Using Confidence Intervals to Minimize Forecasting Error

Sam Schaefer
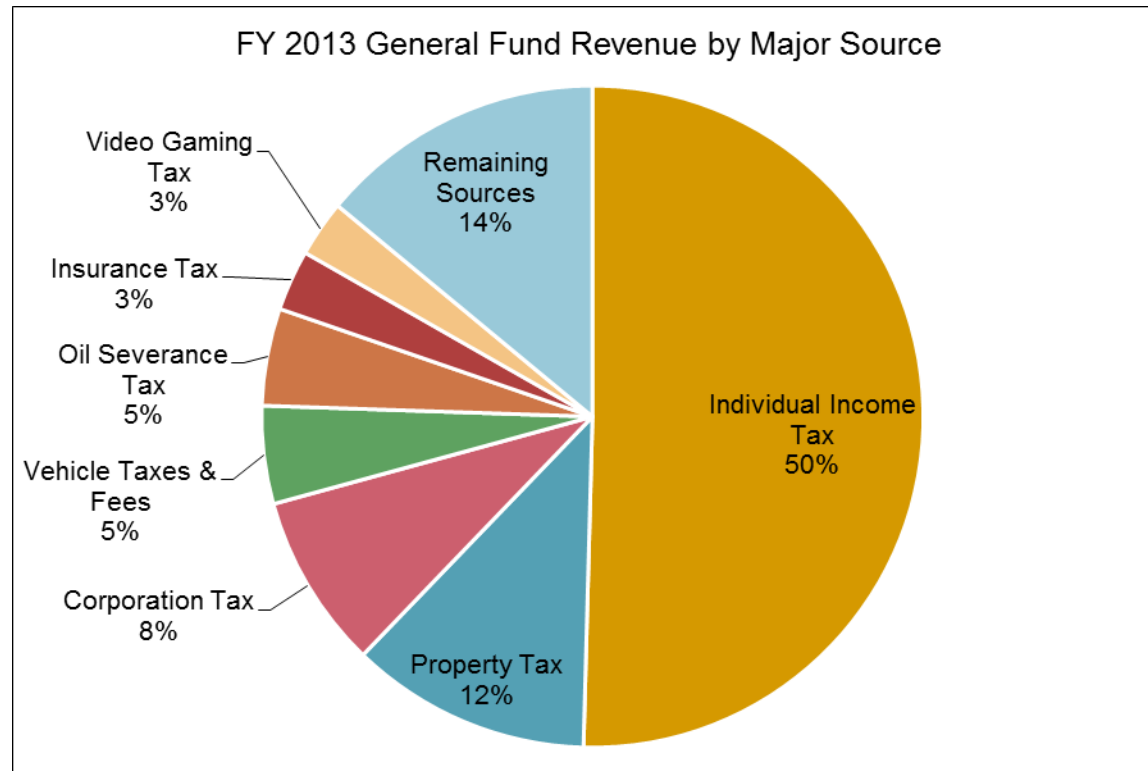
LFD
MONTANA LEGISLATIVE FISCAL DIVISION

Motivation

- In past years there have been numerous requests from the Legislature for standard error analysis of corporation income tax.
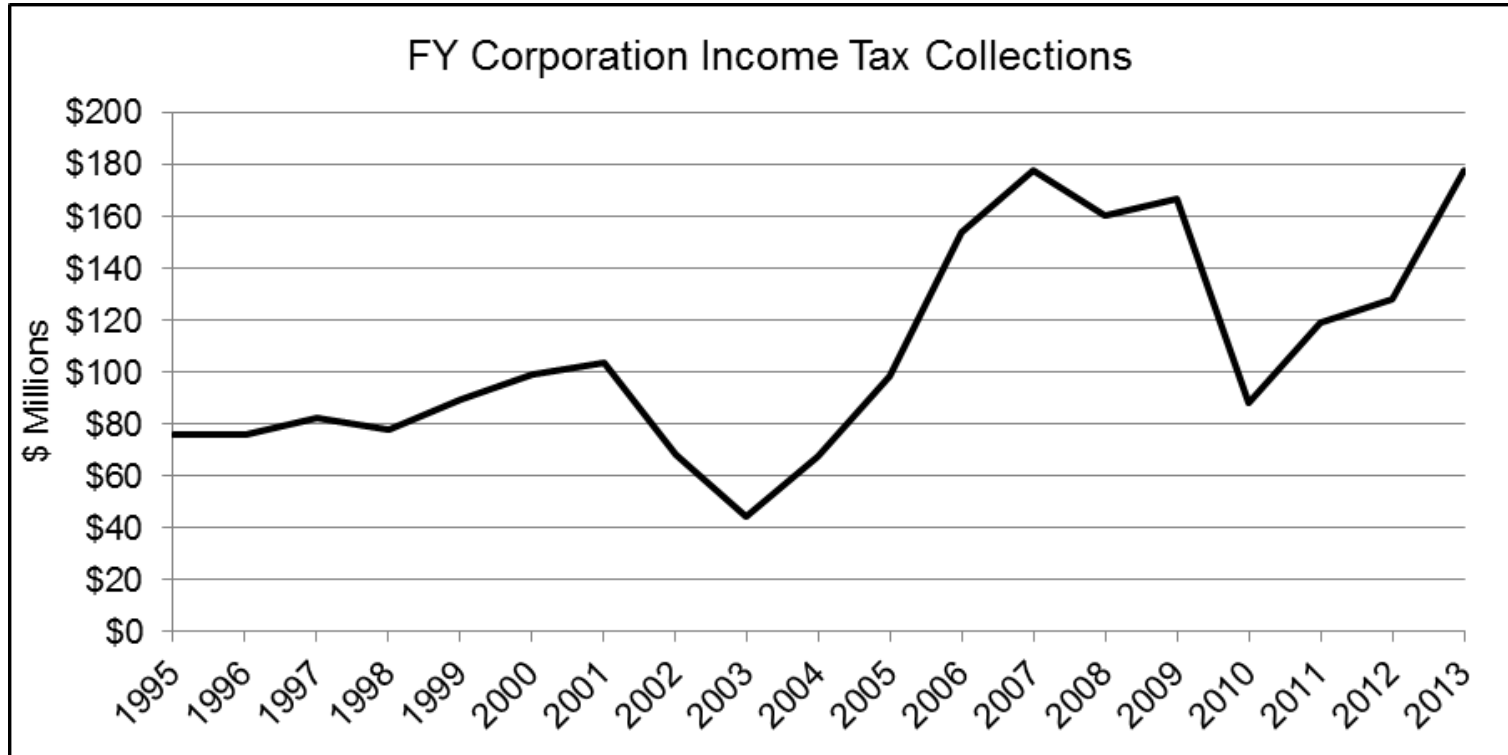
Objectives

- Select economic variables that model past revenue well.
- Select economic variables that IHS consistently predicts well.
- Place some level of certainty on a revenue estimate.
- This will allow for comparison of models that use IHS economic forecasts as the main predictors.

