Statistical Methods and Procedures in Estimates of Methane Emissions from Unconventional Wells – A Comment on Bayesian Applications

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Dataset

Data Source	Whole Gas, Average Emissions per Completion (Mcf)	Modified, Average Methane Emissions per Completion (Mcf)	Rounded, Average Methane Emissions per Completion (Mcf)
Weatherford	667	555	600
Industry Data Set #1	5,820	4,844	5,000
Devon	11,900	9,905	10,000
Williams	24,449	20,351	20,000

[1] Modified emissions are calculated using a methane content value of 0.8324

Objective

- Develop an interval estimate for the mean methane emission per completion given four summary observations.

- Interval estimation is based on the following assumptions:
  - Data collection design is acceptable
  - Measurement error is not influential

Interval Estimate : Least Squares Approach

- **Dependent variable**: Methane Emissions

	Coefficient	Std. Error	t-ratio	p-value	Lower 95% C.I.	Upper 95% C.I.
Const.	8900	4168.53	2.1350	0.12243	-4366.13	22,166.1

- **Conclusion**: The result is not statistically significant at the 1%, 5%, or 10% level.

The Bayesian Approach

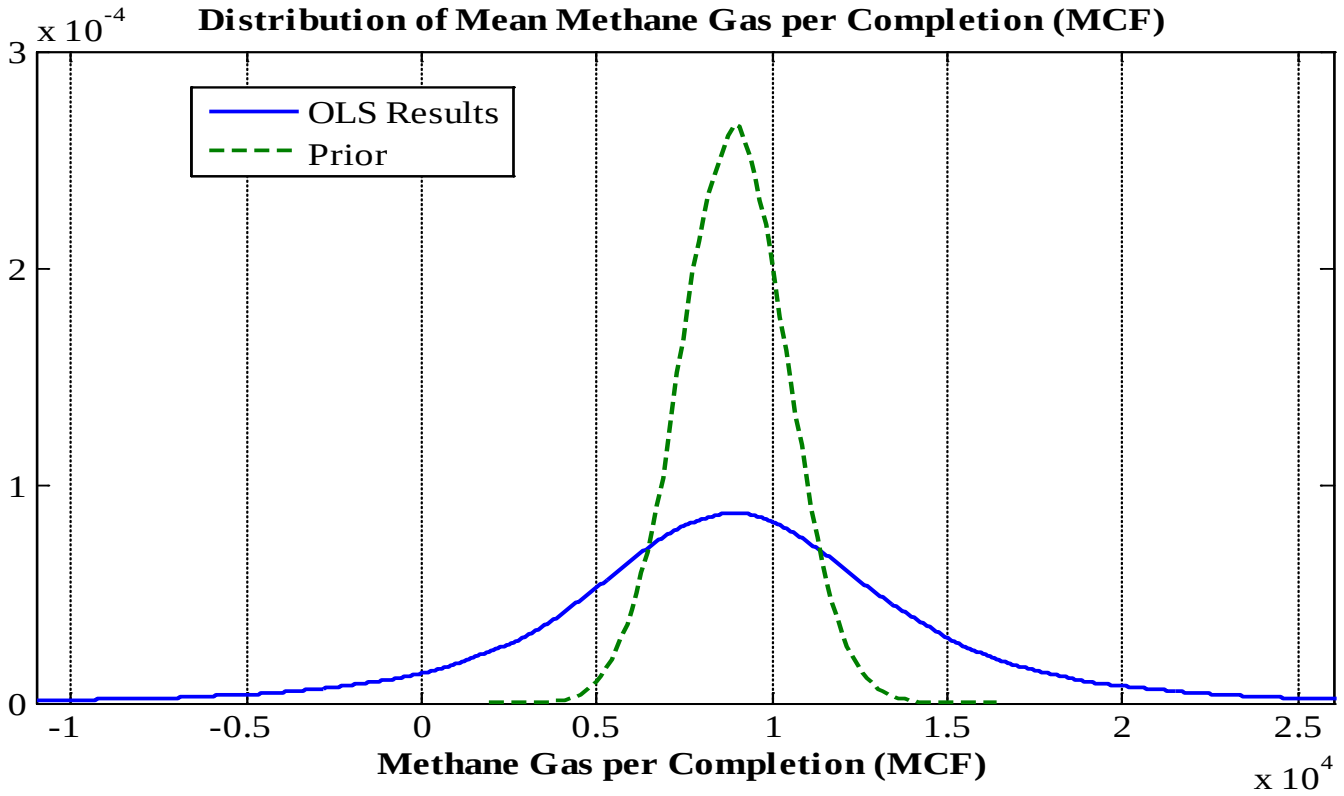
- **Objective**: Reduce the size of the interval to make the result statistically significant.

