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Empirical tests of directional dependence

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Directional dependence

Dodge & Rousson (2000, 2001)

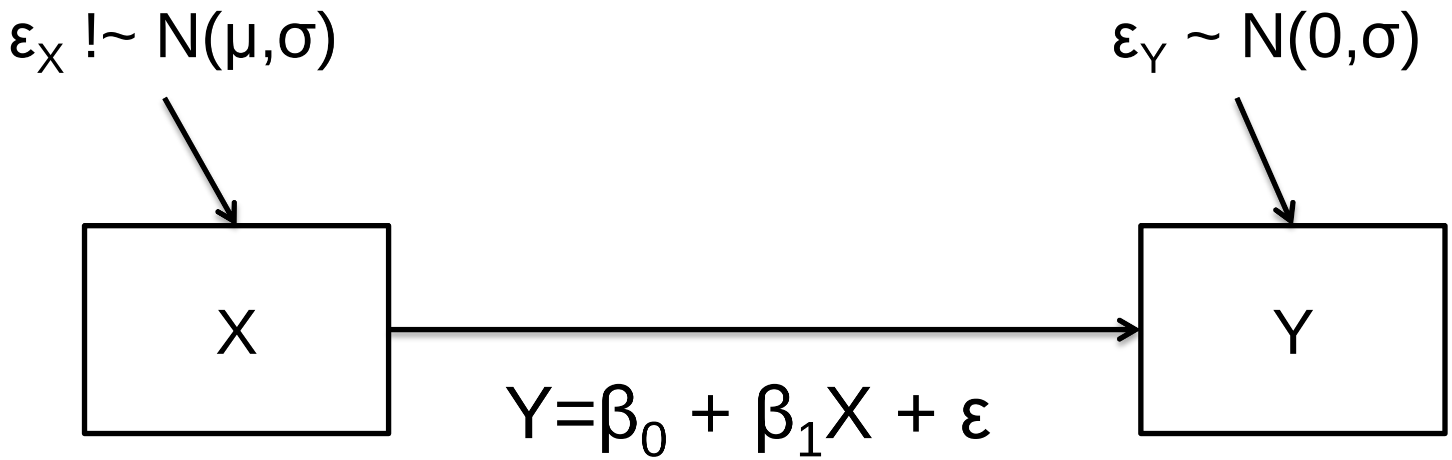
Attempt at devising a statistical tests that yields a decision whether variable X caused variable Y, or vice versa

Directional dependence

- Introduction to social scientists and case studies
  - Von Eye, & DeShon (2011, 2012)

- Simulation studies
  - Pornprasertmanit, & Little (2012)

Directional dependence



Directional dependence

- Is expected to work:
  - When cause is non-normally distributed
  - When relationship to effect is linear
  - When effect is function of non-normally distributed cause and normally distributed random disturbances

Directional dependence

- Is expected *not* to work:
  - When cause is normally distributed
  - When relationship to effect is non-linear
  - When effect is function of other (non-normally) distributed variables, in addition to the putative cause

Tests of directional dependence

- Differences in skew:
  - If variable X has more skew than Y, then conclude that X causes Y
- Differences in kurtosis:
  - If variable X has more (excess) kurtosis than Y, then conclude that X causes Y
- Differences in D'Agostino's K^2
  - If variable X has larger K^2 than Y, then conclude that X causes Y

Tests of directional dependence

- Tests rely on statistical significance tests (often bootstrapped) of correlations, skew, kurtosis, K^2, and differences in skew, kurtosis, and K^2

Outcome of tests

Neither

- No significant correlation

- Some special conditions in which sign of correlation coefficient and sign of difference in skew, or kurtosis are in contradictory directions

Outcome of tests

Undetermined

- Significant correlation, but *neither* variable exhibits significant skew, kurtosis, or K^2, *or* difference in skew, kurtosis, or K^2 is not significant

Outcome of tests

$$X \rightarrow Y$$

- Significant correlation, variables have significant skew, kurtosis, or K^2 and skew, kurtosis, or K^2 is significantly larger in X than in Y

Outcome of tests

$Y \rightarrow X$

- Significant correlation, variables have significant skew, kurtosis, or K^2 and skew, kurtosis, or K^2 is significantly larger in Y than in X

My own biases

"No causes in, no causes out."
Nancy Cartwright, "Hunting Causes and Using Them"

