Calibrating Fuzzy Sets

In physics, chemistry, biology, astronomy and other “hard” sciences, researchers *calibrate* their measuring devices and the readings these instruments produce by adjusting them so that they match or conform to dependably known external standards.

More familiar to social scientists are calibration breakdowns, as when a thermostat reports that an office is a comfortable 70 degrees while the cup of coffee on your desk turns to ice.

Most measures in social science are uncalibrated. They indicate cases’ positions in distributions relative to each other, but not relative to external standards. For example, measures in the social sciences can reveal that one case has a higher temperature than another, or higher than average, but not whether it is *hot* or *cold*. The definitions of hot and cold involve external standards, which are often interpretive in nature. In other words, these labels are knowledge dependent.

Calibration is Rare But Not Unknown in the Social Sciences

Some examples:

1. The measurement of poverty (absolute deprivation)

2. GNP/cap adjusted for purchasing power

3. Human Development Index

4. Not an example: calibration of models in econometrics
   (where specific coefficients are purposefully fixed)

Conventional Measurement: Quantitative Research

1. Usual approach: Find the best possible single indicator of the underlying construct, preferably an interval or ratio scale indicator. Examples: church attendance/year as an indicator of religiosity; years of education as an indicator of learning (accumulated school-based knowledge); and so on.

2. Psychometric approach: identify multiple, correlated indicators of the same underlying theoretical concept; construct an index by first putting the various indicators in the same metric (e.g., z scores) and then averaging the scores. Example: an index of “economic development” based on GNP/cap, literacy, life expectancy, energy consumption, labor force composition, and so on.

3. Structural Equation Models (SEM): same as #2, except the measurement construction is tweaked in the context of a causal model with other constructs included. It’s all on automatic pilot: correlations with other variables and constructs in the model do the tweaking.

What These Three Have In Common

1. Indicators meet only a minimum measurement requirement: cases must vary in a way that (at least roughly) reflects the underlying construct (i.e., the indicator’s variation must correlate with how the construct is thought to vary).

2. There is a deep reliance on observed variation, which is sample specific in definition and construction (the mean and standard deviation are inductively derived). Calibration is implicit and mechanistic, not knowledge based.

3. Cases’ scores are defined and ranked relative to each other, not according to external criteria.

4. All variation is typically treated as meaningful and taken at face value.

5. External criteria are only occasionally used to evaluate observed scores.

Conventional Measurement: Qualitative Research

1. Inductively oriented: understanding of measures changes and develops as researchers learn more about cases.

2. Iterative: there is a back-and-forth between understanding of cases and concept development.

3. Indicators may be used, but scores must be interpreted (i.e., metrics not taken at face value). Example: “early” state formation. Meaningless variation is often truncated.

4. Case-oriented: Focus is on defining “kinds of cases” rather than dimensions of variation, e.g., the “set of democracies” versus “degree of democracy.” Degree of democracy is not the same as degree of membership in the set of democracies.

Bottom line: researcher’s knowledge plays an important role in calibrating measures, but the process is often implicit and not formalized. Often it is personal in the sense that it is based on knowledge that is not easily obtained or shared.

Let’s Have the Best of Both Worlds

Specifically, let’s have measures that are precise and explicitly measured, but which also reflect the researcher’s understanding. They should be calibrated according to the **external criteria** that the researcher brings to the investigation.

These **external criteria** may reflect standards based on social knowledge (e.g., 12 years of education as constituting an important educational threshold), collective social scientific knowledge (e.g., about variation in economic development--what it takes to be considered “developed”) or the researcher’s own knowledge (e.g., derived from in-depth study of cases).

The key is that these external standards must be stated explicitly and they must be applied systematically and transparently.

Remember, the key to measurement calibration is the application of known and explicit external standards.

Fuzzy Sets and Calibration

Fuzzy sets provide a good platform for the development of calibrated measures:

1. Membership scores in sets (e.g., the set of regular church-goers) can be scaled from 0 to 1, with 0 indicating full exclusion and 1 indicating full inclusion. A score of .5 is the cross-over point. They allow precision.

2. Fuzzy sets are simultaneously qualitative and quantitative. Full membership and full non-membership are qualitative states. In between these two qualitative states are degrees of membership.

