Assessing the importance of necessary or sufficient conditions in fuzzy-set social science

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Abstract

Political scientists of all stripes have proposed numerous necessary or sufficient condition hypotheses. For methodologists a question is then how can we assess the "importance" of these necessary conditions. This paper addresses two central questions about the importance of necessary or sufficient conditions. The first regards their "absolute" importance which is addressed via the concept of the trivialness of necessary or sufficient conditions. The second importance question deals with the relative importance of necessary or sufficient conditions: for example, if X_1 and X_2 are necessary or sufficient conditions, is one more important than the other? The paper develops measures to assess the importance of necessary or sufficient conditions in three related contexts: (1) Venn diagrams, (2) 2×2 tables, and (3) fuzzy logic, with an emphasis on fuzzy logic methods. The empirical analysis uses the measures of absolute and relative importance to extend Ragin's (2000) discussion of the causes of IMF riots.

Introduction

Political scientists of all stripes – e.g., game theorists, quantitative scholars, social constructivists, etc. – have proposed numerous necessary condition hypotheses (see the chapters in Goertz and Starr 2002 for many examples). For example, the social and economic "requisites" of democracy have been debated for over 40 years now (Lipset 1959). The agreement of all veto players is a necessary condition for policy change (Tsebelis 1999). For methodologists a question is then how can we assess the "importance" of these necessary conditions. This paper addresses two central questions about the importance of necessary or sufficient conditions. The first regards their "absolute" importance, which I address via the concept of the trivialness of necessary or sufficient conditions. The second importance question deals with the relative importance of necessary or sufficient conditions: for example, if X_1 and X_2 are necessary or sufficient conditions, is one more important than the other?

The concept of a trivial necessary condition forms part of the background knowledge of most social scientists. Since the concept is not taught in methods courses it is not clear where these intuitions come from or whether they are the same for all. A major goal of this paper is to provide an in-depth analysis of the concept of a trivial necessary condition. As Downs illustrates (see below) common examples of trivial necessary conditions invoke factors which are constant for all values of the dependent variable. We shall see that the common notion of trivialness is in fact valid. However, the analysis of trivialness leads to a second alternative conceptualization that is not part of the our collective intuition. This second approach starts from the opposite side by saying that the most nontrivial necessary condition is one that is also sufficient. These two approaches lead to different measures of how trivial a necessary condition is.

If the concept of a trivial necessary condition forms part of our background knowledge, such is not the case for sufficient conditions. However, we can fruitfully ask the same question about sufficient conditions: how trivial are they? While this may seem like a nonsensical question, in fact we shall see that it has a perfectly reasonable interpretation that mirrors nicely that of a trivial necessary condition.

With the publication of *Fuzzy-set social science* Charles Ragin has provided social scientists with an impressive set of new tools for the analysis of social and political behavior. In that book he lays out methods for detecting necessary and/or sufficient conditions for social phenomena. Chapter 8 gives the basic tools for necessary conditions, while chapter 9 does likewise for sufficient conditions (I will take "sufficient condition" to mean either individual factors, e.g., X_1, which are sufficient or conjuctural factors, e.g., $X_1 \cdot X_2 \cdot X_3$, which are sufficient for the outcome). Chapter 10 illustrates these methods with real data about IMF riots and the determinants of welfare provision in advanced, industrial, democratic countries.

One of the things that Ragin does not really discuss (with some exceptions, see below) is how one might evaluate *how important* a necessary or sufficient condition is. *Fuzzy-set social science* tells you how to find necessary or sufficient conditions but only provides hints about how to analyze the absolute or relative importance of those conditions. For example, Goldthorpe criticizes QCA (Qualitative Comparative Analysis, Ragin's 1987 methods of which his fuzzy logic methods are an extension): "In an application of QCA, it should be noted, the independent variables are simply shown to be causality relevant – or not; no assessment of the *relative strengths* of different effects or combinations of effects is, or can be, made" (1997, 7).

Questions of importance arise almost without fail in the discussion of causal explanations. For example, is resource mobilization more important than political opportunity structure in explaining social movements? In the specific case analyzed by Ragin and which I take up here, is urbanization more important than IMF pressure as a cause of IMF riots?

Since fuzzy logic has very close ties to generic 2×2 tables and Venn diagrams I also provide an analysis of importance in these contexts as well. I introduce the key concepts via Venn diagrams and 2×2 tables. It is in fact central to my project that all the procedures that I propose work well for 2×2 tables. An essential goal of this paper is conceptual: what do we mean by trivial or important necessary or sufficient conditions? The answer has to work the same in my three related domains, (1) Venn diagrams, (2) 2×2 tables, and (3) fuzzy logic. Thus the key principles and measures can be understood without any exposure to Ragin's fuzzy logic book. However, the fuzzy logic analysis assumes a basic knowledge of Ragin's book (2000). Importantly, my analysis is conceived of as an *extension* of his methods. Hence I take up the analysis of IMF riots where he stops.

The importance of necessary conditions

Trivialness of necessary conditions

In some respects it is not natural to ask how important a necessary or sufficient condition is. I propose that one way to attack the importance question is via its opposite "trivialness." It seems clear that if X is a trivial necessary condition then it has little or no importance. Since we have some intuitions about trivialness (at least for necessary conditions) we can perhaps leverage that into an analysis of the importance of necessary conditions.

For example, Lupia and McCubbins propose three necessary conditions as the core of their influential book:

> *Theorem 4.1: Communication leads to enlightenment [knowledge] if and only if:*
> 1. the speaker is persuasive,
> 2. only the speaker initially possesses the knowledge that the speaker needs, and
> 3. common interests or external forces induce the speaker to reveal what he knows.
>
> (1998, 69)

A critic might respond that these theoretically important necessary conditions are empirically trivial. In order to respond to such a criticism one must know what a trivial necessary condition is. The purpose of this paper is to provide a set of conceptual tools that allow researchers conceptually and empirically evaluate such comments.

Braumoeller and Goertz (2000) provide the only explicit analysis of trivialness that I am aware of (though see Dion 1998). They start with a typical consideration of trivial necessary conditions:

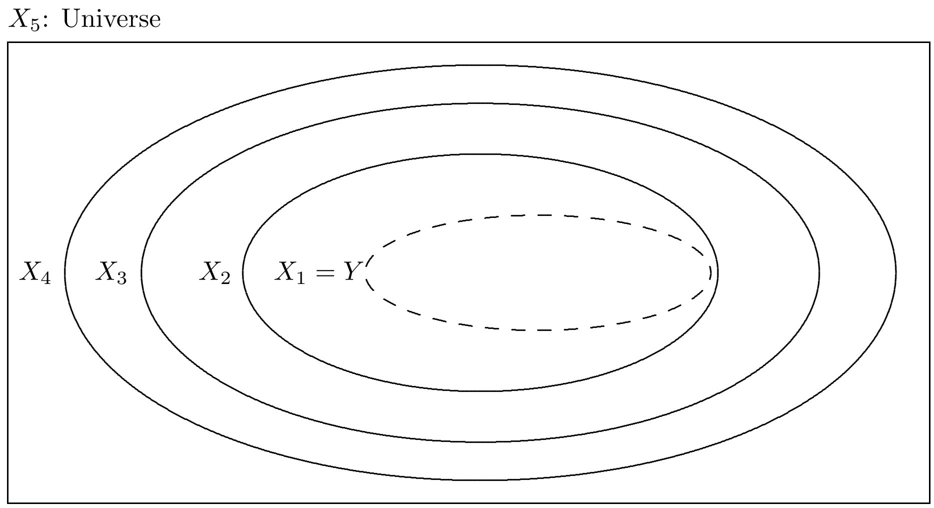
> The search for necessary conditions is problematic because the utility of a necessary condition is contingent and poorly understood. There are an infinite number of necessary conditions for any phenomenon. For example, it is true that all armies require water and gravity to operate, but the contribution of such universals is modest. (Downs 1989, p. 234)

What makes gravity a trivial necessary condition is that it is constant across all cases of armies. Braumoeller and Goertz extend this basic idea to define a trivial necessary condition as being one that is present in all cases in the universe of analysis, both when the dependent variable is present and absent.

Before analyzing the trivialness of a necessary condition we need to define what a necessary condition is. In terms of set theory we have:

X is a necessary condition for Y if Y is a subset of X.

Figure 1: Trivial necessary conditions: a set theoretic perspective



In figure 1 Y is contained in X_i hence Y never occurs unless X_i does which is a definition of a necessary condition.

