models, using implementation findings to explain variation in impacts, and distilling multiple pathways to successful outcomes.

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Online Resources and Software Packages for QCA

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