3. Fuzzy sets distinguish between relevant and irrelevant variation.

4. Because they are all about degree of set membership (e.g., in the set of “democracies”), they are “case-oriented.”

5. They can be used to evaluate both set-theoretic and correlational arguments. Recall, however, that almost all social science theory, because it is verbal, is set-theoretic in nature.

Table 1: Mathematical Translations of Verbal Labels: The Three Metrics

1. Verbal label	*2. Degree of membership*	*3. Associated odds*	*4. Log odds of full membership*
Full membership	0.993	148.41	5.0
Threshold of full membership	0.953	20.09	3.0
Probably in	0.881	7.39	2.0
More in than out	0.622	1.65	0.5
Cross-over point	0.500	1.00	0.0
More out than in	0.378	0.61	-0.5
Probably out	0.119	0.14	-2.0
Threshold of full nonmembership	0.047	0.05	-3.0
Full nonmembership	0.007	0.01	-5.0

Table 2: Degree of Membership in "Developed" Countries (20000, 5000, 2500)

Country	*1. National income*	*2. Deviations from cross-over*	*3. Scalars*	*4. Product of 2 x 3*	*5. Degree of membership*
Switzerland	40110	35110.00	.0002	7.02	1.00
United States	34400	29400.00	.0002	5.88	1.00
Netherlands	25200	20200.00	.0002	4.04	.98
Finland	24920	19920.00	.0002	3.98	.98
Australia	20060	15060.00	.0002	3.01	.95
Israel	17090	12090.00	.0002	2.42	.92
Spain	15320	10320.00	.0002	2.06	.89
New Zealand	13680	8680.00	.0002	1.74	.85
Cyprus	11720	6720.00	.0002	1.34	.79
Greece	11290	6290.00	.0002	1.26	.78
Portugal	10940	5940.00	.0002	1.19	.77
Korea, Rep	9800	4800.00	.0002	.96	.72
Argentina	7470	2470.00	.0002	.49	.62
Hungary	4670	-330.00	.0012	-.40	.40
Venezuela	4100	-900.00	.0012	-1.08	.25
Estonia	4070	-930.00	.0012	-1.12	.25
Panama	3740	-1260.00	.0012	-1.51	.18
Mauritius	3690	-1310.00	.0012	-1.57	.17
Brazil	3590	-1410.00	.0012	-1.69	.16
Turkey	2980	-2020.00	.0012	-2.42	.08
Bolivia	1000	-4000.00	.0012	-4.80	.01
Cote d'Ivoire	650	-4350.00	.0012	-5.22	.01
Senegal	450	-4550.00	.0012	-5.46	.00
Burundi	110	-4890.00	.0012	-5.87	.00

The scalars are calculated as follows:

Above the cross-over point:

3/15,000 = .0002

There is an increase of 3 logit units from the cross-over point (logit = 0) to the threshold for full membership (logit = 3). This difference provides the numerator. The corresponding increase in national income per capita is from 5,000 to 20,000, a difference of 15,000. So if we multiply deviations from the cross-over point by this scalar, we convert the income per capita metric to logit units.

Below the cross-over point:

-3/-2,500 = .0012

There is a decrease of 3 logit units from the cross-over point (logit = 0) to the threshold for full nonmembership (logit = -3). This difference provides the numerator. The corresponding decrease in national income per capita is from 5,000 to 2,500, a difference of -2,500. So if we multiply deviations from the cross-over point by this scalar, we convert the income per capita metric to logit units.

Figure 1: Plot of Degree of Membership in the Set of Developed Countries Against National Income Per Capita