The rectangle (set X_5) is the universe of cases. The various sets X_1, X_2, X_3, and X_4 are all necessary conditions for the set Y, since Y is a subset of them all. X_3 is *more trivial* than X_2 which is *more trivial* than X_1 because the set Y as a proportion of the set X_i decreases from X_1 to X_4. The set X_5=universe is a completely trivial necessary condition because no matter what Y is, it must *always* be a subset of X_5, the universe of cases. I believe that this constitutes the commonly held intuition about what a trivial necessary condition is (illustrated by Downs's remarks above). X_5 is a trivial necessary condition because it always occurs: X_5 *is* a necessary condition since Y is a subset of X_5 but a trivial one.

Conversely, we can see that necessary conditions become more important as the set $X_i - (X_i \cap Y)$ approaches the empty set. In other words, as the set X_i shrinks in its coverage of Y its importance increases. Since $Y \subset X$ the small possible set X_i is when $X = Y$. Hence, X_i is the least trivial (i.e., most important) when X and Y are equal.

The most common way to think about necessary conditions uses 2×2 tables. In the discussion below each Venn diagram has its parallel $2{\times}2$ table which presents the same pattern: if the observation is in the set X_i or Y then

Table 1: Trivial necessary conditions in 2×2 tables

	$\neg X_i$	X_i
Y	0	100
$\neg Y$ (X_1)	500	0
$\neg Y$ (X_2)	400	100
$\neg Y$ (X_3)	300	200
$\neg Y$ (X_4)	100	400
$\neg Y$ (X_5)	0	500

it has value one in the X column or Y row in the 2×2 table; an observation lies outside X_i or Y will have its parallel place in the $\neg X$ column or $\neg Y$ row.

It is important in examining 2×2 tables to keep in mind that I am only concerned with necessary conditions. This means that the $(\neg X \cap Y)$ cell is empty. In the context of figure 1 it means that Y is always included or a subset of X. Hence I am not considering general Venn diagrams or 2×2 tables but those that satisfy the requirements of a necessary condition.

It is thus useful to translate the ideas of figure 1 into the 2×2 table context. In that table we have the sets X_1 through X_5 like those in figure 1. Table 1 represents five 2×2 tables compressed into one table: the Y row is constant while a new 2×2 table can be constructed with each successive ($\neg Y$ (X_i)) row. Notice that as the sets X_i in figure 1 get larger they cover more of the entire population; in the case of X_5 there are no cases of $\neg X$: the same occurs in table 1, eventually for the X_5 2×2 table there are no cases of $\neg X_5$.

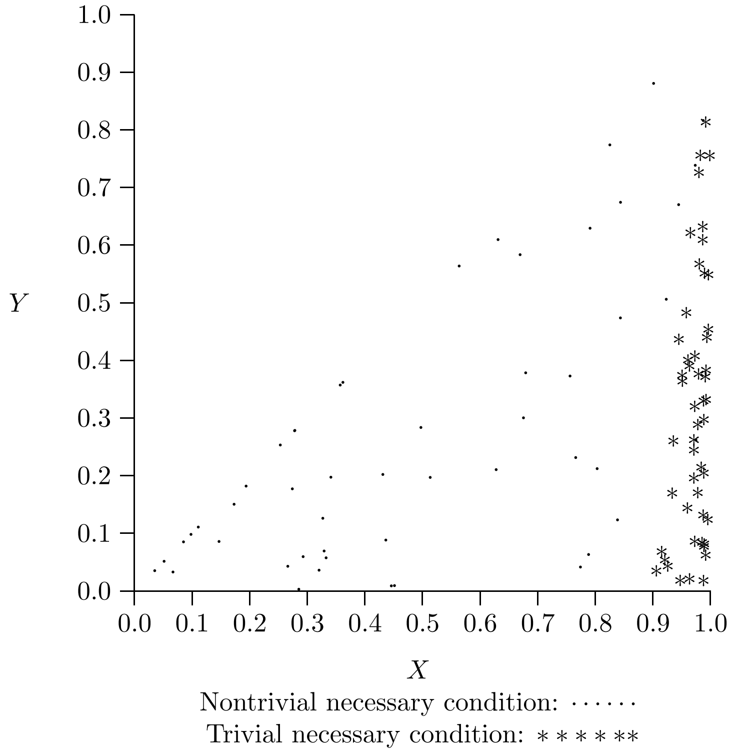
This permits a new insight into the logic of necessary conditions in 2×2 tables:

> The $(\neg X, \neg Y)$ cell is the "trivialness cell" of a 2×2 table.

As X_i becomes more trivial the $(\neg X, \neg Y)$ cell has fewer and fewer cases; complete trivialness occurs when there are no cases in that cell.

How does this notion of a trivialness cell correspond to the Braumoeller and Goertz (2000) proposal for testing trivialness? Their idea was that a necessary condition was trivial as the proportion of cases in the "trivialness" row (i.e., the $\neg Y$ row) was the same as in the necessary condition row

Figure 2: Trivial necessary conditions: a fuzzy logic perspective



(i.e., the Y row). In table 1 perfect trivialness is when all the cases in the population fall into the X column. This means that there are zero cases in the $\neg X$ column – hence no cases in the crucial $(\neg X, \neg Y)$ cell – which means then by definition that the two rows of the table will have exactly the same proportions, i.e., 1.00. Hence, the view of trivialness presented by figure 1 and table 1 fits perfectly with the statistical procedures for evaluating trivialness suggested by Braumoeller and Goertz.

Fuzzy logic extends the tradition Boolean or Aristotlean logic by allowing continuous values between zero and one instead of dichotomous (or "crisp" in fuzzy logic terminology) values. The fuzzy logic "membership score" can be seen as a continuous value of the X or Y variable. While space considerations prevent a complete exposition of why in fuzzy logic the fact that X is necessary for Y means that the fuzzy logic value of X is greater than or equal to the fuzzy logic value of Y. Basically the set theoretic notion of containment becomes the relationship of less than: in an important sense a number which is less than another is "contained in" the larger number. This fuzzy logic sense of containment for necessary conditions produces triangular data like those in figure 2.

One can apply the basic insight of Venn diagrams and 2×2 tables to the fuzzy logic definition of a necessary condition. If $X = 1$ for *all* Y then it is a necessary condition for Y, since Y must lie in the [0,1] interval is must be less than or equal to one. Figure 2 illustrates this for the lower-triangular data typical of a necessary condition. The dots represent a standard nontrivial necessary condition. The asterics are a trivial necessary condition. Notice that they all hover very near the $X = 1$ vertical line. Perfect trivialness is achieved in the case where $X = 1$ for all cases in the population.

I propose then that the fuzzy logic trivialness of variable X be based the distance between x_i and 1. If x_i is always 1 then the trivialness score will be zero since the distance between x_i and 1 is always zero. As x_i moves away from 1 then its importance increases and the trivialness score moves away from zero.

We now know the minimum trivialness score for each x_i which is zero, but we do not know what its maximum "importance" score can be. In figure 1 a necessary condition becomes important as it approaches Y. In fuzzy logic a necessary condition *must* be greater than or equal to the membership score of the dependent variable. In figure 2 this means that $x_i \geq y_i$. Hence we can "standardize" how trivial x_i is by how far from 1.00 y_i is: $(1 - x_i)/(1 - y_i)$.

I suggest that the trivialness of X be defined as the average distance between x_i and 1 standardized by the maximum importance that this value can attain based on y_i. The measure of trivialness, $\mathcal{T}_{nec}$, of X is thus the average distance from x_i to 1.00 standardized by how far y_i is from 1.00:

$$\mathcal{T}_{nec} = \frac{1}{N} \sum (1 - x_i)/(1 - y_i) \tag{1}$$

A completely trivial necessary condition has $x_i = 1$ for all i so a completely trivial necessary condition has a $\mathcal{T}_{nec}$ value of zero. This means that the further $\mathcal{T}_{nec}$ is away from zero the more nontrivial, i.e., important, the necessary condition is.

Going at things from the other direction, by definition of necessity, i.e., $x_i \geq y_i$, maximal importance (i.e., least nontrivial) occurs when $x_i = y_i$ which gives a maximum $\mathcal{T}_{nec}$ score of 1.00. This means that if X is a necessary and sufficient condition then it has the maximum importance score of 1.0 which confirms our intuitive understanding of the ultimate importance of a necessary condition as being also sufficient (see the next section for more on this). This measure also has the advantage of using the same logic as does Braumoeller and Goertz's statistical measure of trivialness.[1]

The "relevance" approach to the importance of necessary conditions

The previous section attacked the importance of a necessary condition via the concept of trivialness. In terms of table 1 trivialness focuses on the fact that the "trivialness cell," $(\neg X, \neg Y)$, approaches zero in value, or, in set-theoretic terms $X_i \cap (X_i - Y) \rightarrow \emptyset$. However, one can approach the issue of the importance of a necessary condition via what I will call its "relevance" (to give it a name). Instead of defining the importance of a necessary condition via trivialness we can define it in terms of a necessary condition that is maximumally relevant. Here we have an intuition which we can build on:

> A maximally important necessary condition is also a sufficient condition.