My own biases

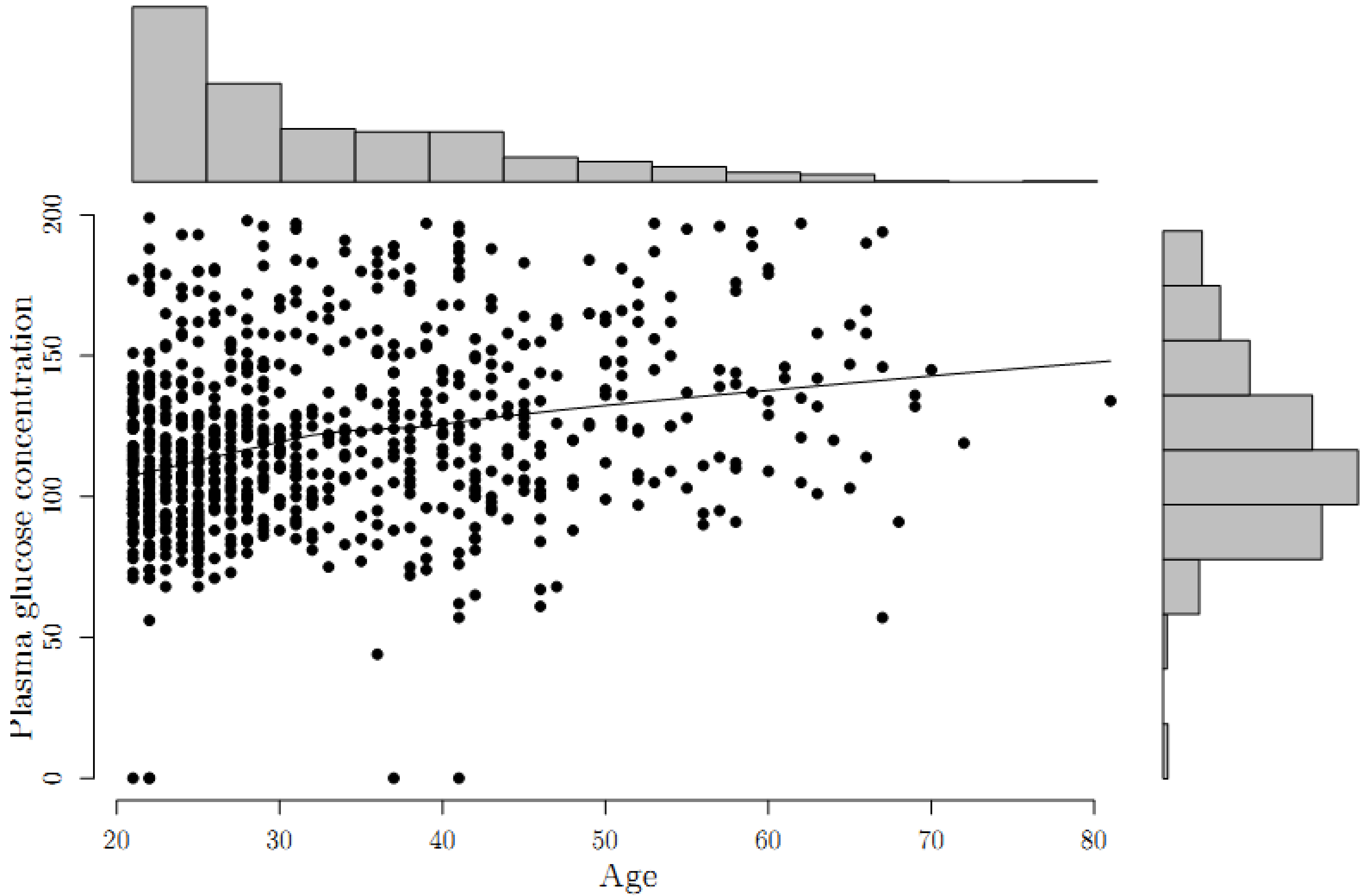
- I was fundamentally opposed to the general concept of inferring causal direction from a statistical test
- I was unconvinced by published case studies
- I accepted simulation results but heavily questioned whether real data would conform to the conditions of the simulation study that resulted in good performance
- I conducted my study with the hope of showing the bad performance of directional dependence test