Background:
FY 2013=$2,078 million

FY 2013 General Fund Revenue by Major Source

- Video Gaming Tax 3%
- Insurance Tax 3%
- Oil Severance Tax 5%
- Vehicle Taxes & Fees 5%
- Corporation Tax 8%
- Property Tax 12%
- Individual Income Tax 50%
- Remaining Sources 14%

Volatility of Corporation Tax

FY Corporation Income Tax Collections

Sources of Forecasting Error

- Taxpayer Behavior
  - Montana law allows corporations to carry back current year losses for three years, and carry forward losses for up to seven years.
- Reliance on a limited number of large taxpayers.
- Random Error
- Inherent error of IHS variables used for modeling.

Forecast Methodology

- Corporation tax liabilities are divided into numerous sectors.
- These sectors include, but are not limited to, mining, manufacturing, retail trade, and financial sectors.
- IHS economic variables are used to model each sector individually.
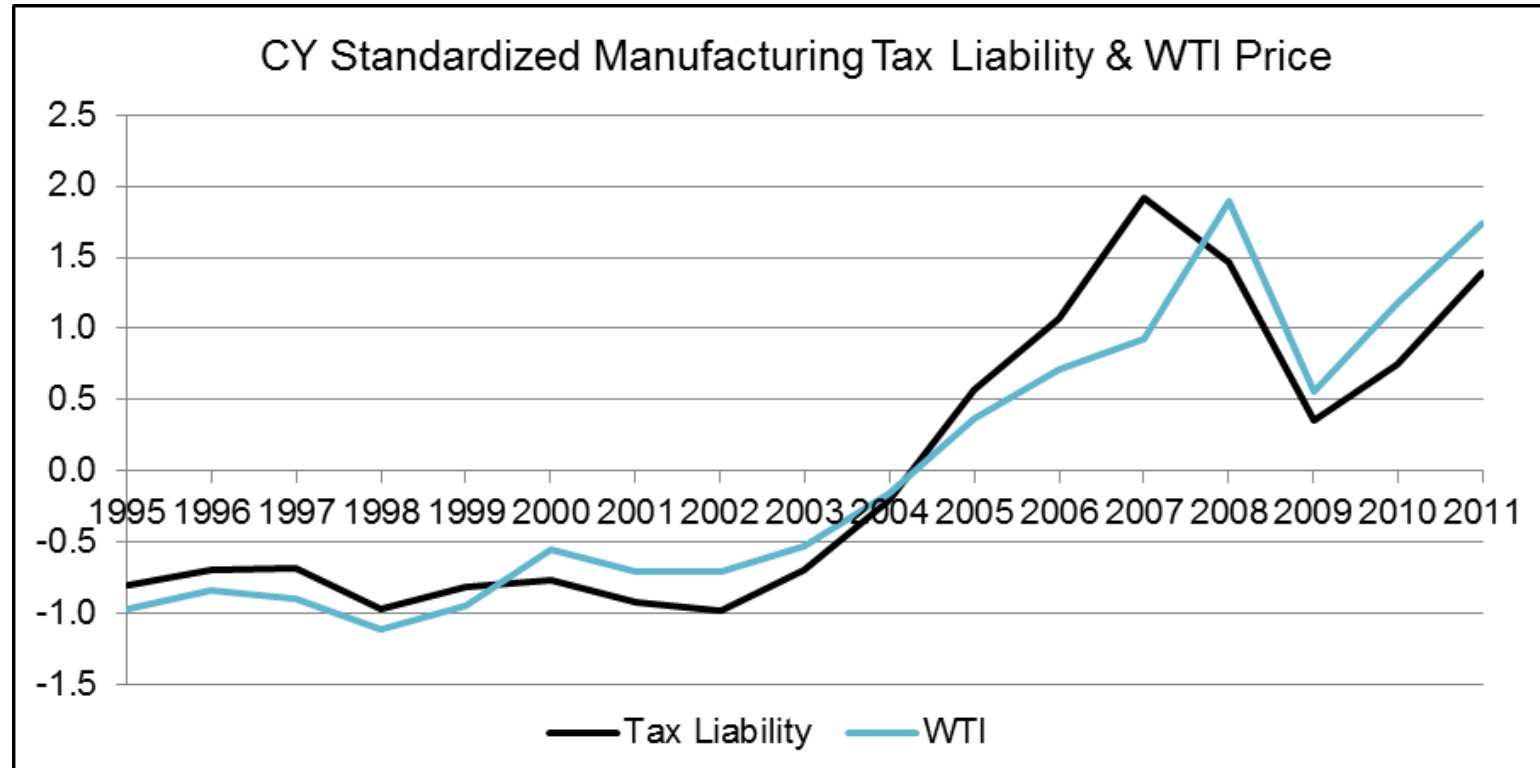- Sector estimates are combined to form a final revenue estimate for corporation tax liability.