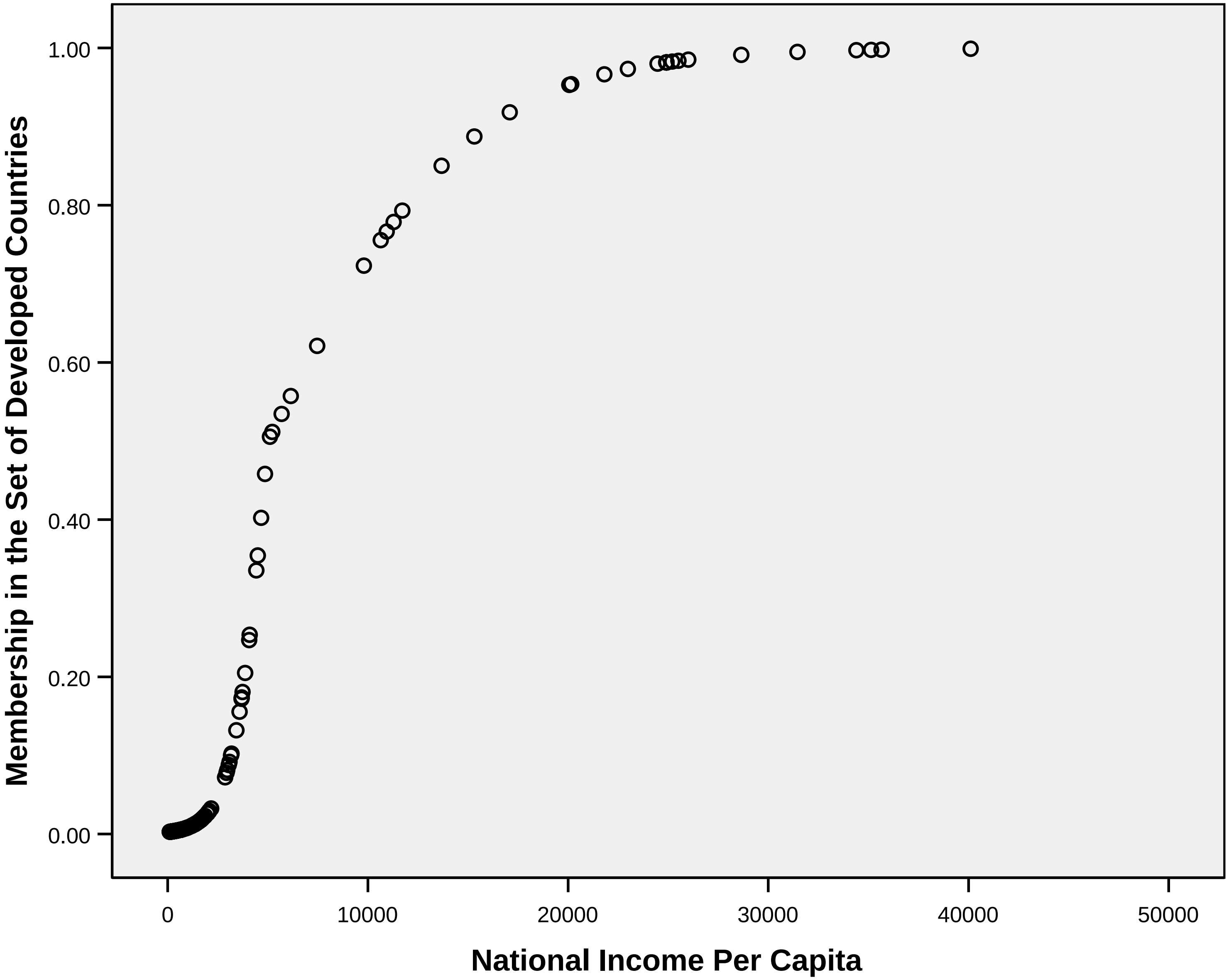


Table 3: Degree of Membership in "Moderately Developed" Countries (7500, 2500, 1000)

Country	*1. National income*	*2. Deviations from cross-over*	*3. Scalars*	*4. Product of 2 x 3*	*5.Degree of membership*
Switzerland	40110	37610	.0006	22.57	1.00
United States	34400	31900	.0006	19.14	1.00
Netherlands	25200	22700	.0006	13.62	1.00
Finland	24920	22420	.0006	13.45	1.00
Australia	20060	17560	.0006	10.54	1.00
Israel	17090	14590	.0006	8.75	1.00
Spain	15320	12820	.0006	7.69	1.00
New Zealand	13680	11180	.0006	6.71	1.00
Cyprus	11720	9220	.0006	5.53	1.00
Greece	11290	8790	.0006	5.27	.99
Portugal	10940	8440	.0006	5.06	.99
Korea, Rep	9800	7300	.0006	4.38	.99
Argentina	7470	4970	.0006	2.98	.95
Hungary	4670	2170	.0006	1.30	.79
Venezuela	4100	1600	.0006	.96	.72
Estonia	4070	1570	.0006	.94	.72
Panama	3740	1240	.0006	.74	.68
Mauritius	3690	1190	.0006	.71	.67
Brazil	3590	1090	.0006	.65	.66
Turkey	2980	480	.0006	.29	.57
Bolivia	1000	-1500	.0020	-3.00	.05
Cote d'Ivoire	650	-1850	.0020	-3.70	.02
Senegal	450	-2050	.0020	-4.10	.02
Burundi	110	-2390	.0020	-4.78	.01