In general a necessary condition is more important the more sufficient it is.

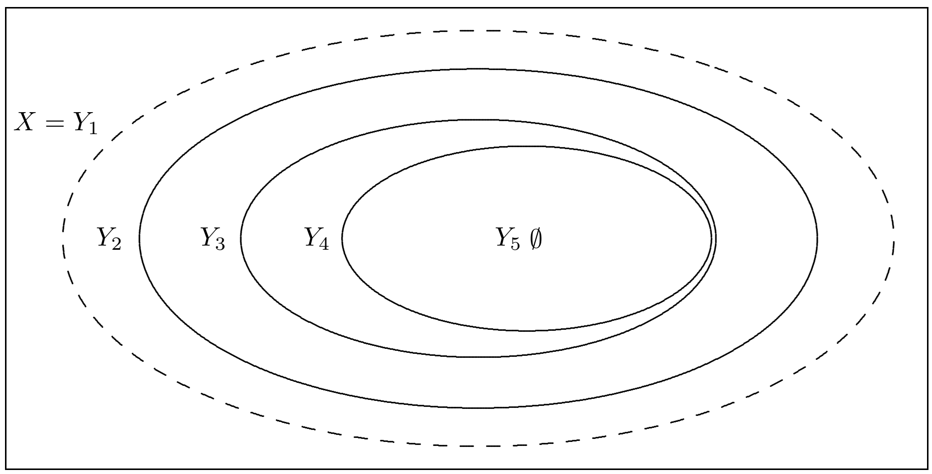
Figure 3 shows how relevance works. In figure 1 X_i expands to cover the whole universe of cases. In figure 3 we start with a necessary condition X which is sufficient for Y_1 and shrink Y. As the sets Y_i approach the empty set (Y_5) X becomes a less and less relevant necessary condition. In short, a trivial necessary condition is when X *always* occurs, an irrelevant necessary condition is when Y *never* occurs.

Another way to see this is via 2×2 tables. In table 2 the X column is what we focus on, since as in figure 3 it is the values of Y which change. As the cases in the X column move from $\neg Y$ to Y X is becoming "more sufficient." This is what Goertz (2003) in a non–fuzzy logic context has called the "sufficiency effect" of a necessary condition: the extent to which the presence of a necessary condition X helps produce Y.

One can think of the cases in the $(X, \neg Y)$ cell as counter-examples to the proposition that X is sufficient for Y: as the number of these counter-examples decreases the support for the sufficiency hypothesis increases. So as the table illustrates, as one moves more and more cases from the $\neg Y$ to the Y cell the importance of the necessary condition goes up. Eventually

[1] One difference between Ragin (2000) and Braumoeller and Goertz is that the latter use negative cases (where the dependent variable is absent or zero) while Ragin (2000) discourages the inclusion of these cases in the analysis.

Figure 3: Relevant necessary conditions: a set theoretic perspective



maximal relevance is achieved when the $(X, \neg Y)$ cell has zero cases and we have the classic diagonal table of a necessary and sufficient condition.

The relevance approach to the importance of necessary conditions contrasts with the trivialness one. One can compare table 2 with table 1 to see the difference in perspective between the trivialness and relevance approaches to the importance of necessary conditions. A completely relevant necessary condition is sufficient so in the case of X_1 in table 2 we have the classic necessary and sufficient condition in a 2×2 table with zeros in the diagonal cells. In contrast, table 1 is the classic trivial necessary condition with zeros in the $\neg X$ column. Hence we have a principle for the relevance of necessary conditions in 2×2 tables:

The $(X, \neg Y)$ cell is the "relevance cell" for necessary conditions.

Above I noted that the "trivialness cell" for necessary conditions was the $(\neg X, \neg Y)$ one. Braumoeller and Goertz (2000) described the $\neg Y$ row as the trivialness row. We have seen above how this plays out more specifically with regard to two my two measures of importance. Notice that both the relevance cell, $(X, \neg Y)$, and the trivialness cell, $(\neg X, \neg Y)$, lie in the trivialness row of $\neg Y$. Hence, the current analysis represents a refinement of the Braumoeller and Goertz analysis of trivialness.

Table 2: Relevant necessary conditions in 2×2 tables

	$\neg X_i$	X_i
Y (X_1)		500
Y (X_2)		400
Y (X_3)	0	300
Y (X_4)		100
Y (X_5)		0
$\neg Y$ (X_1)		0
$\neg Y$ (X_2)		100
$\neg Y$ (X_3)	200	200
$\neg Y$ (X_4)		400
$\neg Y$ (X_5)		500

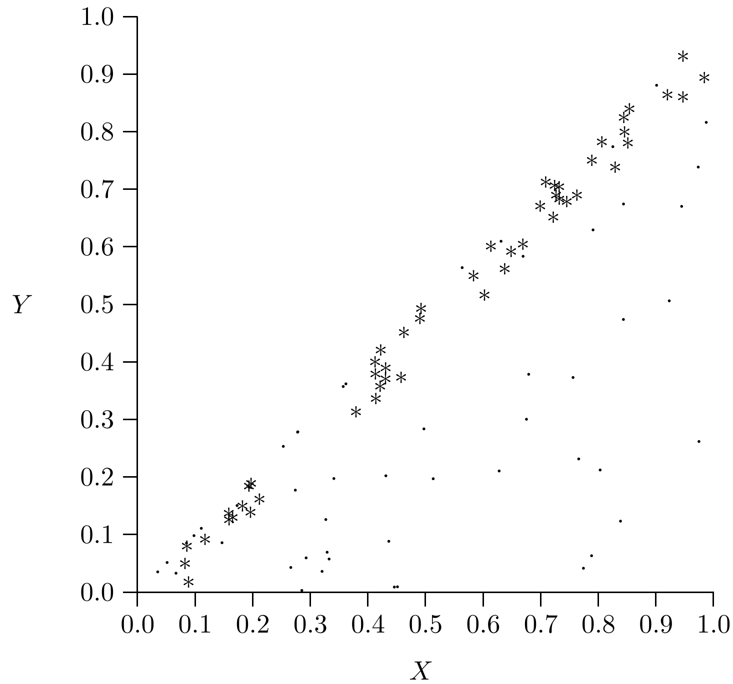
One can ask what relevance looks like in a fuzzy logic context. A necessary and sufficient condition in fuzzy logic is one that lies on the $X = Y$ diagonal line. As illustrated in figure 4 a very relevant necessary condition is one where all the observations lie on or just below the diagonal line. This, of course, contrasts with trivialness which puts all the cases near the $X = 1$ line.

Just as I defined a trivialness score, $\mathcal{T}_{nec}$, as the relative distance to the $X = 1$ vertical line we can create a measure of the relevance of a necessary condition, $\mathcal{R}_{nec}$, which is how close, relatively, X is to sufficiency in the fuzzy logic sense. Recall that by definition a necessary condition is one where $x_i \geq y_i$. If trivialness is $1 - x_i$ then relevance is closeness to y_i. So we can define the relevance measure of a necessary condition as $\sum y_i/x_i$. As above, maximal relevance is achieved when $x_i = y_i$, which means that the maximum value of the $\sum y_i/x_i$ is N, which we then use to standardize the measures so it ranges from zero to one:

$$\mathcal{R}_{nec} = \frac{1}{N} \sum y_i/x_i \tag{2}$$

In short, when $\mathcal{R}_{nec}$ is near zero that indicates a nonrelevant necessary condition, while relevance increases as $\mathcal{R}_{nec}$ does.