- **Method**: Bayesian Econometrics

Bayesian Basics

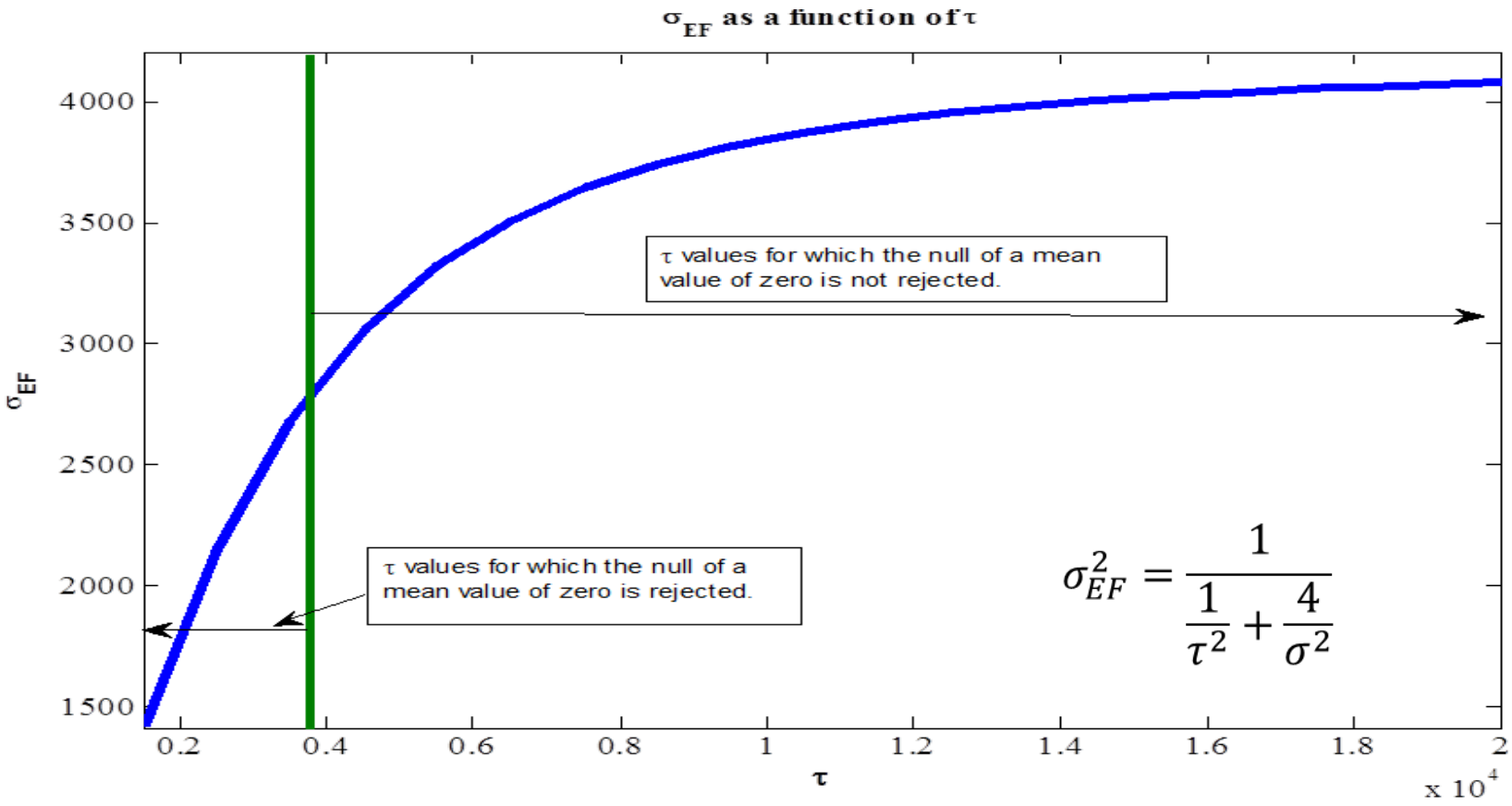
- $p(\theta|y) \propto p(y|\theta) * p(\theta)$
  - Posterior: $p(\theta|y)$
    - Represents a combination of the data-driven likelihood function and the researchers prior beliefs.
  - Likelihood: $p(y|\theta)$
    - Data-driven density.
  - Prior: $p(\theta)$
    - Researcher's prior beliefs independent of the data.

Comparison



- Notice how "tight" the distribution of the prior is relative to the OLS results.

Influence of Prior



Concerns, Considerations and Conclusions

- **Variance is assumed to be known**
  - **Issue:** Assumption is not adequately justified. **Solution:** Bayesian methods can estimate models with an unknown variance in a straightforward manner. A commonly used linear regression model with a natural conjugate prior results in a distribution that would follow a t-distribution with a wider and more representative interval once the variance has been integrated out.

- **Small dataset**
  - **Issue:** Only a few data points which suffer from measurement error. **Solution:** Collect more data at the well level using a survey/process designed explicitly to measure vented methane emissions.

- **Prior**
  - **Issue:** Prior, rather than the data, is driving the results. **Solution:** Combine a diffuse or uninformative prior with the data to allow for empirically grounded conclusions.