Study Sector-by-Sector Error

$$\epsilon \, (error) = \frac{actual \; value - estimate}{actual \; value}$$

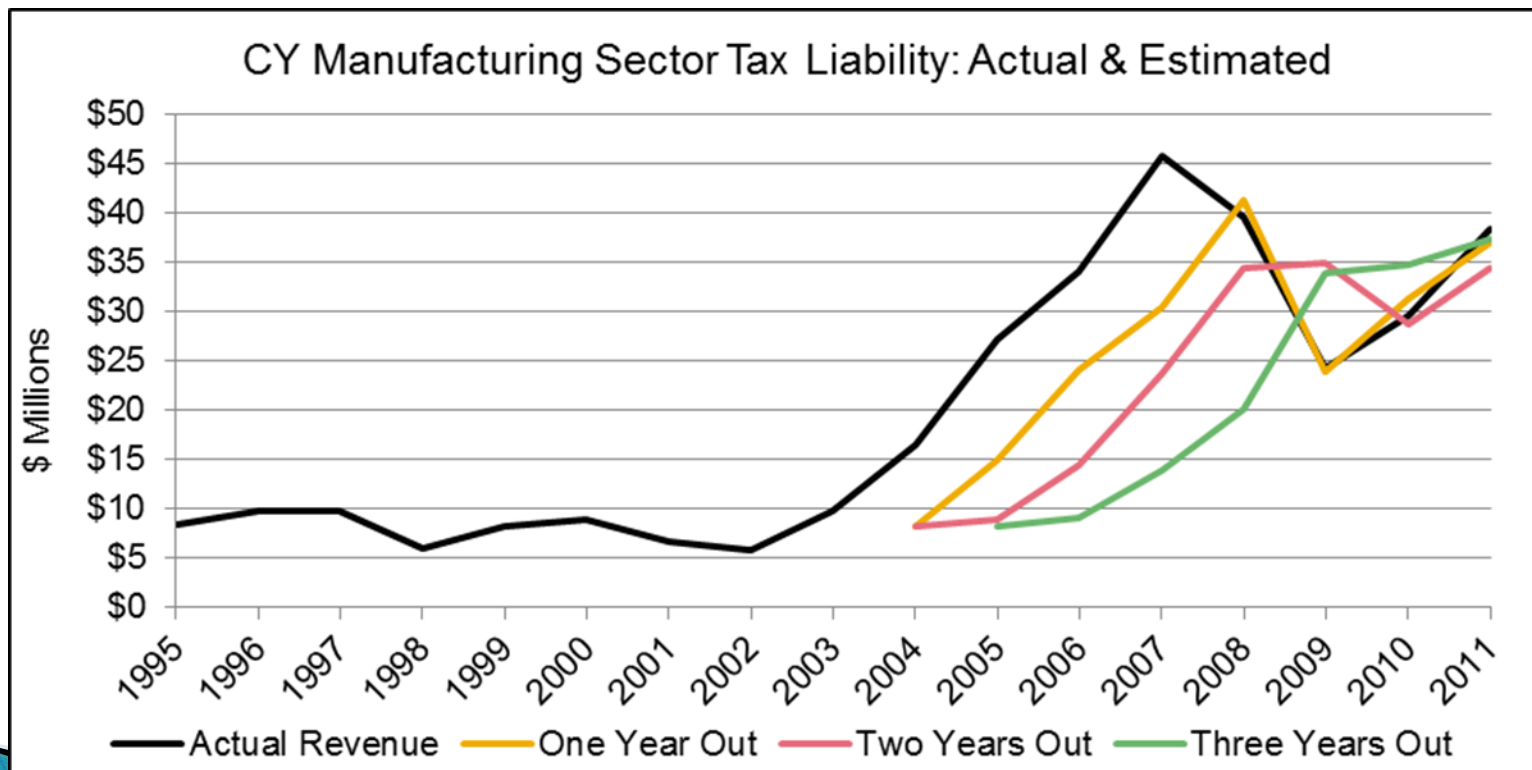# Example: Manufacturing Sector

CY Manufacturing Sector Corporation Tax Liability
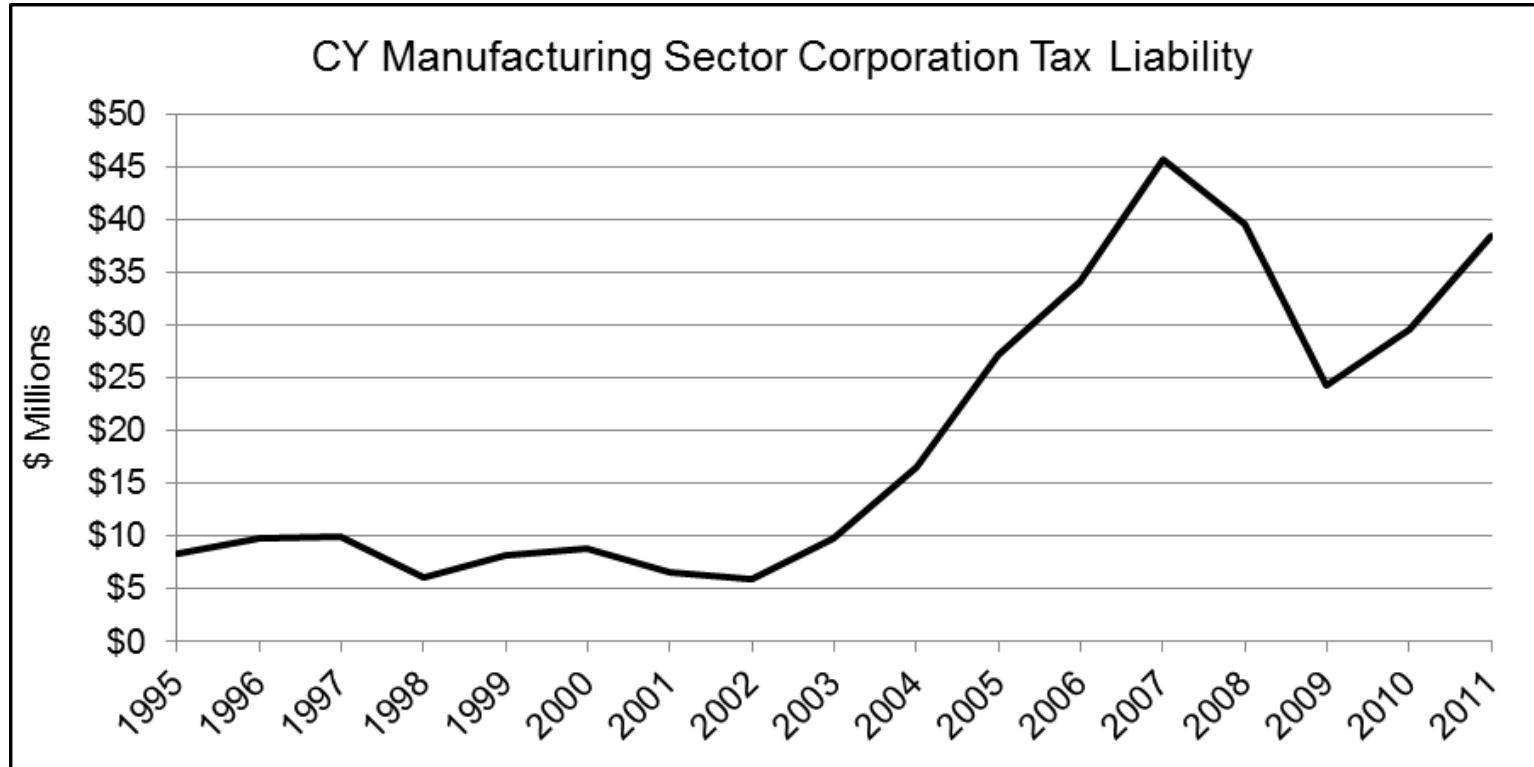
WTI Price Fits Historical Data Well…

CY Standardized Manufacturing Tax Liability & WTI Price

…but how well do IHS forecasts of WTI predict manufacturing tax liability?

CY Manufacturing Sector Tax Liability: Actual & Estimated

Actuals vs. Estimates

Error Term by Year of Estimate			
CY	First Year	Second Year	Third Year
2004	50%	50%	N/A
2005	45%	67%	70%
2006	29%	57%	73%
2007	33%	48%	70%
2008	-5%	13%	49%
2009	1%	-44%	-40%
2010	-6%	3%	-17%
2011	4%	11%	3%

Statistical Theory

▸ A confidence interval for the individual errors would require that their distribution be known.