Figure 4: Relevance of necessary conditions: a fuzzy logic perspective



Average necessary condition: · · · · · ·
Very relevant necessary condition: * * * * **

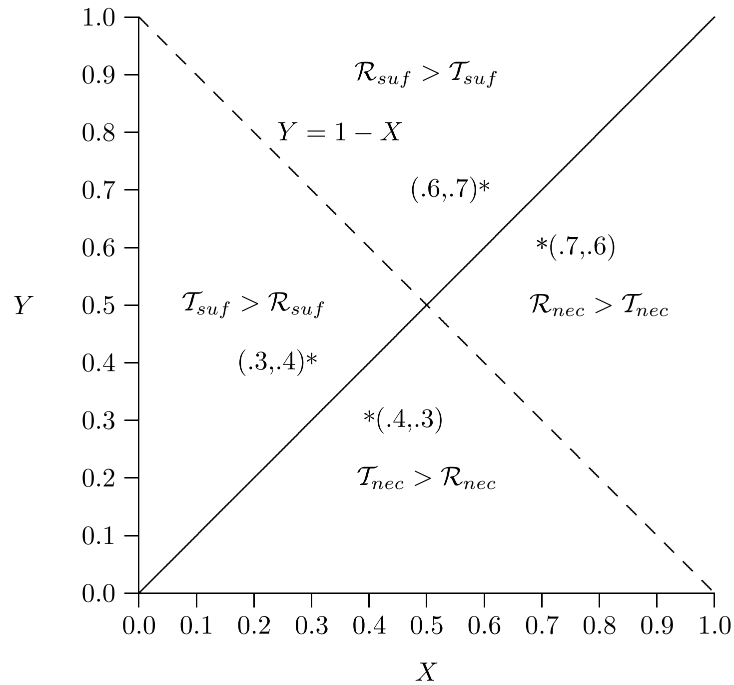
Comparing the trivialness and relevance measures of the importance of necessary conditions

We now have two measures of the importance of necessary conditions. One, $\mathcal{T}_{nec}$, evaluates necessary conditions based on the criterion of trivialness, while the other, $\mathcal{R}_{nec}$, uses the standard of sufficiency to determine how strong a necessary condition is. How do they compare?

First of all it is important to notice that they are not identical. One way to look at this is to ask when the two measures are in fact equal.

$$\begin{aligned}
\frac{1-x_i}{1-y_i} &= \frac{y_i}{x_i} \\
x_i(1-x_i) &= y_i(1-y_i) \quad \text{which is true when} \\
x_i &= y_i \quad \text{or when} \\
y_i &= 1-x_i
\end{aligned}$$

Figure 5: Comparing trivialness and relevance perspectives on necessary or sufficient condition importance



So when we are on the $X = Y$ diagonal the two measures are identical. Recall that both measures achieve their maximum (1.00) when $x_i = y_i$ which is what we want since it is then a sufficient condition and hence the least trivial necessary condition.[2]

[2] In the equations for trivialness and relevance there are two special cases that merit a brief discussion: when the denominators are zero. For the trivialness measure the denominator $1-y$ is zero when $y = 1$. Now since we are dealing with necessary conditions, i.e., $x \geq y$, this can only occur when $x = 1$, i.e., the northeast corner point (1,1). Similarly, for the relevance measure, it is zero when $x = 0$. Again, because we are dealing with necessary conditions, this can only occur when $y = 0$, i.e., at the origin (0,0). What should be the values of trivialness and relevance in these two cases? The answer to this question involves recalling that for all cases on the $X = Y$ diagonal the trivialness and the relevance measures are equal to each other. Since the points (0,0) and (1,1) also lie on the diagonal we can use the rule that if trivialness or relevance is undefined due to division by zero it is equal to the other measure. Practically, since this only occurs on the diagonal where both measures are always equal to 1 this means defining these two special cases to have value 1.

In turns out that the $Y = 1 - X$ diagonal line divides the two measures, while the two measures are identical for all points on the line. As illustrated in figure 5 for points to the southwest the $\mathcal{T}_{nec}$ gives higher importance scores while for observations to the northeast it is the $\mathcal{R}_{nec}$ measure which is the larger of the two. This makes sense when one thinks about what the $Y = 1 - X$ line represents. Recall that the key "relevance cell" was the $(Y, \neg X)$ one. In terms of figure 5 this is now the $Y = 1 - X$ line. In table 2 we increased relevance by moving cases from the $(\neg X, Y)$ into the (X, Y) cell. So as we move toward northeast the relevance measure becomes more important than the trivialness one. We found that $(\neg X, \neg Y)$ cell is key for the trivialness measure. In terms of figure 5 this is the origin. It is thus not surprisingly that as we move southwest toward the origin (i.e., the $(\neg X, \neg Y)$ cell) the trivialness measure trumps the relevance one.

Why this is true can be seen with some simple examples. It must be recalled that X is necessary for Y hence $x_i \geq y_i$. Take y_i and x_i to be the point (.7,.6) which is in the $\mathcal{R}_{nec}$ region of figure 5. Now $\mathcal{R}_{nec} = .6/.7 = .86 > .75 = (1 - .7)/(1 - .6) = \mathcal{T}_{nec}$. If we take the point (.3,.4) which is in the $\mathcal{T}_{nec}$ part of the graph we get $\mathcal{T}_{nec} = (1 - .4)/(1 - .3) = .86 > .75 = (.3)/(.4) = \mathcal{R}_{nec}$.

Notice that I have chosen two examples that are symmetric across the $Y = 1 - X$ diagonal, as can be seen in figure 5. Using this example we can see that $\mathcal{T}_{nec}$ for the point (.3,.4) equals $\mathcal{R}_{nec}$ for the point (.7,.6) as well as the converse. This is a product of the symmetry of the two around the $Y = 1 - X$ line. For the point (.7,.6) X is .7 so $1 - X$ gives .3 which is the X-value of the point (.3,.4). A similar calculation gives the two corresponding Y-values.

Notice that the $\mathcal{R}_{nec}$ and $\mathcal{T}_{nec}$ measures divide the lower triangular necessary condition region of the graph in two equal parts. Hence if the data happen to be uniformly and symmetrically distributed across both regions then we will get the same overall values for how important X is from each measure.

Is $\mathcal{T}_{nec}$ better than $\mathcal{R}_{nec}$ or vice versa? Both are based on valid notions of relevance and trivialness. Given the symmetry of their behavior it seems that a good overall measure of the importance of a necessary condition would be the mean of the two. Hence I propose that the measure of the absolute importance of a necessary condition, i.e., $\mathcal{TR}_{nec}$, be the mean of the two.

Trivialness and relevance in 2×2 tables

I have defined trivialness and relevance for fuzzy logic membership functions, it worth going back now to see how my principles play out in the context of 2×2 tables. Can we use without modification the trivialness and relevance formulas for crisp sets, i.e., where X and Y can only take on values of zero or one?

The basic measure of trivialness is $(1 - x_i)/(1 - y_i)$. If we go to back to table 1 note that trivialness is really about the $\neg Y$ row. Recall that trivialness varied by moving cases from $\neg X$ to X but always within the $\neg Y$ row, i.e., $Y = 0$. Since we are in the $\neg Y$ row this means that trivialness is basically then:

$$\mathcal{T}_{nec} = \frac{1}{N_{\neg Y}} \sum (1 - x_i), \text{for all } x_i \text{ where } Y = 0 \tag{3}$$

In the case where all x_i are equal to 1 then clearly we get a trivialness score of zero. As observations move from the X cell to the $\neg X$ cell trivialness decreases.

In short we can apply the $\mathcal{T}_{nec}$ measure to 2×2 tables as long as we recall that it is only the $\neg Y$ row that we use. This means setting $y_i = 0$ and using as N the number of observations in the $\neg Y$ row.

The basic measure of relevance is y_i/x_i. Going back to table 2 we note that all the action is in the $X = 1$ column. So as with trivialness we use the $X = 1$ column and the basic relevance measure is:

$$\mathcal{R}_{nec} = \frac{1}{N_X} \sum y_i, \text{ for all } y_i \text{ where } X = 1 \tag{4}$$

Relevance increases as we move cases from the $\neg Y$ cell to the Y one. Perfect relevance, i.e., sufficiency, is achieved when all the observations have value $X = 1$. In this case $\mathcal{R}_{nec}$ has a value one as it should. As we move cases from Y to $\neg Y$ relevance decreases as one would expect (and as illustrated by table 2). So here too the relevance measure works perfectly with the modification that one is only looking at the X column of the 2×2 table.

We saw in the case of fuzzy logic that there was a clear pattern to the relationship between $\mathcal{R}_{nec}$ and $\mathcal{T}_{nec}$, how do things look in the 2×2 setup? Table 3 gives the values of my measures of trivialness and relevance for the five 2×2 tables contained in tables 1 and 2. Notice that in both of these two tables the nonrelevant row or column for a given measure always has the same 0/100 configuration; likewise the four subtables use the same basic pattern of change (1) 500/0, (2) 400/100, (3) 300/200, (4) 100/400 and (5) 0/500.

