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The How, Why, and When of *PRIDIT*: An Example from Hospital Quality

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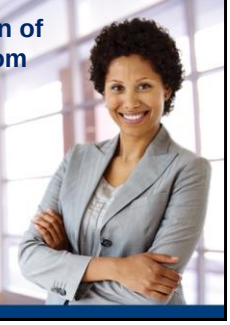

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Three learning objectives organized around how, why, and when

1. Discuss the problem of detecting hospital quality (Why)
2. Describe the inputs and outputs of *PRIDIT* in the context of the hospital quality problem (How)
3. Examine actuarial applications of *PRIDIT* (When)

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Why: Hospital quality data looks like this

Process measure	Average		Jefferson hospital	
	US	PA	Adherence	Patients (N)
Antibiotic timing	87%	88%	82%	303
Correct antibiotic	93%	93%	98%	302

- Source: CMS Hospital Compare, 7/1/2009-12/31/2009
- Both measures contain some discretion

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Hospital outcomes data are poor or nonexistent

- No outcomes data in some cases
- Current outcomes—30 day readmission and mortality
  - Condition specific—pneumonia, heart failure, heart attack
- Hospitals do many things and can only control some outcomes

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Measuring performance with real variables

- Very low mortality is a very good measure of high quality
  - Everyone agrees it's important
  - Tightly distributed measure
- Hospital amenities are probably not good measures of quality
  - Likely uncorrelated with process measures, clinical outcomes
- Most variables are in the middle of these extremes

Hospital quality measures are plentiful

- Process measure adherence
  - Smoking cessation counseling
- Patient satisfaction
  - HCAHPS scores
- Thousands of comparator hospitals
- Many binary indicators of quality
  - Acute versus critical access hospitals

Challenges and opportunities in the hospital quality context

- Determining the quality of hospitals can be difficult
- Overall hospital quality is a result of a multi-factoral process
- Practical applications
  - Patients: select the right hospital
  - Providers: assess and improve their quality
  - Actuaries: create preferred provider networks, implement pay-for-performance

How: *PRIDIT* applied to hospital measures

- *PRIDIT* can summarize these multiple factors into a single score
- In a mathematically efficient way
- Prioritizing most informative variables
- Result is a relative ranking of hospitals by level of quality

Real world hospital process measures

- Smoking cessation counseling after heart attack
- ACE inhibitor for heart failure patients
  - Lower blood pressure
- Proper antibiotic for pneumonia
- All of these should be 100%
  - They are not—meaningful variation!
- One measure in isolation is not useful

Principles for selecting data

- There is more data than we can use
  - Kitchen sink: More variables give more, and more useful, variation
  - Expert opinion: Experts know which variables proxy for hospital quality
  - Cut a middle path: Use a combination of evidence base for variable selection and indicators that should be important
- Mortality—include it!
- Parking cost—exclude it
- Hospital ownership structure—include it (an open question in the literature)

Step 1: Score selected hospital measures with Ridit

Smoking cessation: 4 hospitals

Hospital	Adherence	Rank	Ridit score
A	95%	1	0.75
B	90%	2	0.00
C	85%	4	-0.75
D	90%	2	0.00
Average	90%	2.25	0.00

Smoking cessation: 5 hospitals

Hospital	Adherence	Rank	Ridit score
A	95%	1	0.80
B	90%	2	0.00
C	85%	4	-0.40
D	90%	2	0.00
E	85%	4	-0.40
Average	89%	2.60	0.00

- Rank is from best to worse (1=best)

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Properties of the Ridit score

- Better rank means higher Ridit score
- Ranking is relative
  - Relatively more impressive performance means higher Ridit score
- Example 1: Hospital A
  - Has best adherence (95%)
  - Best of 4: score = 0.75
  - Best of 5: score = 0.80
- Example 2: Hospital C
  - Has the worst adherence (85%)
  - Worst of 4: score = -0.75
  - Tied for worst of 5: score = -0.40
- Scores add up to 0
  - Average performance means score = 0
  - Norm to the average performance (relative measure)

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Multiple process measure example

Hospital	Smoking cessation			ACE inhibitor			Proper antibiotic		
	Value	Rank	Ridit score	Value	Rank	Ridit score	Value	Rank	Ridit score
A	0.90	2	0.4	0.99	2	0.4	1.00	3	0.6
B	0.85	5	-0.8	0.92	4	-0.4	0.99	1	-0.2
C	0.89	3	-0.2	0.90	5	-0.8	0.98	1	-0.8
D	1.00	1	0.8	1.00	1	0.8	1.00	5	0.6
E	0.89	3	-0.2	0.93	3	0.0	0.99	3	-0.2
Average	0.906	2.80	0.00	0.948	3.00	0.00	0.992	2.60	0.00

- Hospital D
  - Less credit for adherence to antibiotic guidelines than for smoking cessation counseling and ACE inhibitor usage
- Less “impressive” 100% performance

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Final Ridit score matrix

Hospital	Smoking cessation	ACE inhibitor	Proper antibiotic
A	0.4	0.4	0.6
B	-0.8	-0.4	-0.2
C	-0.2	-0.8	-0.8
D	0.8	0.8	0.6
E	-0.2	0.0	-0.2

- Good hospitals: A and D (D>A)
- Bad hospitals: B, C, E (E>C, E>B)
  - What about B versus C?
  - Important if someone lives near B and C but not A or D

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Step 2: Ridit normalization for measuring performance

- Divide by the square root of the Ridit score sum of squares
- Smoking cessation
  - Divide by $[(0.4)^2+(-0.8)^2+(-0.2)^2+(0.8)^2+(-0.2)^2]^{0.5}=1.23$