Comparing the Two Calibrations

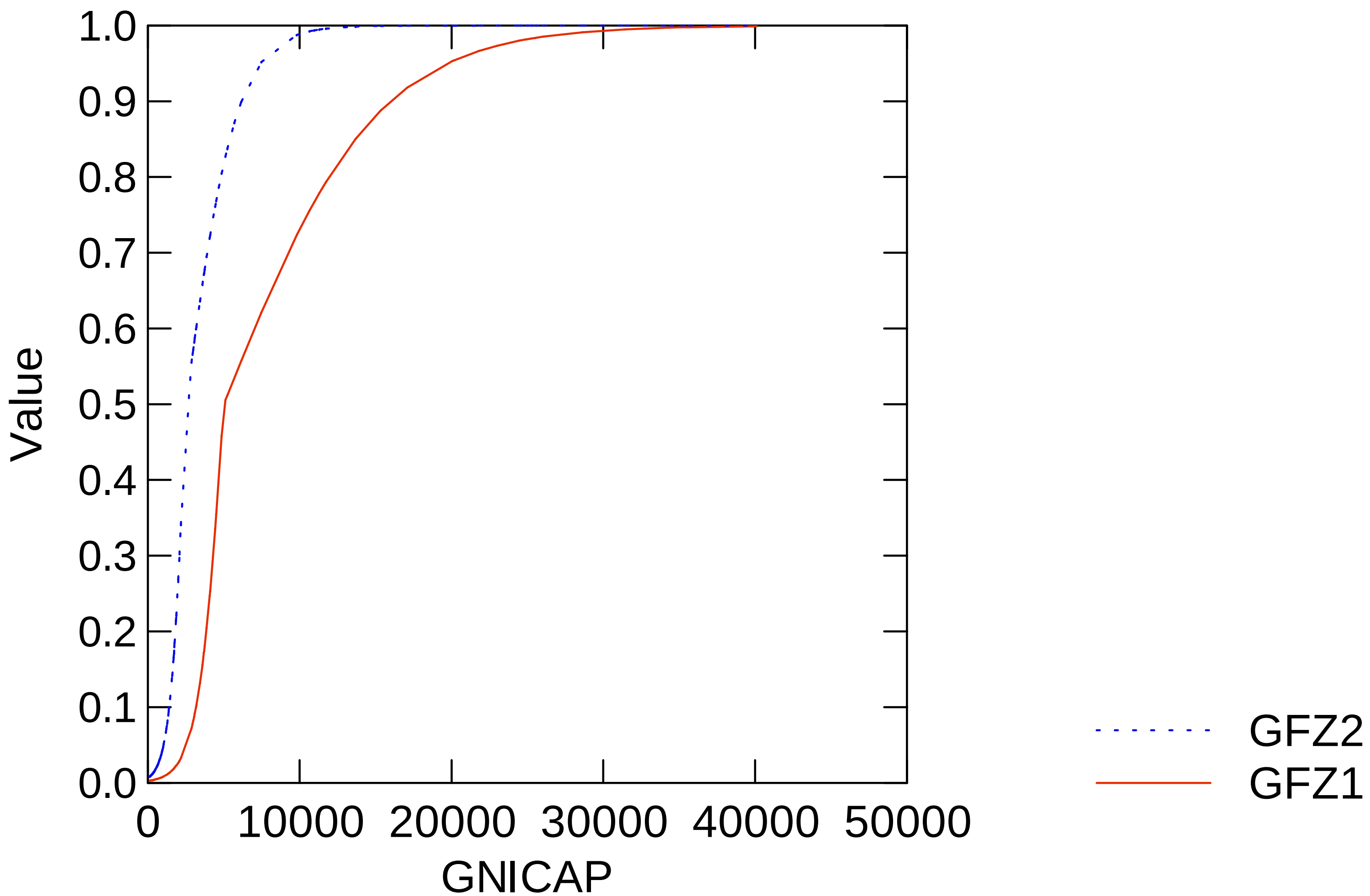


Table 4: Degree of Membership in "Democratic" Countries (9, 2, -3)