▸ With such a small sample, confidence in the true distribution is small.

Error Summary and Distribution

Summary Statistics of Manufacturing Tax Liability Error Term by Estimate Year			
Statistic	First Year	Second Year	Third Year
Mean	19%	26%	30%
Standard Deviation	23%	37%	47%

Histogram of Manufacturing First Year Estimates' Error Terms
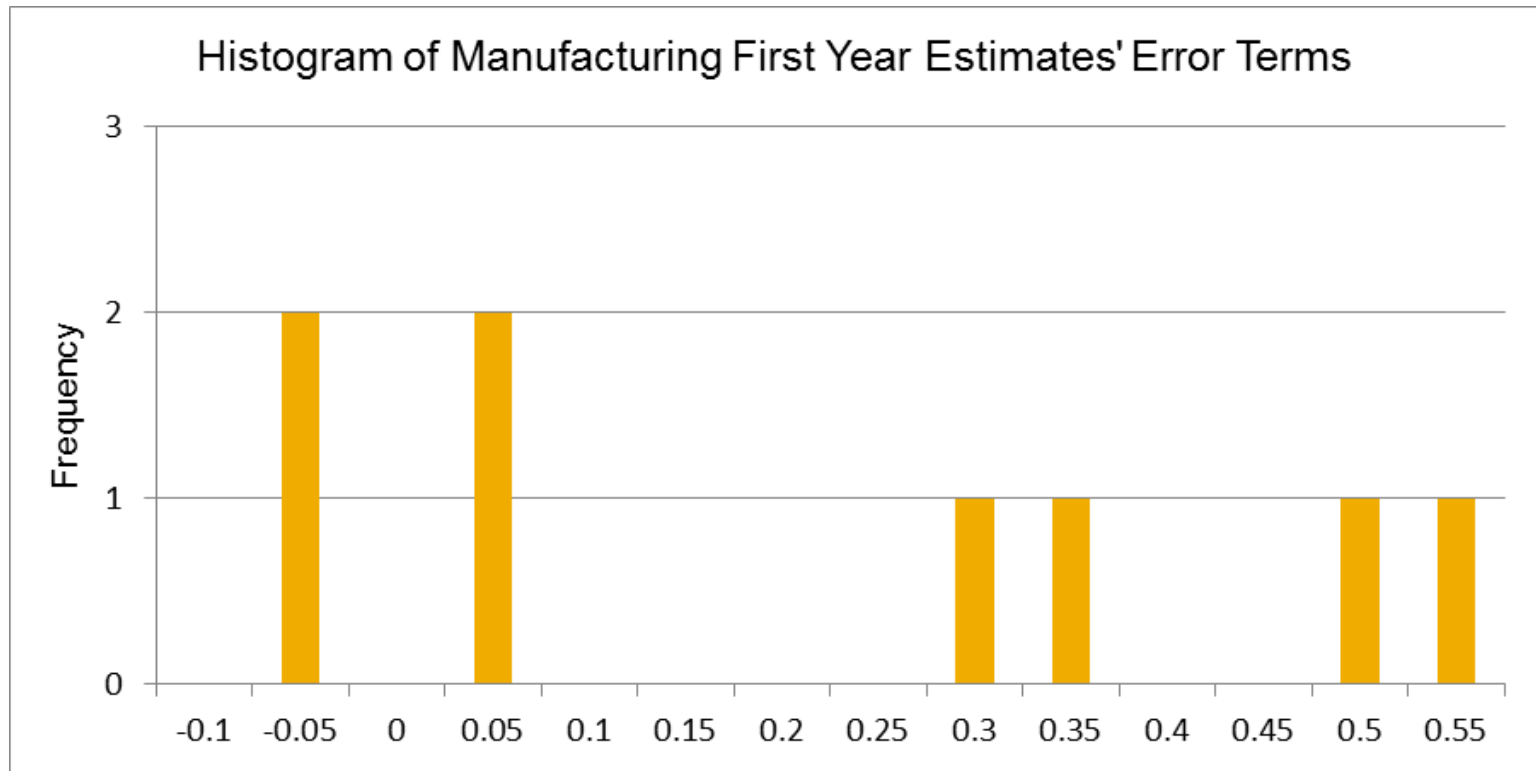
Bootstrap Sample Mean

Summary Statistics of Manufacturing Tax Liability Average Error Term by Estimate Year			
Statistic	First Year	Second Year	Third Year
Mean Error	19%	26%	30%
Standard Error	8%	12%	16%

Histogram of First Year Estimates' Mean Error Terms
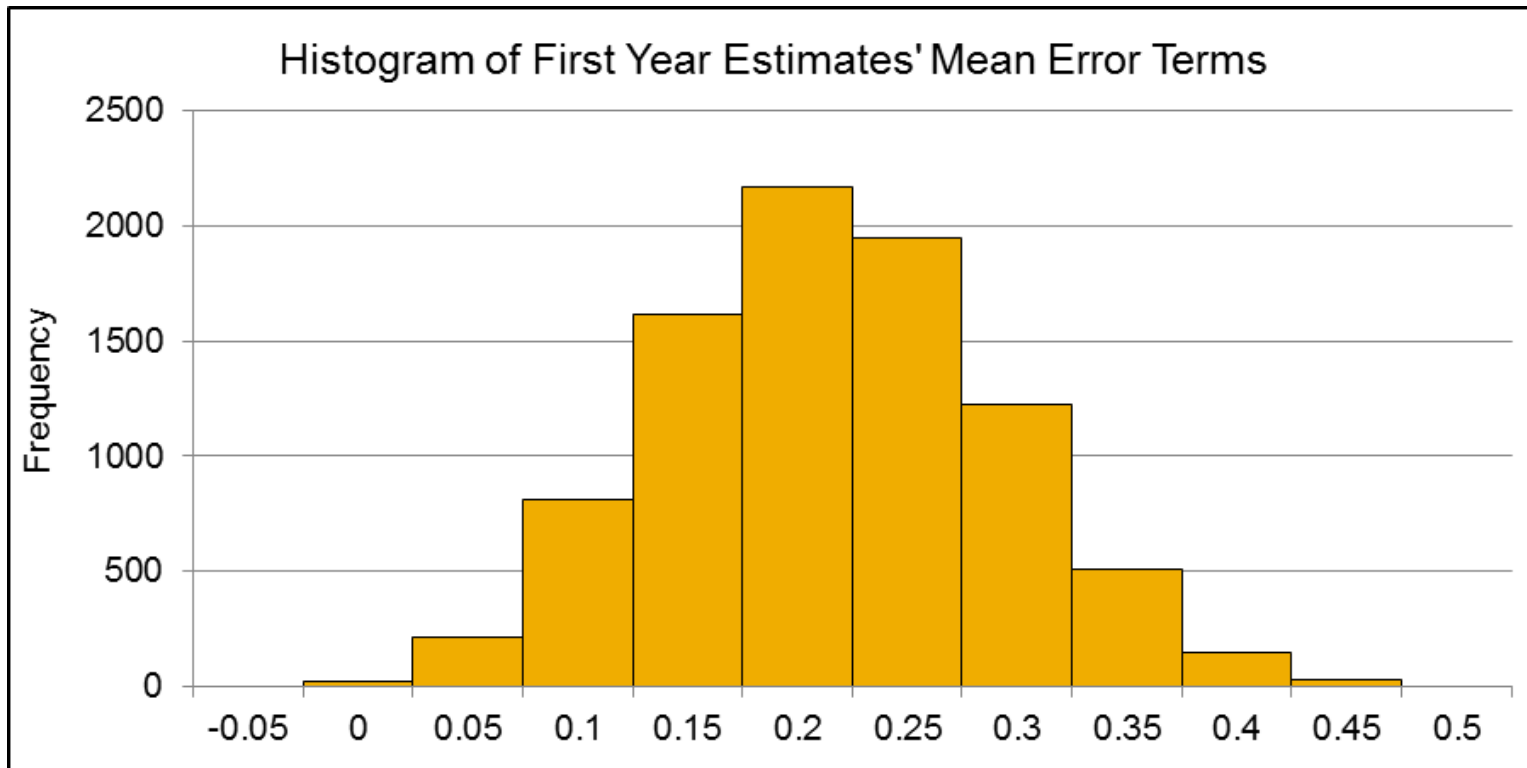
Aggregate Results

