Estimating confidence intervals for the median hospital charge

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Presenter Disclosures

Cody Olsen

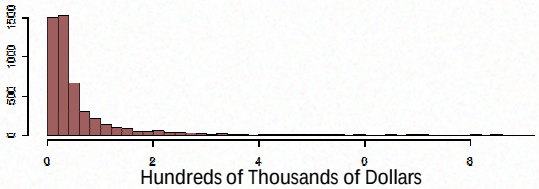
(1) The following personal financial relationships with commercial interests relevant to this presentation existed during the past 12 months:

No relationships to disclose

INTRODUCTION TO THE PROBLEM

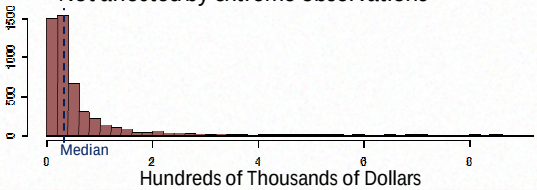
Hospital charges

- Charges are a useful outcome in injury research
- Charges are typically skewed



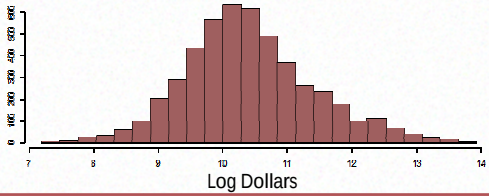
Median Charges

- The sample median is often used to describe charges
  - 50th percentile, or middle observation
  - Not affected by extreme observations



Hospital charges

- Transformed charges are often analyzed



Complication: Missing Data

- Administrative hospital datasets often have missing data
- This can be handled using multiple imputation
  - Fill-in missing data with plausible values determined by a statistical model
  - Results in multiple imputed datasets, each with different sets of imputed values
  - Combine results from multiple datasets for final result (Rubin, D.B. 1987)

A confidence interval for the Median

A confidence interval for the median can be obtained by:

- Log transformation of the data
- Quantile regression: A non-parametric method combined with bootstrapping

Methodological Assumptions

- Transformation Method
  - Assumes that the distribution of charges is normal when transformed
  - Uses the mean and a 95% confidence interval for the mean of the transformed distribution, then back-transform
- Quantile regression
  - No distributional assumptions
  - Uses the sample median and bootstrapping to obtain 95% confidence interval

Study Objectives

- Using multiple imputed charges, compare confidence intervals from:
  - Transformation method
  - Quantile regression
- Simulate data from a known distribution
- Apply the methods to an administrative dataset: motor vehicle crash related injuries

SIMULATIONS

Simulation Methods

Using a known population:

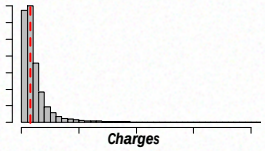
- Sample n=2000
- Simulate 10% missing data
- Impute missing data: 5 imputed datasets
- Estimate confidence intervals for the median
- Repeat 100 times
- Compare Mean Square Error, Bias, Coverage, Mean Width of the Confidence Interval

Simulated Populations

1. Population which is normal when log transformed

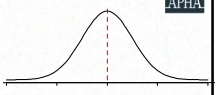
Median = $15,636, Variance of log(charges)= 0.88

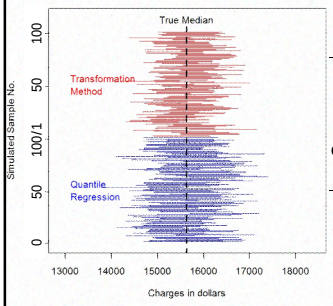
2. Empirical distribution based on observed injury-related charges
   - Utah hospital discharge database (n=112k)
   - Adjusted for inflation



Median = $15,636, Variance of log(charges) = 0.88

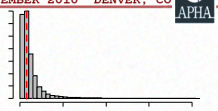
Simulation 1: Normal

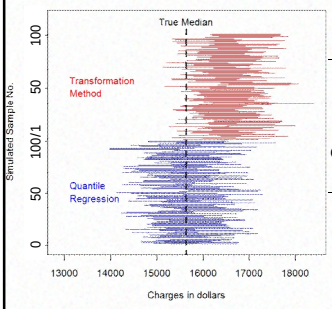




	Transformation Method	Quantile Regression
MSE	105,990	120,401
Bias	$24	$32
Coverage	95%	96%
Width	$1,268	$1,656