Table 3: Trivialness and relevance in 2×2 tables

	X_i	Trivialness	Relevance	Mean
	X_1	1.00	1.00	1.00
	X_2	.80	.50	.65
Trivialness Table 1	X_3	.60	.33	.47
	X_4	.20	.20	.20
	X_5	.00	.17	.09
	X_1	1.00	1.00	1.00
	X_2	.50	.80	.65
Relevance Table 2	X_3	.33	.60	.47
	X_4	.20	.20	.20
	X_5	.17	.00	.09

Note: Based on the numbers in tables 1 and 2.

As I have been stressing, the trivialness and relevance measures are tapping slightly different aspects of the importance of a necessary condition. In the case of table 1 we start (i.e., X_1) with a clearly nontrivial necessary condition and arrive at X_5 at a completely trivial one. The relevance measure is also clearly declining indicating lower relevance levels as well. Similarly with table 2 data, we start with a sufficient necessary condition (i.e., X_1) to arrive at X_5, a completely nonrelevant one. The trivialness measure decreases as well indicating an necessary condition which is declining in importance.

X_1 of the trivialness table is a necessary and sufficient condition. Since there are zero observations in the $(X, \neg Y)$ cell both measures give the same result of 1.00. As we start moving cases from the $(\neg X, \neg Y)$ cell to the $(X, \neg Y)$ the trivialness score is greater than the relevance one until we get to X_4. This is the case where the (X, Y) cell and the $(\neg X, \neg Y)$ cell have the same number of observations. You can imagine them pivoting symmetrically around the same $(X, \neg Y)$ cell as they did around the $Y = 1 - X$ line in the fuzzy logic case. After this switch point it is the trivialness measure which is smaller of the two.

The same basic thing happens in the bottom part of table 3. The relevance measure starts out greater than the trivialness one, they are equal at the X_4 switch point. After that it is the trivialness measure which is larger.

In summary, in the context of 2×2 tables using the same basic trivialness and relevance measures one sees the same basic patterns reproduced as we discovered in the fuzzy logic setting. Table 3 illustrates the basic symmetry between the trivialness and relevance measures with one being greater than the other in its region and then that relationship flipping around once the border between the two is crossed.

The trivialness and relevance of necessary conditions in IMF riots

We have seen above that both the trivialness and relevance perspectives on the importance of necessary conditions have validity. It is useful to see how they perform with real-life data. Hence I will use the data on IMF riots that Ragin analyzed in *Fuzzy-set social science*. In chapter 8 he found there were two necessary conditions for IMF riots: urbanization and IMF pressure.

Many Third World countries as they need debt (re)financing were forced to go to the IMF for funding. Typically, the IMF puts policy conditions on such loans. Often these include reduced funding for public services or reduced price supports for basic necessities such as food and fuel. The resulting large increases in prices often led to what were called "IMF riots." The dependent variable in Ragin's analysis is thus the severity (measured of course via fuzzy logic) of the riots.

There is a debate about the causes of these riots (see the original analysis by Walton and Ragin 1990 for a survey). The independent variables that they included in their analysis range from more proximate causes such as "IMF pressure" to more structuralist variables like the degree of urbanization, which reflects in part the size of the groups most affected by price hikes in necessities. Additional independent variables included: (1) degree of economic hardship, (2) degree of dependence on foreign investment, (3) the degree to which a government is "activist," and (4) the degree of political liberalization in the 1980s.

In analyzing the trivialness/relevance of necessary conditions one must only operate on necessary conditions. Hence a key principle is the following:

> One can only analyze the trivialness/importance of a necessary condition if it *is* a necessary condition.

Braumoeller and Goertz only analyze the trivialness of those necessary condition hypotheses that have passed their test of necessity. The same principle applies to the necessary conditions in a fuzzy logic context. Ragin finds that there are two necessary conditions for IMF riots: (1) urbanization and (2) IMF pressure. Ragin does not ask about how trivial these necessary

Table 4: Relevance and trivialness of necessary conditions for IMF riots

Importance	Urbanization	IMF Pressure
$\mathcal{T}_{nec}$	0.60	0.46
$\mathcal{R}_{nec}$	0.41	0.39
$\mathcal{TR}_{nec}$	0.50	0.43

conditions might be. Hence my analysis of trivialness starts where his analysis of necessary conditions ended. Table 4 gives how these two necessary conditions do on the $\mathcal{T}_{nec}$, $\mathcal{R}_{nec}$, and $\mathcal{TR}_{nec}$ measures.

We can see from the results in table 4 that $\mathcal{T}_{nec}$ and $\mathcal{R}_{nec}$ can produce quite different evaluations of the importance of necessary conditions. This is particularly striking in the case of urbanization which has a value of .60 from the trivialness perspective on importance, while the relevance view gives it a significantly lower value of .41. As we saw above, the distribution of cases can play a major role in explaining these kinds of differences. If most of the observations lie in above the $Y = 1 - X$ diagonal then we would expect $\mathcal{R}_{nec}$ to be larger than $\mathcal{T}_{nec}$ and vice versa if a significant majority of cases lie below that diagonal.

Overall, these results suggest that neither of these necessary conditions is trivial or not relevant. Since neither measure is near zero the evidence suggests that both urbanization and IMF pressure are significant necessary conditions for IMF riots.

The relative importance of necessary conditions

The previous sections defined measures of the "absolute" importance of necessary conditions. $\mathcal{TR}_{nec}$ is a measure of the importance of necessary conditions that uses information on how trivial and how relevant the necessary condition is to evaluate its importance.

But naturally one wants know if necessary condition X_1 is more or less important than necessary condition X_2. For example, it has become standard practice in event history methods to evaluate relative importance in terms of the percentage change in the dependent variable for a one standard deviation change in the independent variable. If a one standard deviation change in X_1 gives a 50 percent increase in the probability of Y while for X_2 the change is 100 percent then X_2 is more important than X_1.

Often the variables in the model reflect major theoretical differences. So debates about the relative importance of X_1 vis-à-vis X_2 impinge on the evaluation of theory 1 versus theory 2. While both X_1 and X_2 might be statistically significant the researcher often wants to argue that X_1 "explains more variance" than X_2.

One might suspect that IMF pressure is the key variable in explaining IMF riots since, after all, the dependent variable is IMF riots. However, structuralist approaches such as world system/dependency perspectives (Walton and Ragin 1990, 879–80) stress the importance of the structural "preconditions" for such riots. In short, we have many reasons to want to assess the relative importance of necessary conditions.

The measure of "relative $\mathcal{I}$mportance" that I shall propose takes advantage of a idea that Ragin proposes in his analysis of conjuctural sufficient conditions for welfare provision (pp. 297–99). The most important of the conjuctural sufficient conditions is the one that has the maximum score the most often. Hence, Ragin finds that "strong left parties" is the most important sufficient condition because it provides the maximum more often than the other sufficient conditions.

We can generalize this logic and apply it to necessary conditions. Necessary condition 1 is more important than necessary condition 2 if the value of necessary condition 1 is smaller than that of necessary condition 2. In terms of trivialness, a necessary condition is more important the further away it is from 1. So for each case we can see which necessary condition is the smallest (i.e., the furthest from 1.00). Hence, x_1 is the most important necessary condition if it is the minimum over all the K necessary conditions in that particular case, i.e., $x_{1i} = \min(x_{11}, x_{12}, \ldots\ x_{1K})$. In general, X_1 is more important if it is the minimum in a higher percentage of cases than X_2. One measure of relative importance, $\mathcal{I}_{nec}$, is thus the ratio of the percentage of times X_1, X_2, etc., provide the minimum value.

Table 5 gives the $\mathcal{I}_{nec}$ values for the urbanization and IMF pressure variables. In turns out that urbanization has the minimum score 60 percent of the time while IMF pressure has the lowest value only 40 percent of the cases. This means that $\mathcal{I}_{nec}$ rates urbanization as quite a bit more important than IMF pressure, 50 percent more important. This might lead one to conclude that the domestic context is more important in explaining IMF riots than the actions of the IMF itself.

The $\mathcal{I}_{nec}$ measure implicitly employs a dichotomous weighting scheme: a variable gets a weight of 1.00 if it is the minimum and zero otherwise. This does not take into account that there may be little difference between the minimum and the next lowest value. For example, the $\mathcal{I}_{nec}$ measure treats the two cases of (x_1, x_2) with values (.2, .8) and (.2, .25) in exactly the same way: in both cases X_1 gets a value of 1 while X_2 gets a value of 0.