CY Corporation Income Tax Liability 95% Confidence Intervals for the Aggregate Average Error Term of the Sector-Based Estimate ($ Millions)									
		Mean Error		t-Statistic		Standard Error		Interval	
First Year Error Bound	=	$15.1	±	2.365	×	$6.7	=	[-$0.8,$30.9]	
Second Year Error Bound	=	$13.3	±	2.450	×	$9.3	=	[-$9.6,$36.1]	
Third Year Error Bound	=	$10.2	±	2.571	×	$12.2	=	[-$21.2,$41.6]	

CY Corporation Income Tax Liability 95% Confidence Intervals for the Sector-Based Estimate ($ Millions)				
Estimate Year	Estimate	Lower Bound	Upper Bound	% Range
2015	$135.0	$134.2	$165.9	24%
2016	$139.2	$129.6	$175.3	33%
2017	$145.3	$124.1	$186.9	43%

Fiscal Year Results

FY Corporation Income Tax Liability				
Using 95% Confidence Intervals for the Sector-Based Estimate				
($ Millions)				
Estimate Year	Estimate	Lower Bound	Upper Bound	% Range
2015	$149.7	$149.0	$177.7	19%
2016	$147.9	$147.2	$176.2	20%
2017	$151.7	$142.9	$184.8	28%