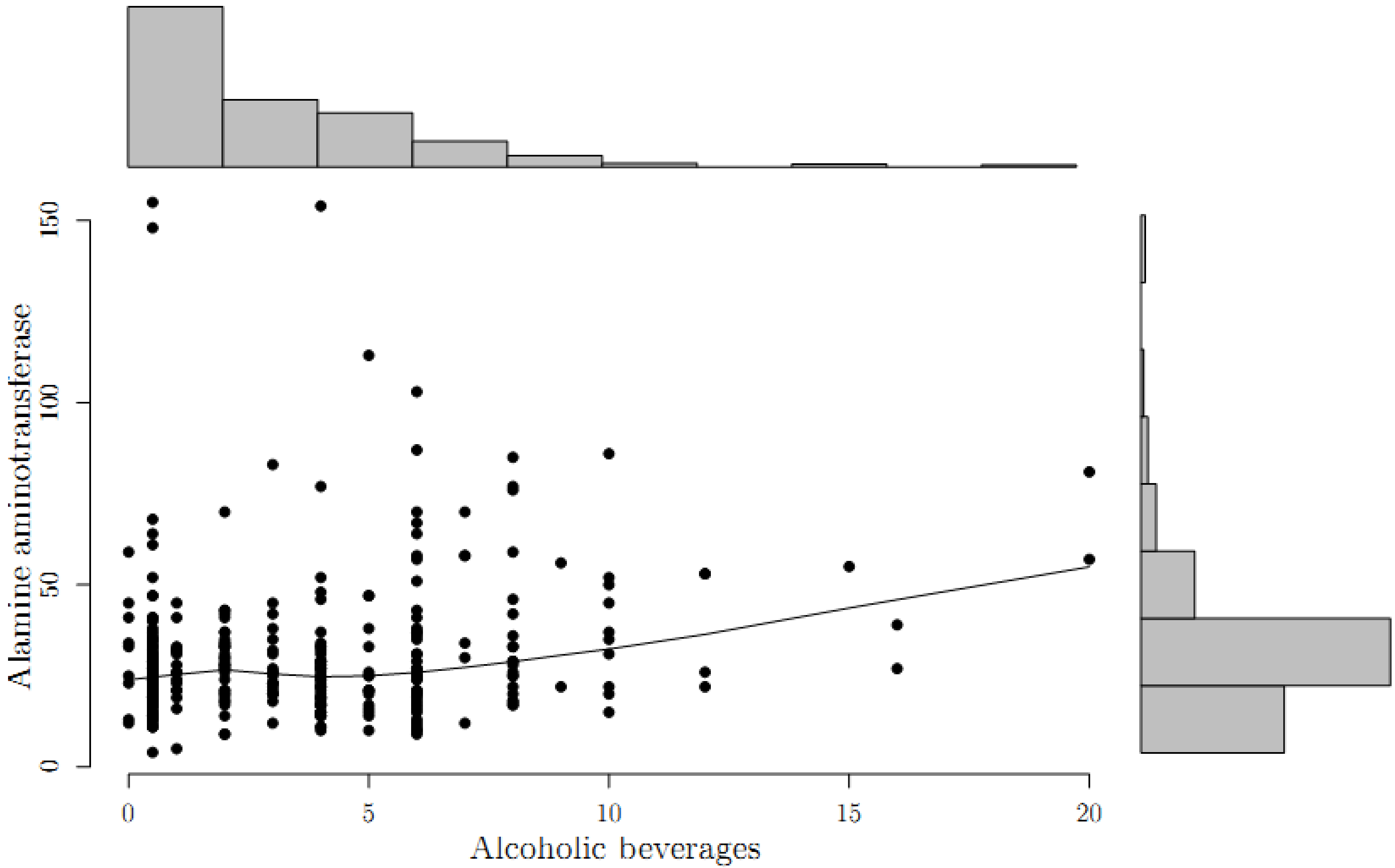
Test database

- Max-Planck Institute for Biological Cybernetics database on cause-effect pairs
- Total of 65 independent, two-variable pairs with continuous variables
- All were tested with all three directional dependence tests

Test database

- "Benign" subset was selected that consisted of variables that
  - Had at least one variable that was significantly non-normal
  - Had linear relationships
  - Had no outliers (Cook's D)
  - Had normally distributed residuals in the true model