Country	*1. Polity score*	*2. Deviations from cross-over*	*3. Scalars*	*4. Product of 2 x 3*	*5. Degree of Membership*
Norway	10	8.00	0.43	3.43	0.97
United States	10	8.00	0.43	3.43	0.97
France	9	7.00	0.43	3.00	0.95
Korea, Rep	8	6.00	0.43	2.57	0.93
Colombia	7	5.00	0.43	2.14	0.89
Croatia	7	5.00	0.43	2.14	0.89
Bangladesh	6	4.00	0.43	1.71	0.85
Ecuador	6	4.00	0.43	1.71	0.85
Albania	5	3.00	0.43	1.29	0.78
Armenia	5	3.00	0.43	1.29	0.78
Nigeria	4	2.00	0.43	0.86	0.70
Malaysia	3	1.00	0.43	0.43	0.61
Cambodia	2	0.00	0.60	0.00	0.50
Tanzania	2	0.00	0.60	0.00	0.50
Zambia	1	-1.00	0.60	-0.60	0.35
Liberia	0	-2.00	0.60	-1.20	0.23
Tajikistan	-1	-3.00	0.60	-1.80	0.14
Jordan	-2	-4.00	0.60	-2.40	0.08
Algeria	-3	-5.00	0.60	-3.00	0.05
Rwanda	-4	-6.00	0.60	-3.60	0.03
Gambia	-5	-7.00	0.60	-4.20	0.01
Egypt	-6	-8.00	0.60	-4.80	0.01
Azerbaijan	-7	-9.00	0.60	-5.40	0.00
Bhutan	-8	-10.00	0.60	-6.00	0.00