FY Corporation Tax Liability Using 95% Confidence Intervals
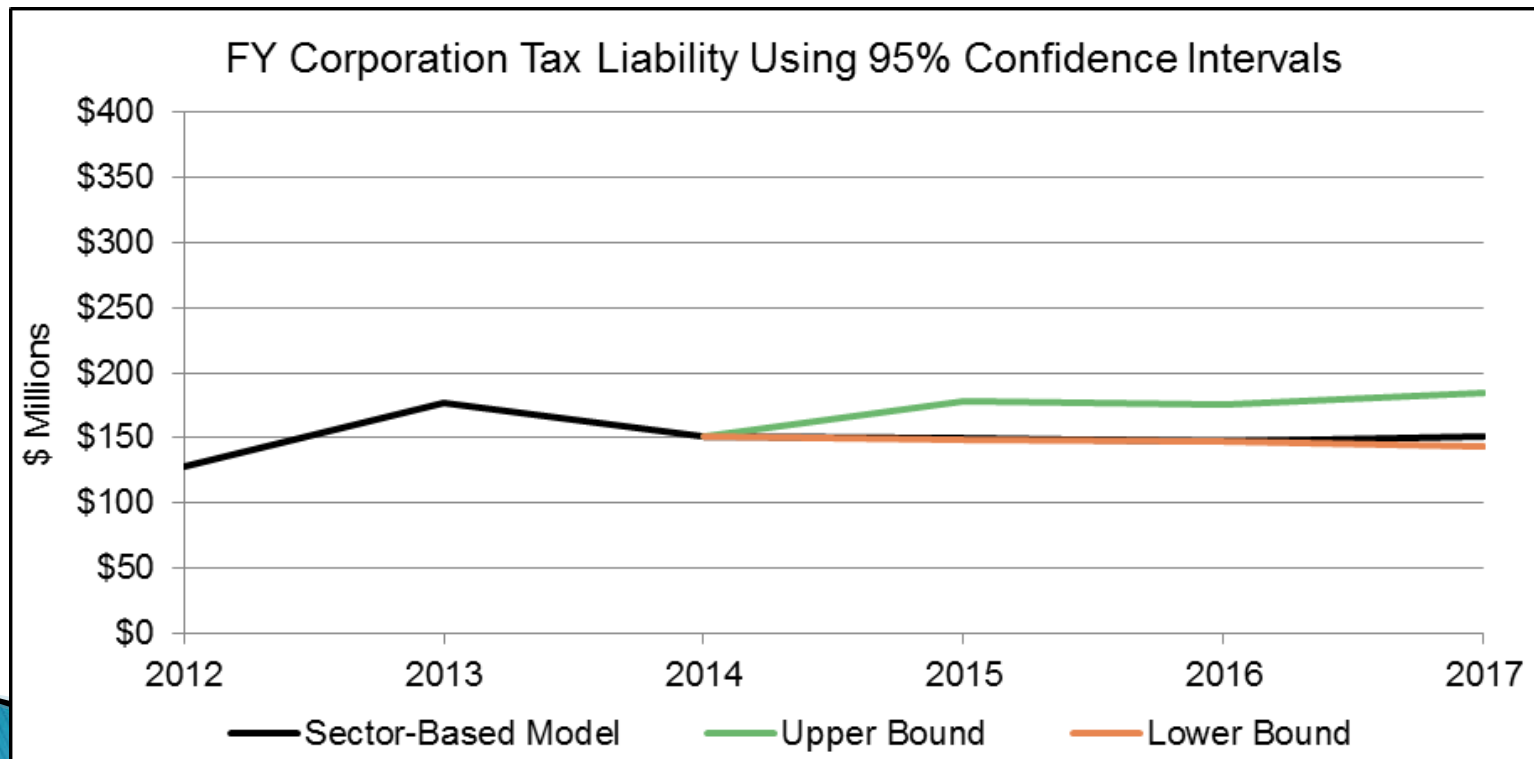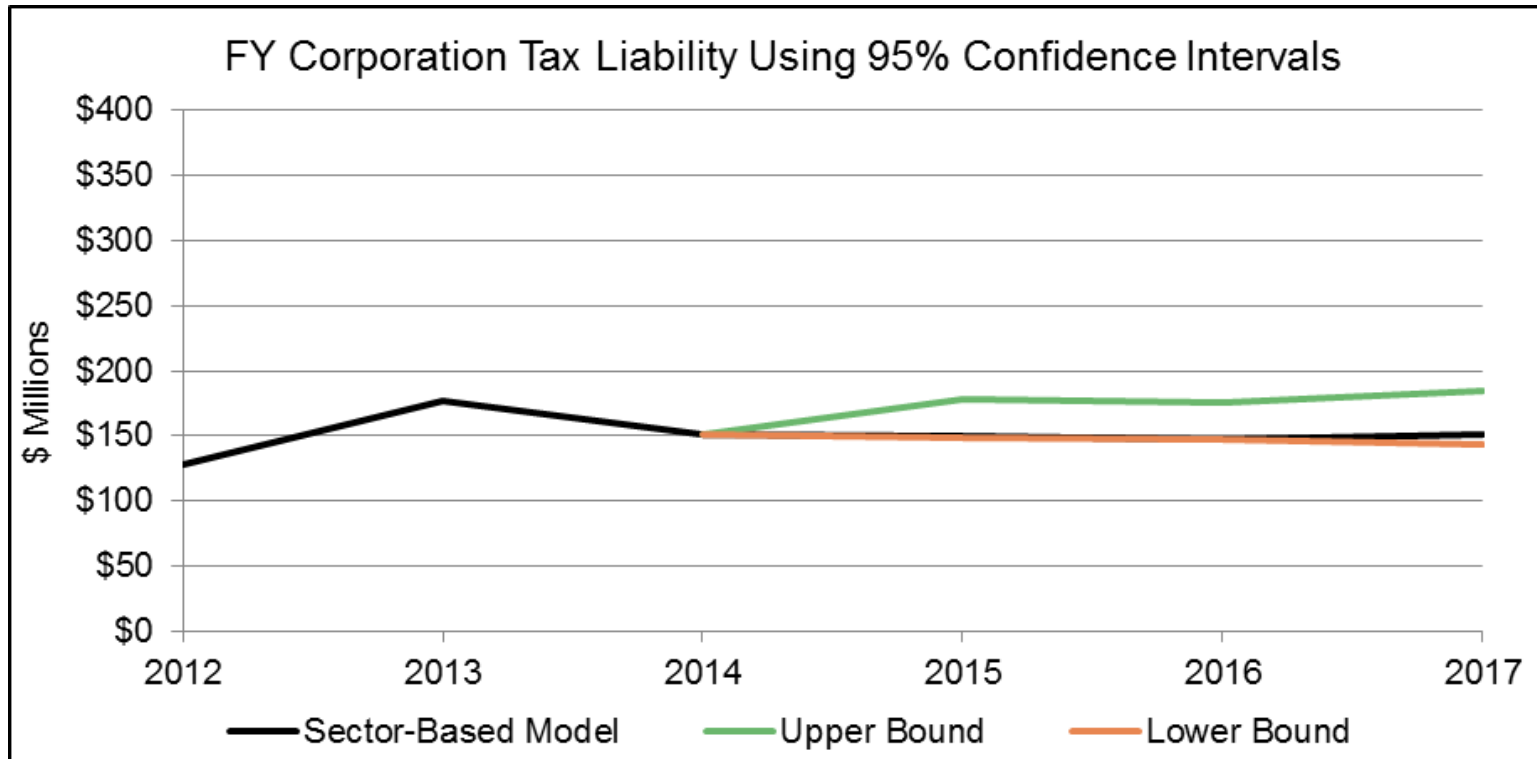
Are the Variables Independent?

FY Corporation Income Tax Liability 95% Confidence Intervals for the Sector-Based Estimate Assuming Partial Dependence ($ Millions)				
Estimate Year	Estimate	Lower Bound	Upper Bound	% Range
2015	$149.7	$142.0	$184.7	29%
2016	$147.9	$140.0	$183.3	29%
2017	$151.7	$133.9	$193.9	40%