We might then want to develop a more refined and sensitive weighting scheme that takes into account how close the other necessary conditions are to the smallest one. One can do this by considering "how close" the other necessary condition(s) are to the minimum: the closer they are the larger their weight should be. When they are equal then they should get the same weight as the minimum (which is the procedure I applied above when there were ties). Formally, this can be expressed in terms of the relative trivialness of the two necessary conditions. Looking at the individual values of variable X_1, i.e., $x_{1i},\ i = 1, \ldots, N$ over K necessary conditions:

$$\mathcal{IT}_{nec}(x_{1i}) = \frac{1 - x_{1i}}{1 - x_{1,min}} \quad \text{where } x_{1,min} = \min(x_{11}, x_{12}, x_{13}, \ldots x_{1K}) \qquad (5)$$

Notice that trivial necessary conditions, i.e., $x_{1i} = 1$ receive zero weight because $1 - x_{1i} = 1 - 1 = 0$. The relative importance score for X_1 in general is then just the average of the relative importance scores for each case, i.e., x_{1i}.

It is quite clear from the preceeding sections that in addition to a trivialness measure of relative importance one can define a relevance measure as:

$$\mathcal{IR}_{nec}(x_{1i}) = \frac{x_{1,min}}{x_{1i}} \quad \text{where } x_{1,min} = \min(x_{11}, x_{12}, x_{13}, \ldots x_{1K}) \qquad (6)$$

These two relative importance measures have strong links to the measures of the absolute importance of necessary conditions developed above. The measures of the importance of a necessary condition *tout court* examine its "necessariness" and hence are relative to the dependent variable Y. The relative importance measures developed in this section look at the relationship *between* necessary conditions. The absolute indicators answer the question "how necessary is X for Y?", while the relative importance measures respond to the query "is X_1 more necessary than X_2?" The latter question is about the relations among the X's.

Table 4 gives the relative importance scores for the urbanization and IMF pressure variables for the measures discussed above. Urbanization is the more important necessary condition for all indicators but how much more important than IMF pressure varies significantly. Not surprising, the most extreme value – 1.50 – occurs with the $\mathcal{I}_{nec}$ measure which gives zero weight to the necessary condition which is not the minimum. All other measures give some weight to the non-minimum and thus one expects the continuous

Table 5: The relative importance of necessary conditions: IMF riots

Relative Importance	Urbanization	IMF Pressure
$\mathcal{I}_{nec}$	1.50	1.00
percent	.60	.40
$\mathcal{IT}_{nec}$	1.26	1.00
$\mathcal{IR}_{nec}$	1.10	1.00
$\mathcal{ITR}_{nec}$	1.18	1.00

weighting scheme to reduce the contrast between the two variables. Instead of receiving zero weight the larger of the two necessary conditions gets some nonzero positive weight (unless it has value 1.00). Usually, this will tend to make the relative importance of necessary conditions closer to each other.

As we saw above in terms of the absolute importance of necessary conditions, the trivialness and relevance measures can produce quite different results. Here the trivialness version of relative importance, i.e., $\mathcal{IT}_{nec}$, makes urbanization much more important than IMF pressure with a value of 1.26; in contrast with the relevance measure, $\mathcal{IR}_{nec}$, the two come out about equal at 1.10. As with absolute importance, a good overall measure of relative importance would be the mean of $\mathcal{IT}_{nec}$ and $\mathcal{IR}_{nec}$. In the case of IMF riots this mean, i.e., $\mathcal{ITR}_{nec}$, produces the value of 1.18. In short, it seems that overall the urbanization necessary condition is roughly 20 percent more important than the IMF pressure necessary condition.

This section has presented a basic measure, with variations, that describes the relative importance of necessary conditions. It is important to keep in mind that they all rest on the basic notions of trivialness or relevance developed in the preceeding section. I propose that the $\mathcal{ITR}_{nec}$ measure gives a good overall view of the relative importance of necessary conditions in fuzzy logic methods.

The importance of sufficient conditions

All the principles and techniques discussed above for necessary conditions can be directly applied to the analysis of the trivialness, relevance, and relative importance of sufficient conditions. My treatment will therefore be much briefer. A key issue will be to develop our intuitions about what "trivial sufficient conditions" are. It is common to speak of trivial necessary conditions, but as far as I know no one has analyzed trivial sufficient conditions. Similarly, it seems natural to talk of sufficiency as the ultimate level of relevance of a necessary condition; in contrast, it is less obvious to say that necessity is the ultimate relevance value for a sufficient condition.

The trivialness of sufficient conditions

The key to transferring the measures of trivialness and relevance from necessary conditions to sufficient ones lies in inverting the set or fuzzy logic relationship between X and Y. X is a necessary condition for Y if $Y \subseteq X$ or $Y \leq X$ in terms of fuzzy logic membership scores. For sufficient conditions this becomes $Y \supseteq X$ or $Y \geq X$. All the measures of trivialness, relevance, and relative importance for sufficient conditions follow from their necessary condition homologues once this substitution is made.

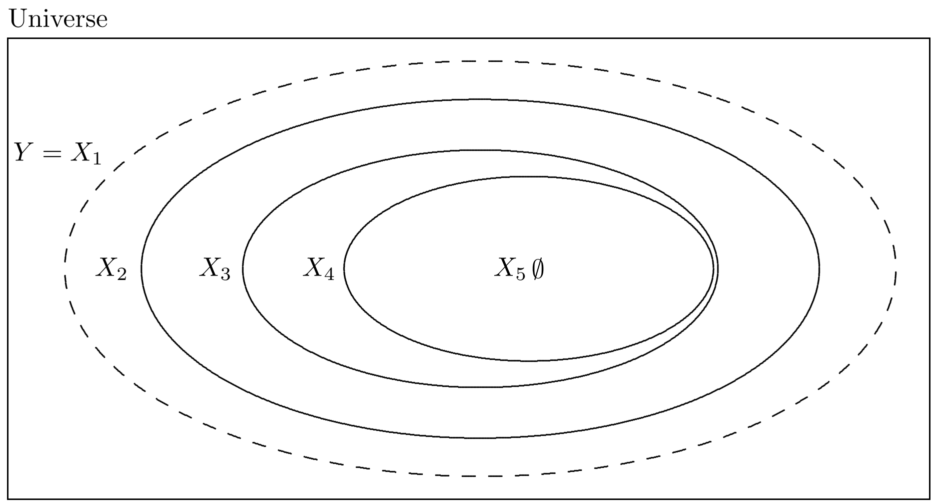
In figure 1 X becomes more and more trivial as the set X_i gets larger and larger. By the inverse principle, for sufficient conditions trivialness means that X is more and more trivial as X *shrinks* in size. Figure 6 shows how this works. The sufficient conditions X_1–X_5 become progressively more trivial because they form a smaller and smaller subset of Y. In an important sense the ultimately most trivial sufficient condition is one that never occurs, i.e., the null set. Here we have the first example of the inverse of the necessary condition principle for sufficient conditions: X is a trivial necessary condition if it always occurs; X is a trivial sufficient condition if it never occurs.

While such a sufficient condition may seem on the face of it to hold no interest, this is not always the case. For example, if the standard view of the democratic peace is correct then we have the sufficient condition hypothesis: "If all nations of the world are democracies then world peace will occur." The democratic peace example suggests that the empirically empty set of sufficient conditions can be a theoretically important one, but one which in practice is virtually impossible to attain. Again, this is the inverse of trivial necessary conditions which are trivial because they are so easy to achieve.

This can be seen in table 6 which presents trivial sufficient conditions in a 2×2 table context. In each case, X_i is sufficient for Y. However, as one moves down the column where X is present there are few and fewer cases of X. In the ultimate X_5 situation, X does not occur at all and is hence a trivial sufficient condition.

The fuzzy logic measure of trivialness of a sufficient condition looks analogous to that for necessary conditions. Trivialness for necessary conditions

Figure 6: Trivial sufficient conditions: a set theoretic perspective



was when $X = 1$ for the whole population. Not surprisingly then, trivial sufficient conditions are those where $X = 0$ for all cases. Figure 7 illustrates trivialness for sufficient conditions in a fuzzy logic framework. If X is zero (or close to zero) for all X then it is easy to fulfill the fuzzy logic requirement for sufficient conditions that $Y \geq X$.

From figure 7 it is clear that my measures of trivialness and relevance will play out in the same manner as for necessary conditions. The equation for trivialness is:

$$\mathcal{T}_{suf} = \frac{1}{N} \sum x_i / y_i \tag{7}$$

Recall that by the definition of sufficiency $y_i \geq x_i$ so that their ratio will always lie between in [0,1]. When X is a trivial sufficient condition it will be zero and hence the ratio will be zero.