Comparison of Measures Using Correlations

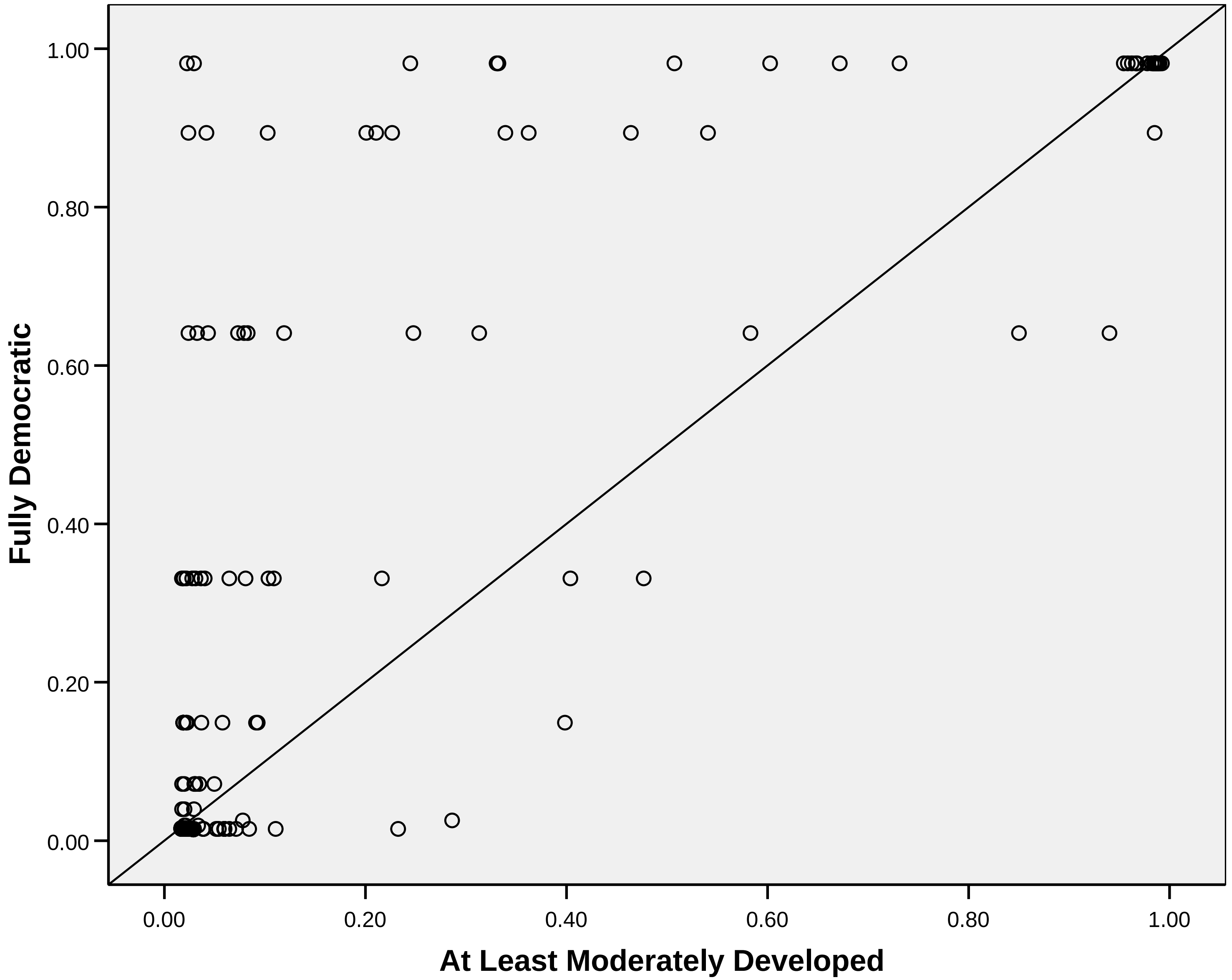
Pearson correlation matrix

	GFZ1	GFZ2	GNICAP	PFZ	POLITY
GFZ1	1.000				
GFZ2	0.911	1.000			
GNICAP	0.929	0.796	1.000		
PFZ	0.492	0.583	0.427	1.000	
POLITY	0.555	0.637	0.485	0.978	1.000

Number of observations: 136

Fuzzy Set Analysis (Sufficiency):

	Consistency	Coverage
PFZ by GFZ1	0.99	0.35
PFZ by GFZ2	0.95	0.52


Fully Democratic
1.00
0.80
0.60
0.40
0.20
0.00
0.00
0.20
0.40
0.60
0.80
1.00
At Least Moderately Developed

Using fsQCA to Calibrate Fuzzy Sets (Direct Method)

1. In fsQCA, create or retrieve your data set. For example, you might have an SPSS, Stata, or Excel file with the relevant interval- or ratio-scale data. Save these files as comma delimited or tab delimited files with simple variable names on the first row of the file. Make sure missing data are blank and not assigned a special code (e.g., -999).

2. With your data in the data spreadsheet window of fsQCA, click the *Variables* menu; then click *Compute*.

3. In the compute dialogue box, name the target fuzzy set. Select a simple name (2-8 characters), using standard alphanumeric characters and no spaces, dashes, or punctuation.

4. Click *calibrate(x,n1,n2,n3)* in the *Functions* menu and then click the up arrow that is next to the word *Functions*. Next, *calibrate(,,,)* will appear in the *Expression* field of the dialogue box.

5. Edit the expression so that *calibrate(,,,)* becomes something like *calibrate(intvar,25,10,2)* where *intvar* is the name of the existing interval- or ratio-scale variable already in the file, the first number is the value of *intvar* you have chosen as the threshold for full membership in the target set (fuzzy score = 0.95); the second number is the value of *intvar* that you have selected for the crossover point (fuzzy score = 0.5), and the third number is the value of *intvar* that you have selected for the threshold for full nonmembership in the target set (fuzzy score = 0.05).

6. Click *OK*. Check the data spreadsheet to make sure it came out as you expected. It is possible to sort the original interval-scale variable in descending or ascending order using the pull-down menus. Click any case in the column you want to sort, then click *Cases*, and then *Sort Ascending* or *Sort Descending*. You can then check the corresponding fuzzy scores to see if they are consistent with your interval- or ratio-scale variable in the manner you intended.