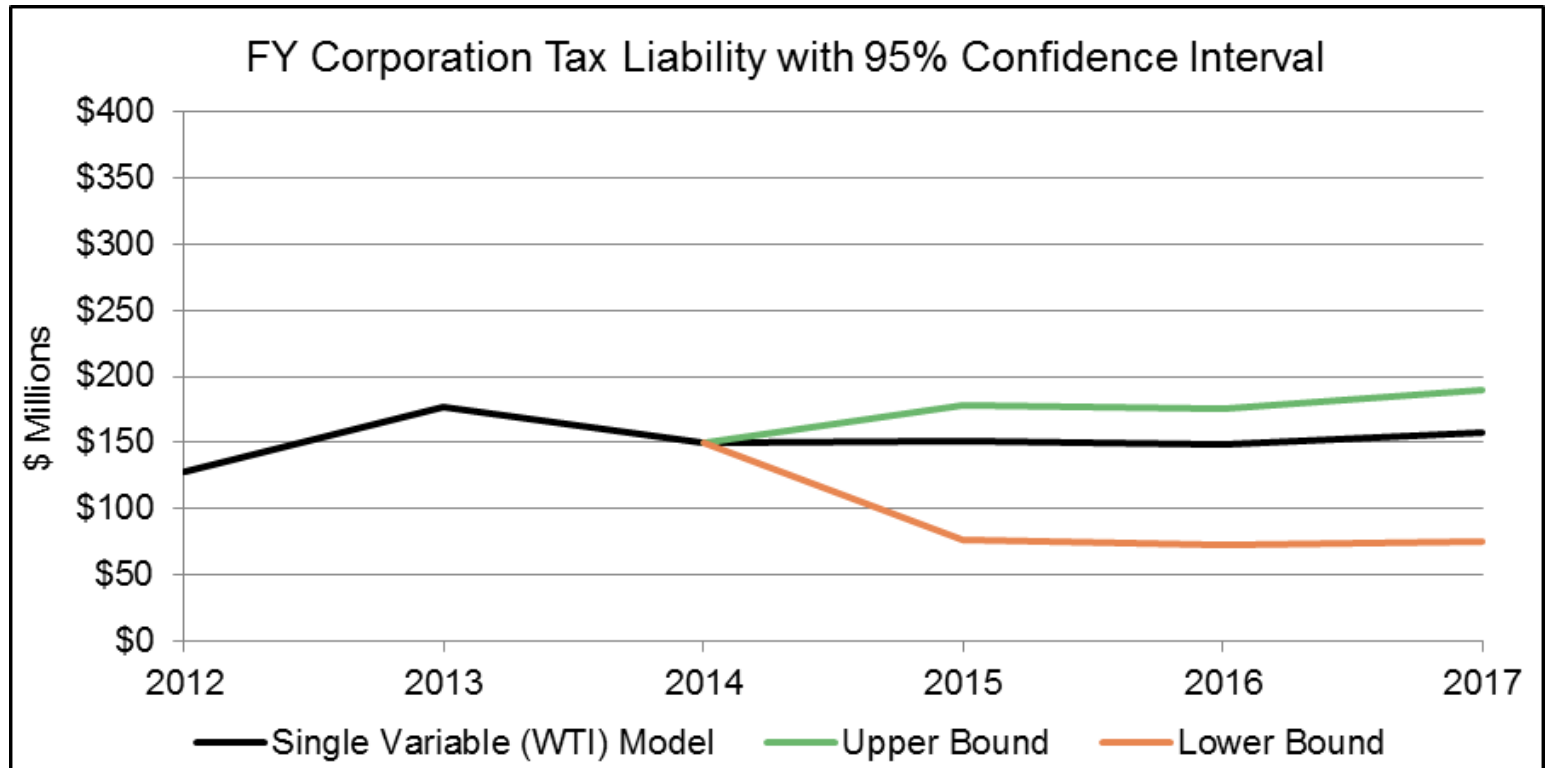
FY Corporation Tax Liability with 95% Confidence Interval
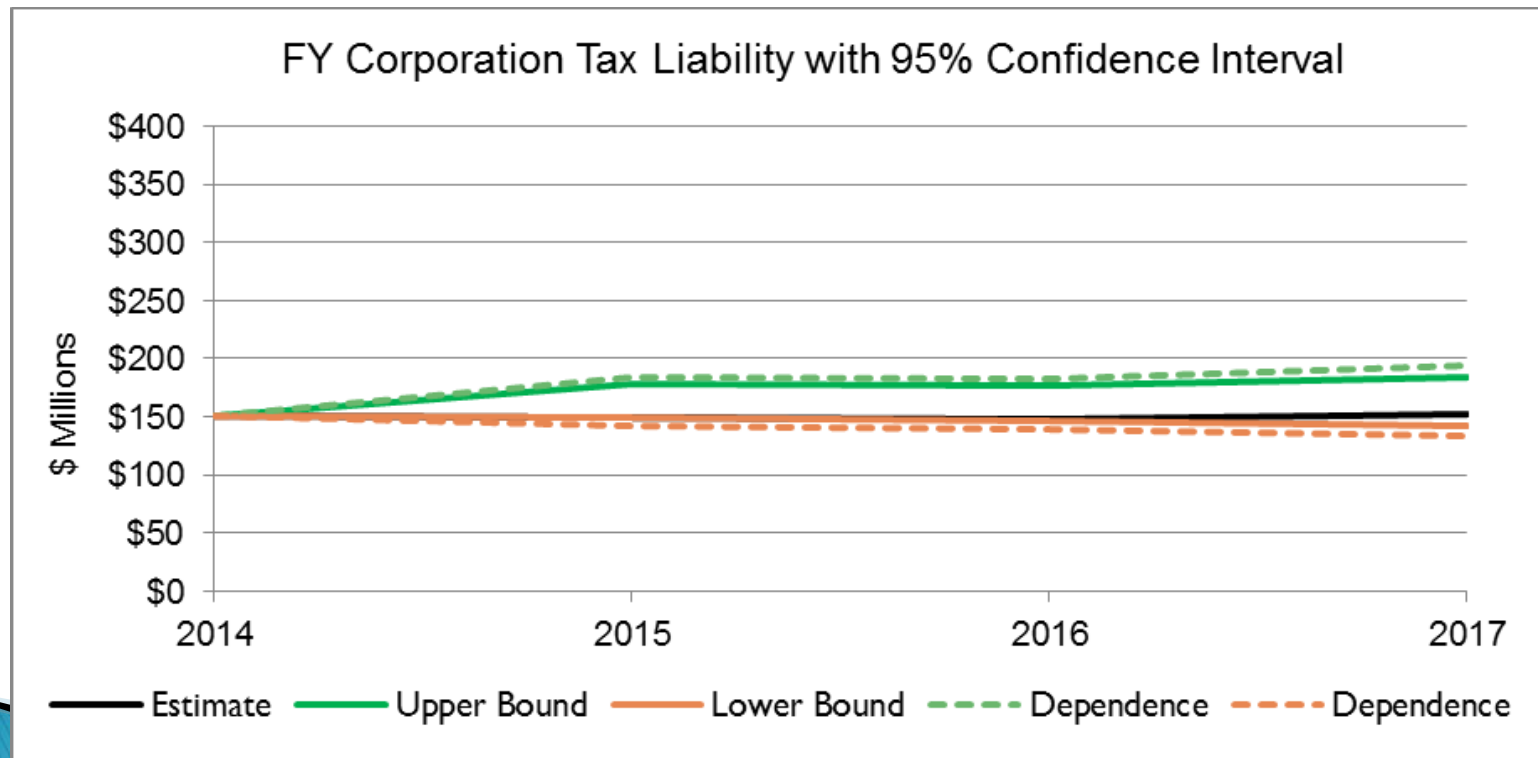
Results