The relevance of sufficient conditions

Recall that a maximumally relevant necessary condition is one that is sufficient. Hence, we need to invert this notion to arrive what at a relevant sufficient condition is: a maximumally relevant sufficient condition is also a necessary condition.

Table 6: Trivial sufficient conditions in 2×2 tables

	$\neg X_i$	X_i
Y (X_1)	0	500
Y (X_2)	200	300
Y (X_3)	300	200
Y (X_4)	400	100
Y (X_5)	500	0
$\neg Y$	100	0

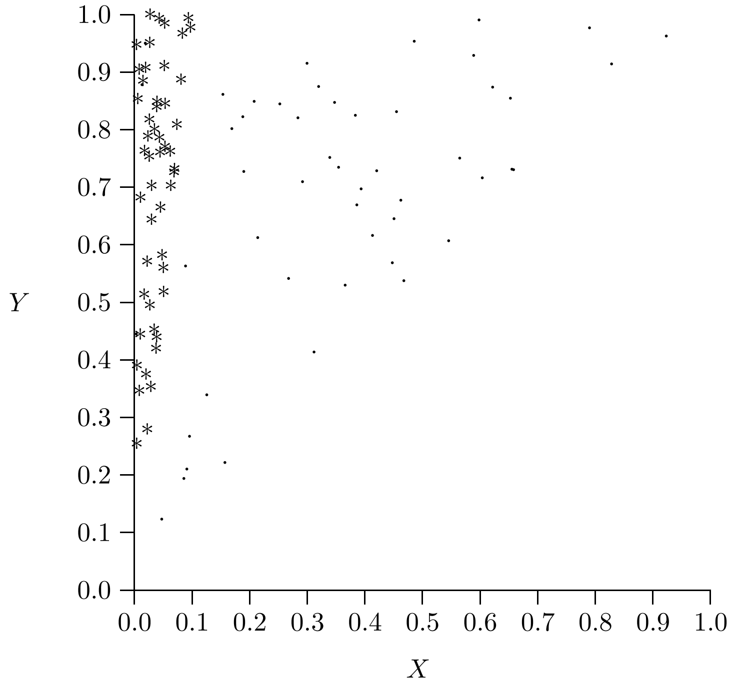
The basic analysis of trivialness involves changes in the size of the X_i sets. Notice that in figure 1 X_i is expanding to cover eventually the whole universe of cases. In contrast, trivialness for sufficiency in figure 3 we see X_i shrinking to become the null set. For relevance the same basic thing happens but now instead of the X_i sets shrinking or expanding, it is the Y_i sets that do it. For the relevance of necessary conditions, we see Y_i shrinking to the empty set, so by the inverse principle relevance for sufficient conditions means that Y_i expands to become the universe of cases, as illustrated in figure 8. In figure 8 the maximumally relevant sufficient condition is when $X = Y_1$; when X is necessary for Y_1. As we expand the set Y_i, X becomes less and less relevant. Ultimately, X is an irrelevant sufficient condition because Y occurs all the time.

Table 7 shows how relevance works in a 2×2 table context. Recall that a maximumally relevant sufficient is also a necessary condition. So in table 7 we see that X_1 is a necessary and sufficient condition. As we move cases from the $(\neg X, Y)$ cell to the $(\neg X, \neg Y)$ one we decrease the level of necessity of X. Ultimate irrelevance occurs for X_5 where Y occurs all the time no matter what the value of X. Hence X is irrelevant to the occurrence of Y since Y always occurs. This of course is exactly what we see in figure 8.

Relevance then is the degree to which the points are near the $X = Y$ diagonal just as it is for necessary conditions (see figure 4). The only difference is that for sufficient conditions the points must be on or *above* the diagonal while for necessary conditions they must be on or below that line.

The fuzzy logic of relevance works in the same manner as relevance for necessary conditions. Going back to figure 4 relevant sufficient conditions

Figure 7: Trivialness of sufficient conditions: a fuzzy logic perspective



Nontrivial sufficient condition: · · · · · ·
Trivial sufficient condition: ∗ ∗ ∗ ∗ ∗∗

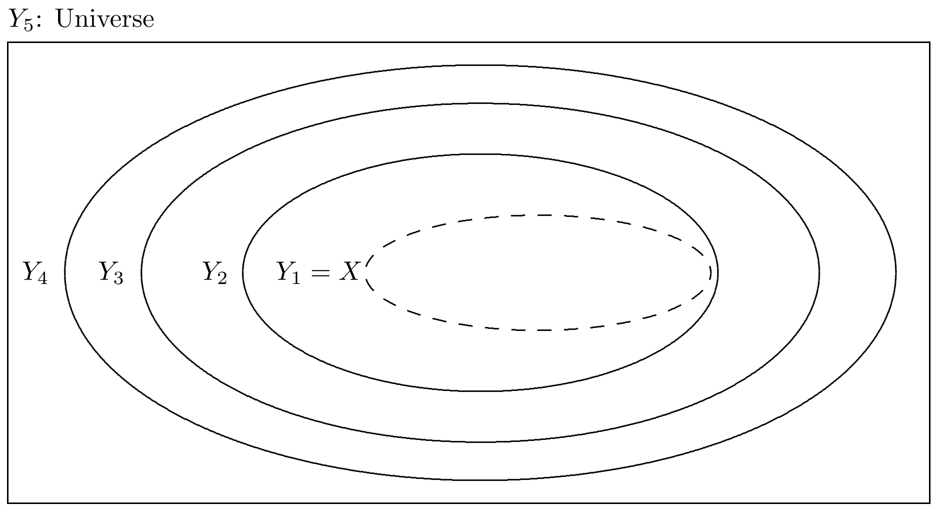
will be those that hug the $X = Y$ diagonal from above, instead of below as is the case for necessary conditions.

The equation for relevance is:

$$\mathcal{R}_{suf} = \frac{1}{N} \sum (1 - y_i)/(1 - x_i) \tag{8}$$

In figure 8 an irrelevant sufficient condition is one for which Y is always equal to one. In equation (8) when $Y = 1$ the ratio $(1-y_i)/(1-x_i)$ is zero. Hence as more and more cases have values of one (or near one) the less relevant the sufficient condition is. Basically as one moves toward the $Y = 1$ line from the $X = Y$ diagonal the relevance of the sufficient condition decreases. Thus the fuzzy logic of equation (8) works in harmony with figure 8 and table 7.

Figure 8: Relevant sufficient conditions: a set theoretic perspective



Notice how the necessary condition trivialness and relevance equations are inverted for sufficient conditions. Here again we the see the basic symmetry that exists between necessary and sufficient conditions with respect to trivialness and relevance.

The relative importance of sufficient conditions

The approach to the relative importance of necessary conditions I have adopted stems from Ragin's use of it for sufficient conditions. Situations of equifinality by definition mean there are multiple paths to the same outcome. It is thus natural to ask if one path is more common or "important" than another path. Ragin's techniques provide the researcher with a way to determine the set of paths, but do not provide much in the way of methods to evaluate the relative importance of paths.

The obvious measure of relative importance is to count how often each path is taken. For necessary conditions this was which of the two necessary conditions provided the smallest value. Since we are now in the realm of sufficient conditions this will be the path which provides the largest sufficiency value (with the constant proviso being that it must be a sufficient condition, $X \leq Y$). This dichotomous measure for sufficient conditions has the same

Table 7: Relevant sufficient conditions in 2×2 tables

	$\neg X_i$	X_i
Y (X_1)	0	
Y (X_2)	100	
Y (X_3)	300	100
Y (X_4)	400	
Y (X_5)	500	
$\neg Y$ (X_1)	500	
$\neg Y$ (X_2)	400	
$\neg Y$ (X_3)	200	0
$\neg Y$ (X_4)	100	
$\neg Y$ (X_5)	0	

disadvantages as its homologue does for necessary conditions: it may be the case that one sufficient condition is just a little lower than another. For example, if sufficient condition one equals .50 and sufficient condition two equals .45, then the dichotomous procedure gives all the weight to sufficient condition one. Thus, we can apply the same corrective us to the sufficient condition measure that I applied to the necessary condition one, applying the trivialness and relevance ideas to weight the sufficient conditions.

The importance of sufficient conditions in IMF riots

Ragin's analysis of IMF riots found three conjunctural sufficient conditions.

1. dependency on foreign capital, liberalization of policy, economic hardship, (necessary conditions: IMF pressure and urbanization).

2. nonactivist government, liberalization of policy, economic hardship, (necessary conditions: IMF pressure and urbanization).

3. nondependency on foreign capital, activist government, liberalization of policy, noneconomic hardship, (necessary conditions: IMF pressure and urbanization).