Simulation 2: Empirical

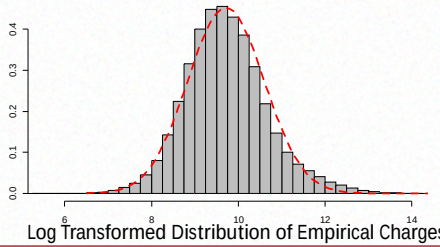




	Transformation Method	Quantile Regression
MSE	944,115	149,574
Bias	$900	$54
Coverage	30%	98%
Width	$1,431	$1,649

Simulation 2: Empirical hospital charges

Skewness persists after log transformation:

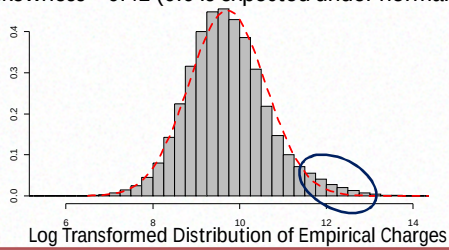


Log Transformed Distribution of Empirical Charges

Simulation 2: Empirical hospital charges

Skewness persists after log transformation:

- Skewness = 0.41 (0.0 is expected under normality)



Log Transformed Distribution of Empirical Charges

APPLICATION:

MOTOR VEHICLE CRASH RELATED INJURIES

CODES

Crash Outcome Data Evaluation System

- Uses medical outcomes related to motor vehicle crashes (MVC) for highway safety and injury research
- Emergency Department Charges
- Inpatient Hospital Charges
- Multiple imputation accounts for missing data

Motor Vehicle Crash related injuries

- 3 years of inflation-adjusted charges
- Utah dataset
  - Emergency Department (n = 53,950 × 5 imputations)
  - Hospital Inpatient (n = 4,827 × 5 imputations)
- Large multi-state dataset
  - 18 States included
  - Emergency Department (n = 1.37M × 5 imputations)
  - Hospital Inpatient (n = 182,398 × 5 imputations)

Computational Efficiency

	Time to compute	
Dataset Size	Transformation Method	Quantile Regression
n = 4,827 x 5	1 second	4 seconds
n = 1.37M x 5	17 seconds	1.74 hours

- Intel® Core™2 CPU 6600 @ 2.40 GHz, 2.0 GB of RAM
- SAS Procedures: Means (transformation method); Quantreg, MIAnalyze (quantile regression)

Motor Vehicle Crash related injuries

Emergency Department Charges: Median (95% CI)

	Transformation Method	Quantile Regression
Utah	$763 (757-770)	$705 (698-712)
Multi-State	$859 (857-860)	$826 (825-828)

Inpatient Charges: Median (95% CI)

	Transformation Method	Quantile Regression
Utah	$32,785 ($31,873-33,723)	$30,138 ($29,267-31,009)
Multi-State	$20,859 ($20,724-20,996)	$19,450 ($19,283-19,617)

DISCUSSION

Transformation Method

- Pros
  - Performed well under normality: narrow intervals with good coverage
  - Computationally efficient
- Cons
  - Provided poor coverage in empirical situation
  - Biased: over-estimated the true median
  - Interval estimate of a mean, which may not be equal to the median

Quantile Regression Method

- Pros
  - Unbiased estimate with good coverage in both simulations
  - Estimates the median regardless of the shape of the distribution
- Cons
  - Required more computing time
  - Wider confidence intervals under normality

Conclusions

- Quantile regression is an unbiased method to obtain confidence intervals for median hospital charges
- Carefully check normality assumptions when analyzing log transformed charges with standard methods
- Quantile regression can be used with multiply imputed charges

Future directions

Compare transformation methods to quantile regression for:

- Estimating differences between group medians
- Estimating regression coefficients in multivariable models of the median

References

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QUESTIONS