Plasma glucose concentration
200
150
100
50
0
20
30
40
50
60
70
80
Age


Alamine aminotransferase
0
50
100
150
0
5
10
15
20
Alcoholic beverages

Performance of the tests

	All pairs		
	K^2	Skew	Kurtosis
Correct			
Incorrect			
Wrong variable			
Undetermined			
Neither			

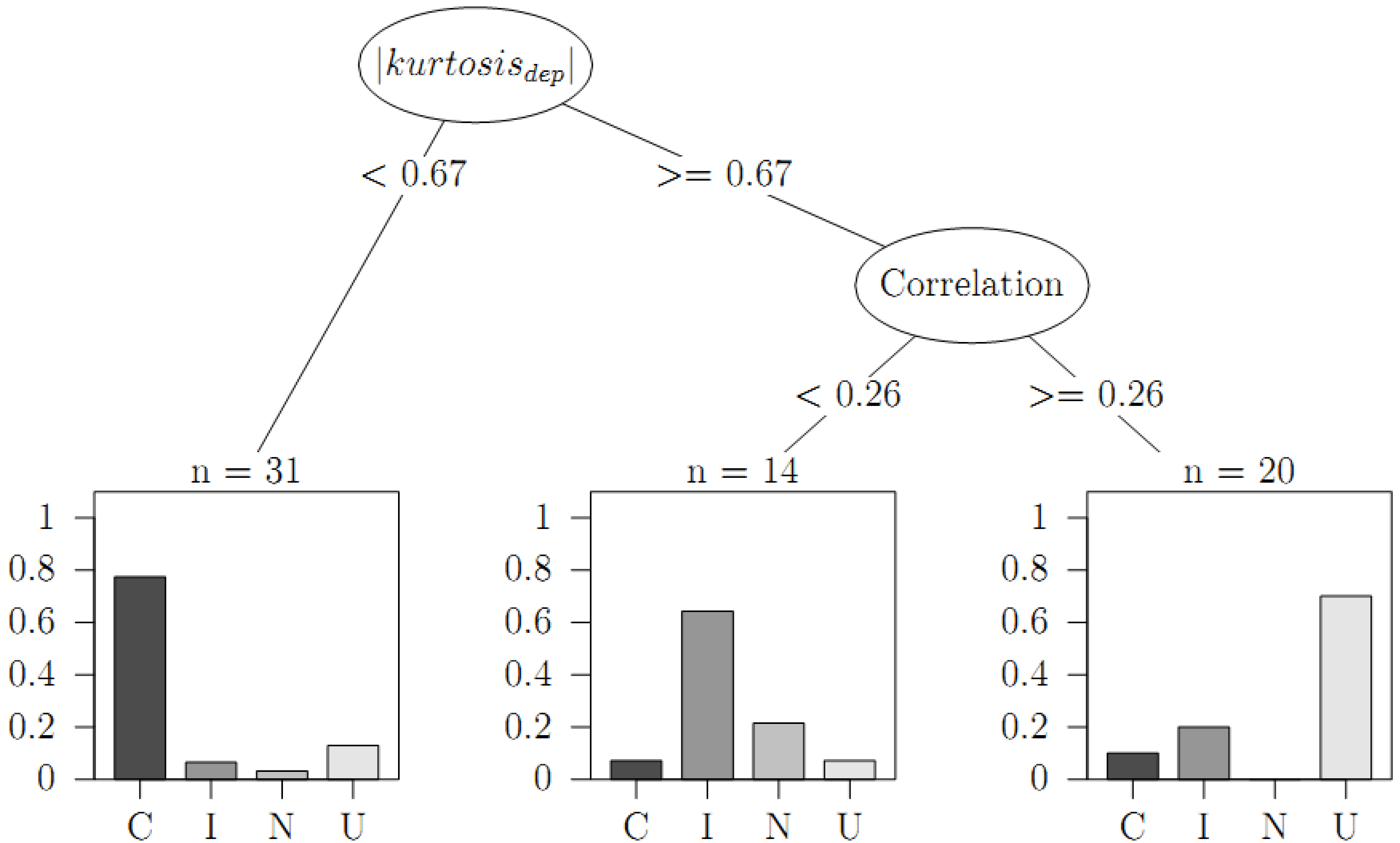
Features that make the tests work

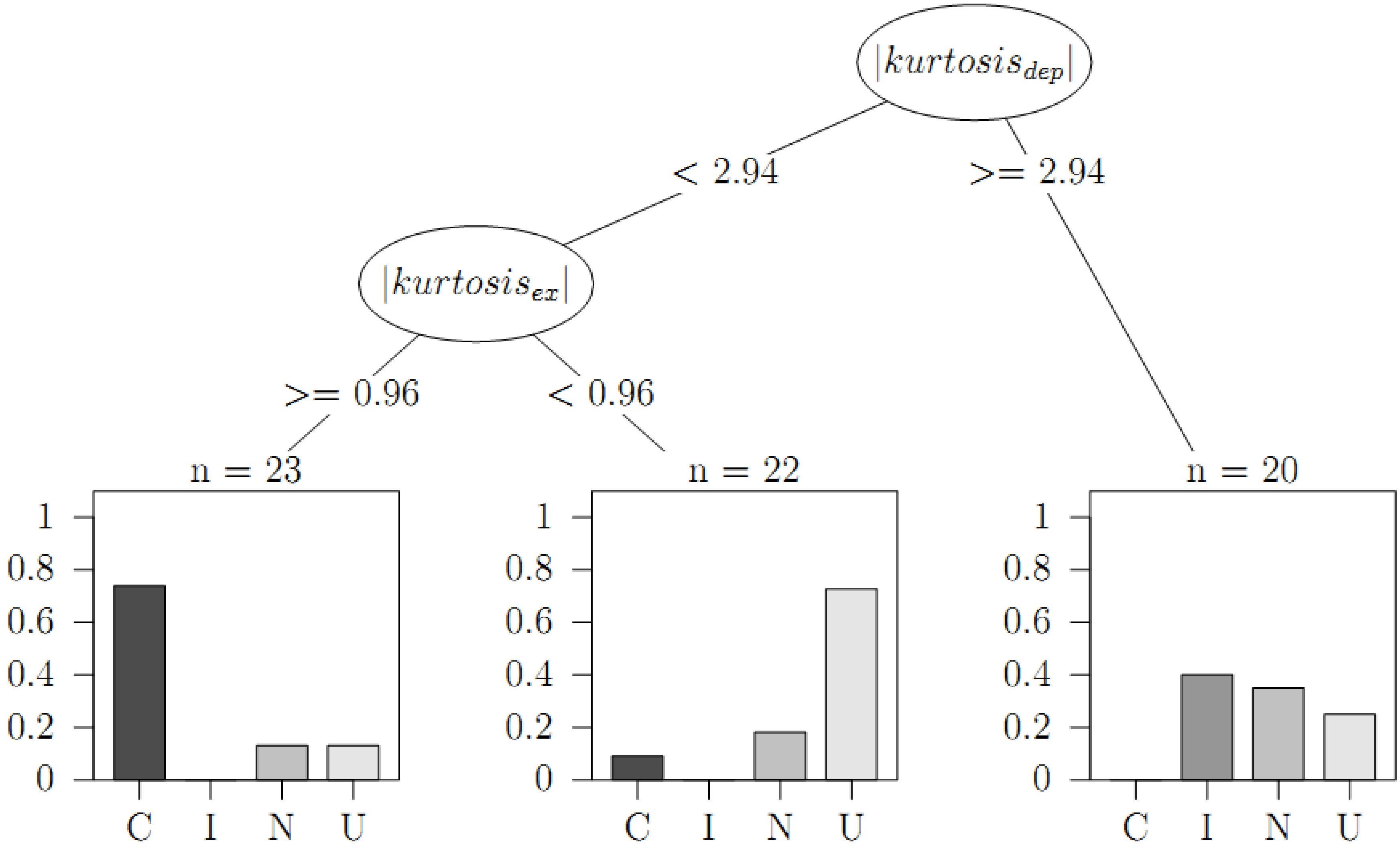
- We used both logistic regression, and regression trees to examine whether particular features of the data make it more or less likely that a directional dependence test yields a correct results