I continue his analysis by examining the absolute and relative importance of these three sufficient conditions.

It is important to keep in mind that "sufficient condition" in a fuzzy logic context usually means a conjunction of factors which are jointly sufficient for the outcome. So when I refer to a sufficient condition for Y, usually this will be a conjunction of factors.

Just as there can be multiple necessary conditions for given outcome it is possible that there are multiple paths – equifinality – to given outcome. By definition, however, all these paths must include the necessary conditions for the event. So, for example, all three sufficient conditions listed above must include IMF pressure and urbanization.

All three of the sufficient conditions have passed Ragin's tests for sufficiency, but we still might want to know if there are trivial sufficient conditions in this list. For example, quite a few countries have a "sufficiency score" of zero, i.e., the value on all three conjunctural sufficient conditions is zero. The sufficiency score is the maximum value for the country over the three sufficient conditions. A sufficiency score of zero means that the country scores zero on all three sufficient conditions.

In the set of cases examined by Ragin 20 out of 54 countries have a zero sufficiency score. In terms of figure 7 they are all cases of X equals zero. No matter what the level of the outcome variable, IMF protest, they will pass the sufficiency test. If the level of IMF protest, however, is zero (i.e., points near the origin of figure 7) then this is not problematic. But as the level of IMF protest increases so does the trivialness of the sufficient condition. So, for example, Sri Lanka has a sufficiency score of zero and an IMF protest value of zero: in this case the data and the model fit well. Morroco, in contrast, has a sufficiency score of zero and an IMF protest score of .50: here the fit is not so good.

Ragin gives the overall sufficiency score, i.e., the maximum of the three sufficiency conditions. This gives us an idea of how well overall the set of sufficient conditions performs. Overall model fit is clearly an important concern, but we may want to evaluate the individual sufficient conditions as well. Table 8 gives the trivialness and relevance scores of the three sufficient conditions. In addition, it provides the trivialness and relevance scores for the set of sufficient conditions.[3]

Table 8 shows that the three sufficient conditions have very similar trivialness and relevance scores. All three are within a couple of percentage points of each other. First of all, none of the trivialness or relevance scores

[3]Ragin considers that if the fuzzy membership score is within one level of the outcome variable it fits. For example $Y = .50$, $X = .67$ counts as a match. I have recoded these cases as $X = Y$.

Table 8: The importance of sufficient conditions for IMF riots

Importance	S.C. 1	S.C. 2	S.C. 3	Max
The absolute importance of sufficient conditions				
$\mathcal{T}_{suf}$	0.55	0.54	0.53	0.60
$\mathcal{R}_{suf}$	0.78	0.78	0.78	0.80
$\mathcal{TR}_{suf}$	0.67	0.66	0.66	0.70
The relative importance of sufficient conditions				
$\mathcal{I}_{suf}$	1.06	1.00	1.08	
percent	.33	.32	.34	
$\mathcal{IT}_{suf}$	.98	1.00	.99	
$\mathcal{IR}_{suf}$	1.00	.98	.98	
$\mathcal{ITR}_{suf}$	.99	.99	.99	

Note: All sufficient conditions contain the necessary conditions.

S.C. 1 – Dependent/Liberalization/Hardship

S.C. 2 – Nonactivist/Liberalization/Hardship

S.C. 3 – Nondependent/Activist/Liberalization/Nonhardship

are near zero, hence we can conclude that each sufficient condition is not trivial since the smallest value is .53 nowhere near zero, the value of a trivial sufficient condition. Once again, we see that trivialness and relevance values can be quite different. The distribution of values in the upper triangular sufficiency region is the cause of these differences. The $\mathcal{TR}_{suf}$ value is what I have proposed as the best overall measure of the absolute trivialness for sufficient conditions. Since the individual sufficient conditions perform well it must be the case that Ragin's overall measure of sufficiency (i.e., "Max" in table 8) does well since it is the maximum of the individual sufficiency scores.

The second part of table 8 gives the relative importance scores for sufficient conditions that are analogous to the relative importance scores for necessary conditions given in table 5. Notice that each sufficient condition has the maximum sufficiency score about one-third of the time. This suggests that there is no clear "main path" to IMF riots. The modifications to the basic dichotomous measure based on trivialness and relevance notions confirms this basic finding. My proposed overall measure of the relative importance of sufficient conditions, $\mathcal{ITR}_{suf}$, indicates all three sufficient conditions are of equal importance.

Conclusions

Figure 9 summarizes the relationships between trivialness and relevance for necessary or sufficient conditions. Trivialness involves changes on the X dimension, while relevance means changes along Y. For example, trivialness of a necessary condition means moving toward the $X = 1$ line, while trivialness for a sufficient condition implies movement toward the $X = 0$ one. Analogously, a sufficient condition is increasing irrelevant at Y increases toward 1.00, a necessary condition is less relevant at X moves down to zero.

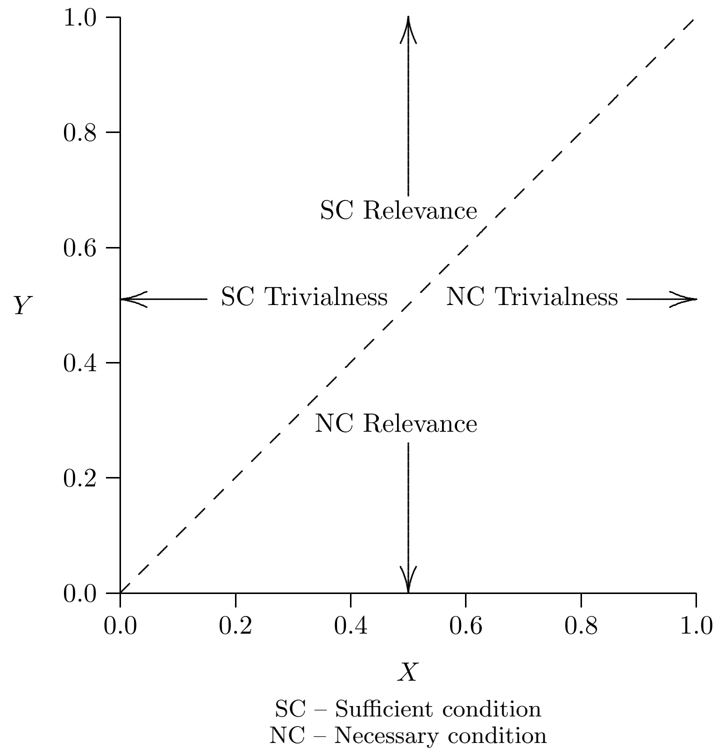
In this paper I have shown how this logic holds uniformly in the three principle contexts where these issues are likely to arise: (1) Venn diagrams, (2) 2×2 tables, and (3) fuzzy logic analyses. At the same time I have developed measures for evaluating quantitatively the trivialness and relevance of necessary or sufficient conditions for fuzzy logic methods. Since the logic works just as well in the 2×2 table context these fuzzy logic measures transfer directly and can be used as well to evaluate relevance and trivialness in 2×2 tables.

The issues of the absolute and relative importance of necessary or sufficient conditions must be addressed by those who use fuzzy logic methods as well as by those who more generally make necessary or sufficient condition claims. It is always possible for critics à la Downs to say that a given necessary condition is trivial. The measures developed here give a concrete means for responding to such criticism.

These empirical measures can also inform theoretical debates about the relative importance of different variables in multivariate explanations. For example, Skocpol (1979) argues that there are two necessary conditions for social revolution: (1) state crisis and (2) peasant insurrection. In her analysis, she stresses the state crisis variable and that is certainly the factor which has drawn the most attention by commentators on her work. However, it might be the case that empirically the peasant insurrection variable is more important than the state crisis one. The measures of relative importance proposed here provide one means for evaluating these kinds of claims.

More than just giving measures of trivialness and relevance I have given a coherent and complete analysis of the concept of a trivial necessary condition. While the concept of a trivial necessary condition belongs to the discourse of social scientists it has not been subjected to rigorous analysis.

Figure 9: Summarizing trivialness and relevance for necessary or sufficient conditions



Note: Arrows indicate increasing trivialness or decreasing relevance

As this paper shows, there are really two forms of trivialness, one which I call trivialness and the other which I have termed (for lack of a better expression) relevance. Both approaches give us useful and crucial information about the importance of necessary or sufficient conditions.

Given the large number of necessary condition hypotheses in the social science literature (see Goertz 2002 for 150 examples) the need for the conceptual and quantitative tools for evaluating the absolute and relative importance of necessary or sufficient conditions is clear. This paper provides one set of answers to these important questions.

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