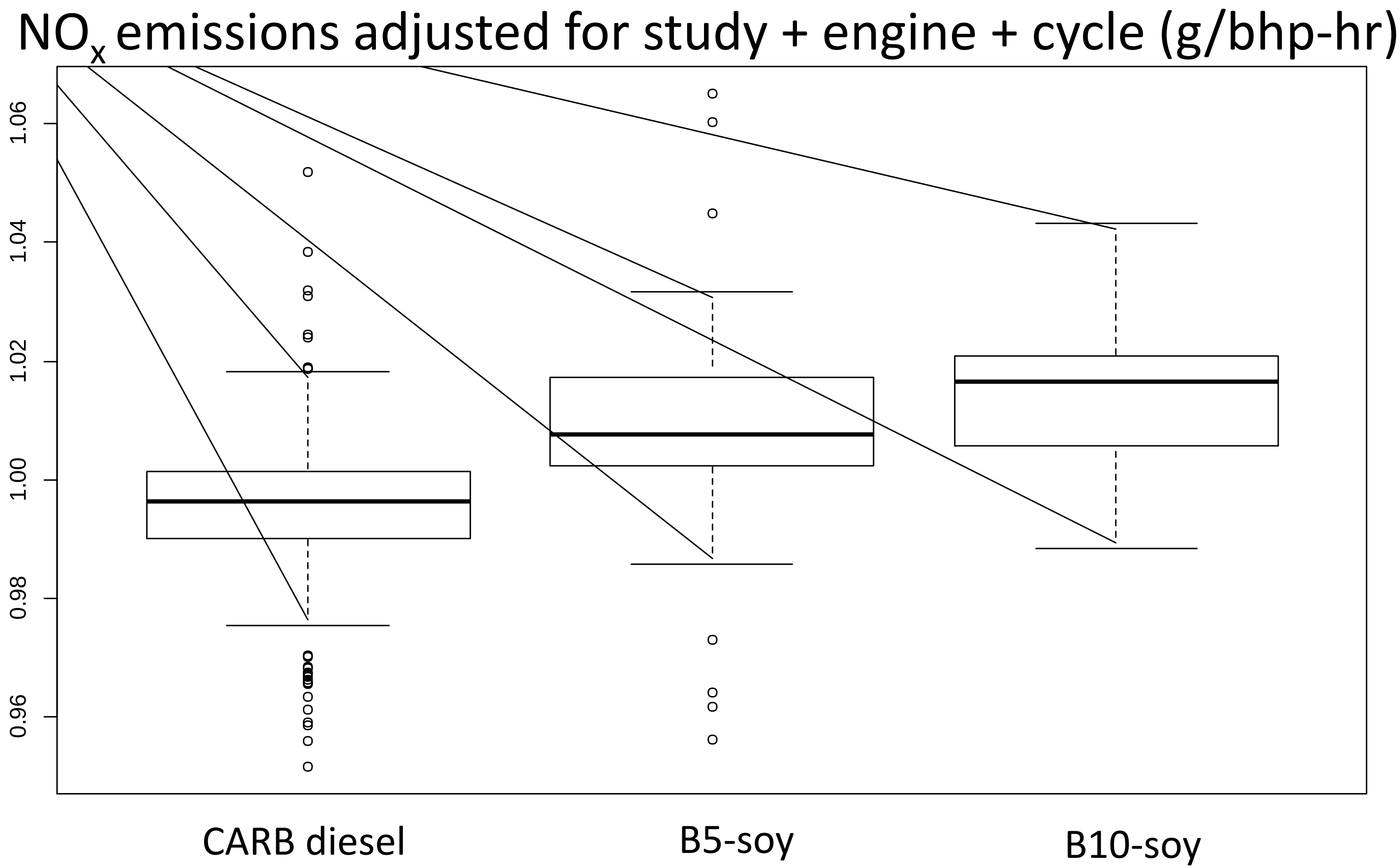
Outline of statistical analysis

- Objective: Estimate the difference in NO_x emissions (if any) between biodiesel blends and conventional diesel fuel
- Meta-analysis, reanalyzing original data from three studies
  - Durbin 2011 (86 observations)
  - Durbin 2013 (32 observations)
  - Karavalakis 2014 (193 observations)
- Used multiple statistical methods and cross-checked results

Analytical considerations

- Focus mainly on engine testing
- Focus mainly on B5-soy
- Make as few statistical assumptions as possible:
  - Analyze each blend level separately, don't assume straight-line relationship between blend level and NO_x emissions
  - Treat each combination of study, engine type and drive cycle as a separate experiment

Biodiesel effect on NOx



Samples are unevenly distributed

Durbin 2011

	CRUISE - 40mph	CRUISE - 50mph	FTP	UDDS
1991 DDC60				
2006 Cummins ISM	5	12	51	68
2007 MBE4000			18	18

Durbin 2013

	CRUISE - 40mph	CRUISE - 50mph	FTP	UDDS
1991 DDC60				
2006 Cummins ISM			32	
2007 MBE4000				

Karavalakis 2014

	CRUISE - 40mph	CRUISE - 50mph	FTP	UDDS
1991 DDC60			48	48
2006 Cummins ISM			48	49
2007 MBE4000				

Mixed model

- A linear mixed-effects model (or “mixed model”) has been the standard statistical approach for this type of problem since the 1950’s
- Available in standard statistical packages such as R or SAS

Mixed model results

- Difference between conventional diesel and

Soy B5	~1%
Soy B10	~2%

- Is the fuel effect significant?

  ➡ Significance test gives a P value of 10^{-15}

  Confidence level = 1-P = Greater than 99.99%

Key Result

- For B5-soy, all our statistical approaches yield approximately the same results:
  - Approximately 1% increase in NO_x emissions, compared with conventional diesel
  - Highly statistically significant (confidence level ≥ 99%)

Additional checks

- Consultant obtained the same result ("approximately 1%", confidence level > 99.9999%)
- Initial inclusion of chassis test data – similar results in magnitude and significance