Features that make the tests work

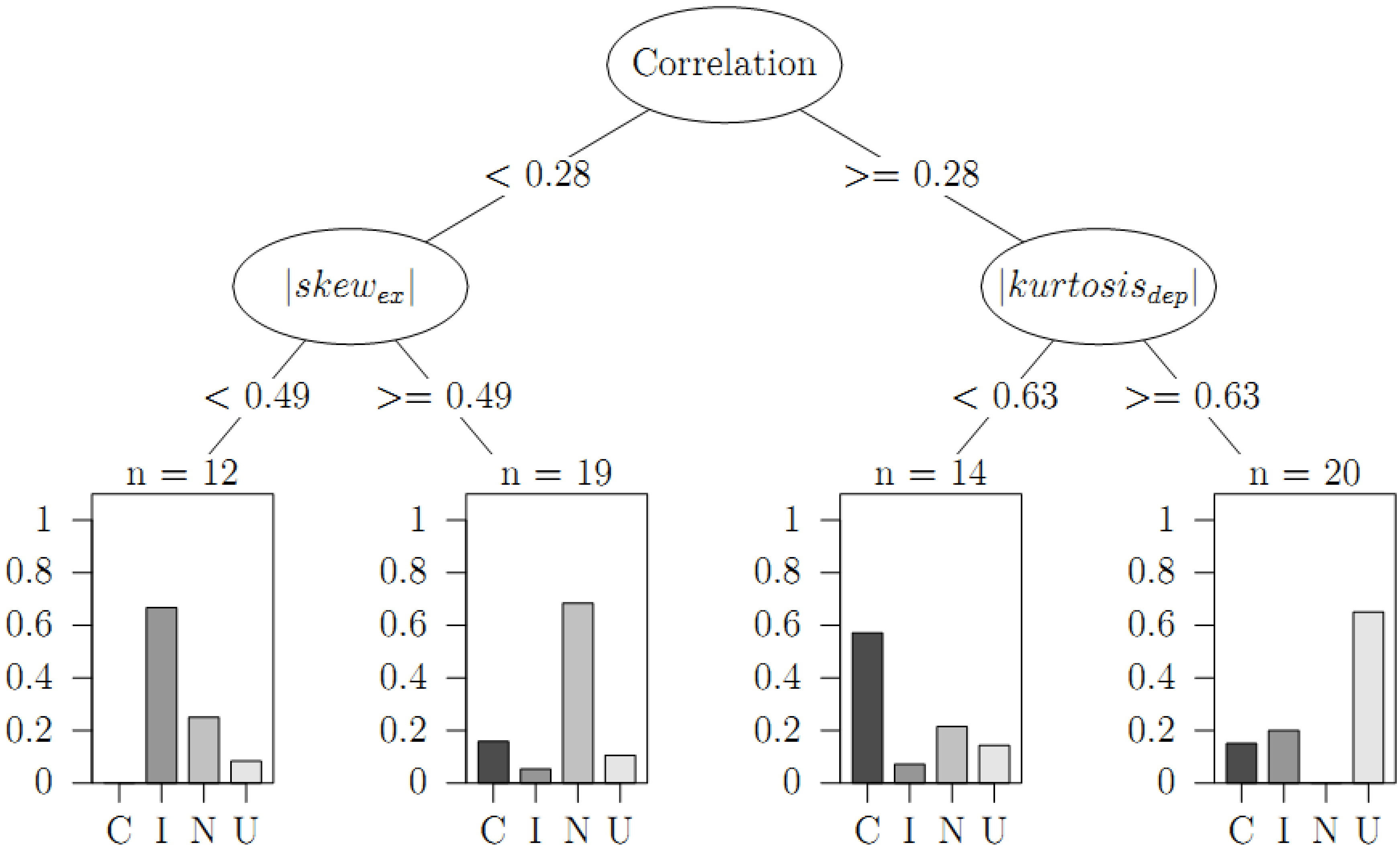
- Results somewhat expected (e.g., if kurtosis of cause is very large, tests based on kurtosis perform well)

- Results also not very informative, because they yield no insight into what an applied researcher could use as a warning sign that the test is not likely to perform well


$|kurtosis_{dep}|$
< 0.67
>= 0.67
Correlation
< 0.26
>= 0.26
n = 31
n = 14
n = 20
1
0.8
0.6
0.4
0.2
0
C
I
N
U



$|kurtosis_{dep}|$
< 2.94
>= 2.94
$|kurtosis_{ex}|$
>= 0.96
< 0.96
n = 23
n = 22
n = 20
1
0.8
0.6
0.4
0.2
0
C
I
N
U


Correlation
< 0.28
>= 0.28
|skew_ex|
|kurtosis_dep|
< 0.49
>= 0.49
< 0.63
>= 0.63
n = 12
n = 19
n = 14
n = 20
1
0.8
0.6
0.4
0.2
0
C I N U

Discussion

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