Hospital	Smoking cessation	ACE inhibitor	Proper antibiotic
A	0.32	0.32	0.50
B	-0.65	-0.32	-0.17
C	-0.16	-0.63	-0.67
D	0.65	0.63	0.50
E	-0.16	0.00	-0.17

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Outperformance on a tightly distributed indicator is meaningful

- Hospital D gets more credit for 100% adherence to smoking cessation than ACE inhibitor
  - Normalized score of 0.65 (smoking) versus 0.63 (ACE)
  - ACE inhibitor: more extremes
  - Smoking cessation: two middle values (ranked 3) are tied
  - ACE inhibitor: no ties, ranks from 1 to 5 are represented
- Smoking cessation may be more “important”

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Breaking "ties" between hospitals in the middle

- We still need to compare Hospitals B and C
- With more measures
  - There will be fewer superior or inferior hospitals
  - There will be more middling hospitals
- Next step: take account of variance/covariance with PCA

Step 3: scoring total performance with PCA

- The variance and covariance of the data can be explained by several factors
- Uncover the first factor that accounts for the largest proportion of the variance
- If we used the right variables, this factor represents quality
  - It's an assumption
  - Relies on utilizing the right variables

Application to the example data

Component	Eigenvalue
1	2.67
2	0.29
3	0.04

Measure	*PRIDIT* weight
Smoking cessation	0.90
ACE inhibitor	0.98
Proper antibiotic	0.95

- Example of the three quality measures used
  - Eigenvalues determined by the PCA process
  - Relative importance of the first component over the other two
- Given the normalized Ridit matrix, the largest eigenvalue, and the *PRIDIT* weights, we can calculate the final *PRIDIT* scores

The result is an overall *PRIDIT* score

- We combine three elements
  - Normalized Ridit matrix: the performance of each hospital on each measure, taking into account relative performance
  - *PRIDIT* weights: the multiplicative terms that represent the variance of each measure and its covariance with all other measures, analyzed via PCA
  - Eigenvalue: a scaling factor that puts all scores on the range (-1,1)
- Then the final formula for the *PRIDIT* scores is:

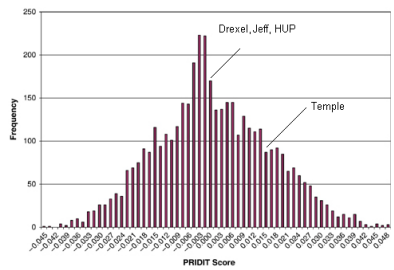
$$\text{Normalized Ridit matrix} \cdot \text{PRIDIT weghts} / \text{maximum eigenvalue}$$

$$\begin{pmatrix} 0.32 & 0.32 & 0.50 \\ -0.65 & -0.32 & -0.17 \\ -0.16 & -0.63 & -0.67 \\ 0.65 & 0.63 & 0.50 \\ -0.16 & 0.00 & -0.17 \end{pmatrix} \cdot \begin{pmatrix} 0.90 \\ 0.98 \\ 0.95 \end{pmatrix} = \begin{pmatrix} 1.08 \\ -1.06 \\ -1.40 \\ 1.68 \\ -0.31 \end{pmatrix} / 2.67 = \begin{pmatrix} 0.40 \\ -0.40 \\ -0.52 \\ 0.63 \\ -0.12 \end{pmatrix}$$

Takeaways from *PRIDIT* in general

- Variable ordering
  1. ACE inhibitor
  2. Proper antibiotic
  3. Smoking cessation
- Hospital quality ordering
  1. D
  2. A
  3. E
  4. B
  5. C
- B is better than C
  - Better performance on ACE inhibitor and proper antibiotic!
- Dispersion of hospitals
  - 3 below average, 2 above average
  - In reality, most hospitals are average (cluster around 0)

Takeaway from *PRIDIT*: Hospital quality is evenly distributed



- Lots of hospitals in the middle, a few "outliers" of high and low quality
- Source: Lieberthal (2008), *Health Services Research*

When: Aspects of the hospital example that call for *PRIDIT*

- Lots of data
  - Missing values are ok
- Each variable may not be very informative
- Multiple outcome measures or benchmarks
- Data is mostly binary or categorical
- Relative rankings are useful

Importance of variables can change over time in *PRIDIT*

- Example: Beta blocker at arrival for AMI (acute myocardial infarction)
  - Purpose: mortality benefit of 10 to 15 percent
  - Grade 1A recommendation in UpToDate® (top grade)
- It has been removed from CMS Hospital Compare reporting
  - We got too good!
- *PRIDIT* is adaptive
- More generally, gaming one measure could be possible, but not every one

Actuarial applications that are similar

- Fraud
- Credit score
- Drug abuse detection
- Marketing?

Current and future implementations of *PRIDIT*

- There are currently versions in SAS, R
- Predictive model—combine process measures and outcomes data
  - Contemporaneously
  - Predict outcomes prospectively
- Missing data work
  - Currently—impute average values
  - Future work in progress

Summary of learning objectives

- How to use *PRIDIT* for hospital quality
  - Gather the relevant variables
  - Enter into *PRIDIT* system
- Why use *PRIDIT* for hospital quality
  - Lots of categorical proxies, few outcome variables
  - Get a prioritization of variables, rank of hospitals
- When to use *PRIDIT*
  - When you have the setup described above
  - For actuarial applications when rankings are needed
  - For actuarial applications when variable priorities are needed (expense of data collection or analysis)
  - When machine learning can help surmount the "gaming" problem