- Adjusted corporation sector liability models to minimize future error bounds.
- Produced an aggregate estimate and corresponding error bounds for the sector-specific model.
- Calculated error bounds associated with alternative models.
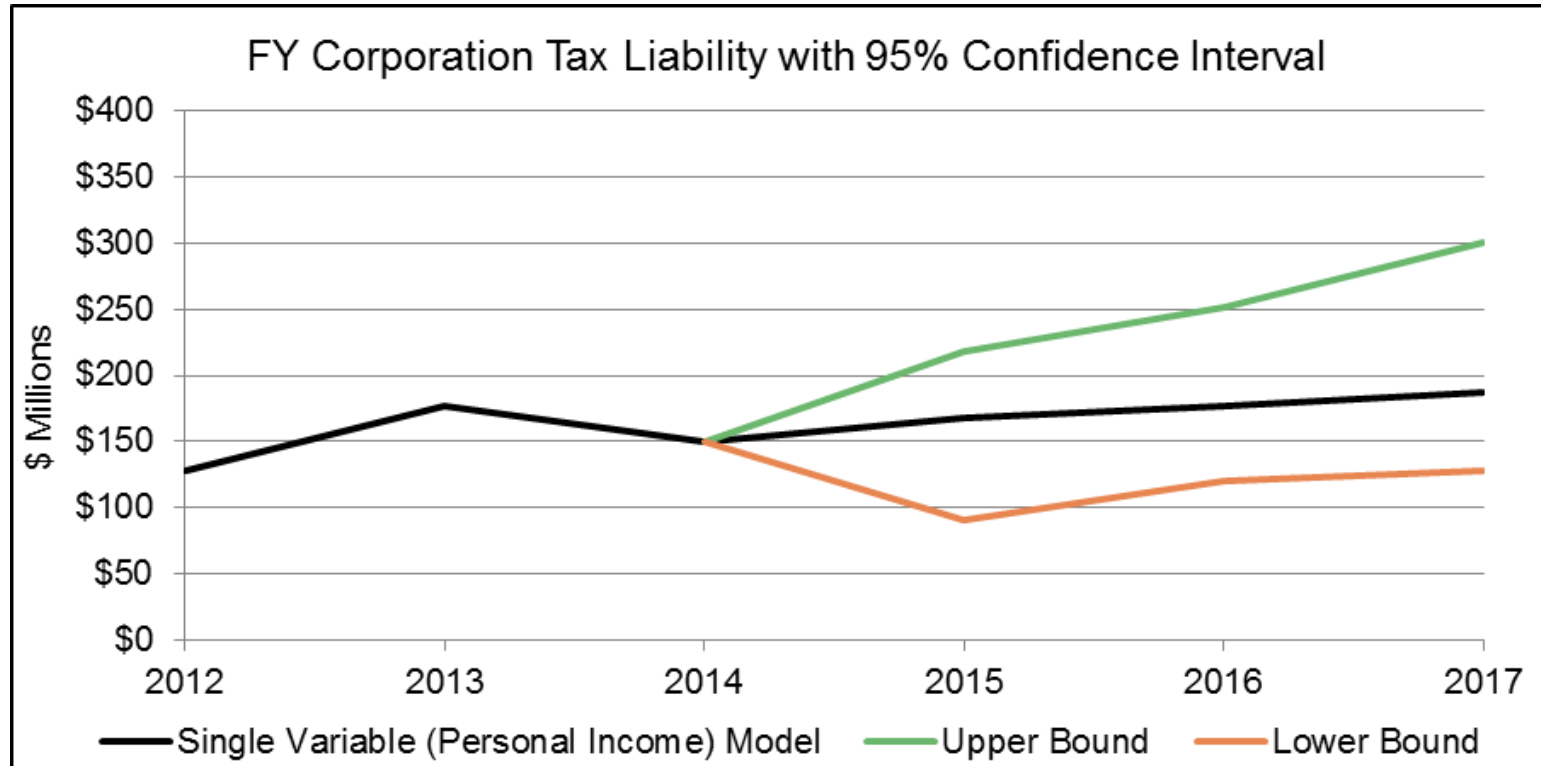- Allows for comparison of forecasts that use economic forecasts as the main predictors.
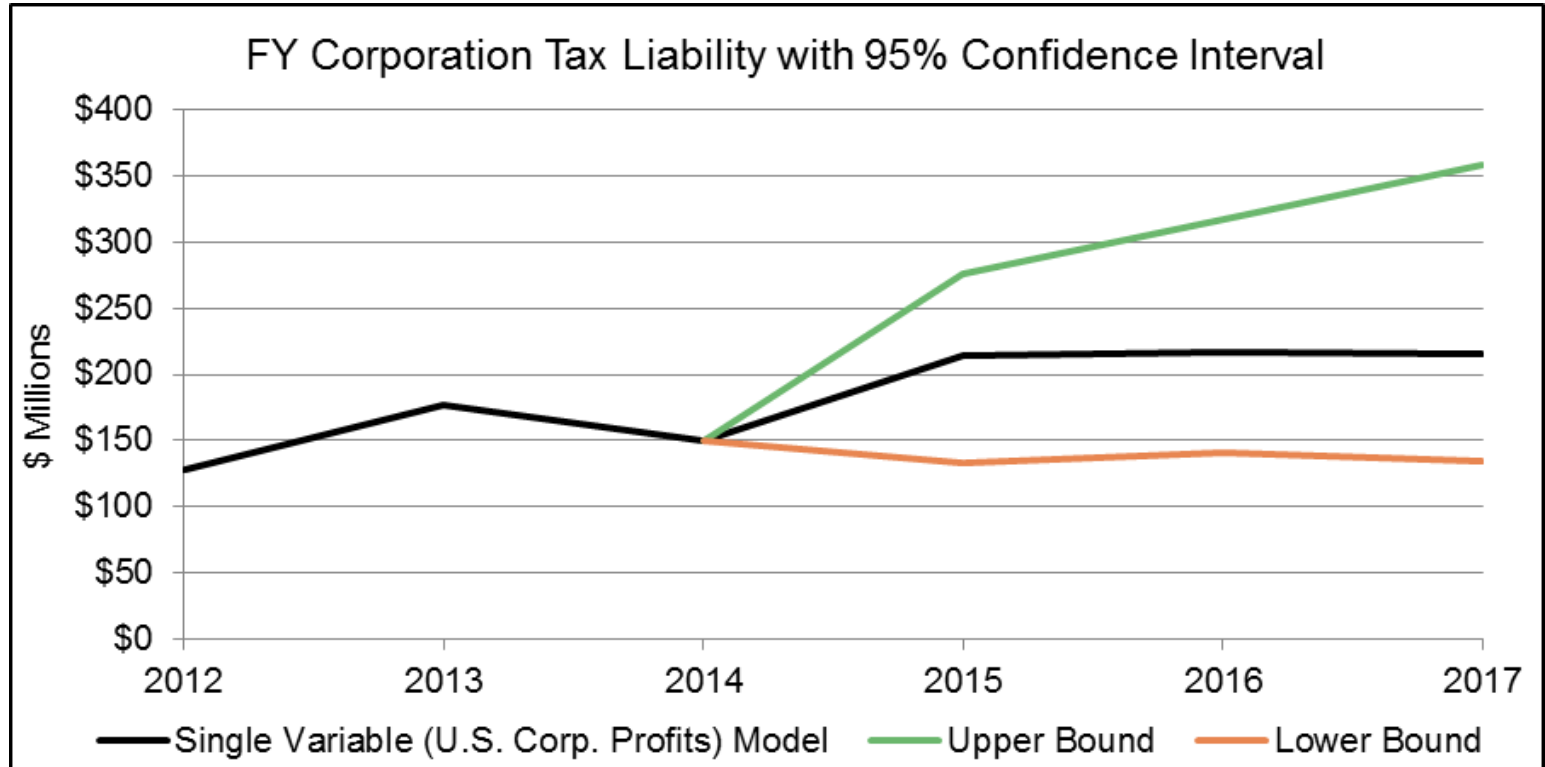
Sector–Based Model

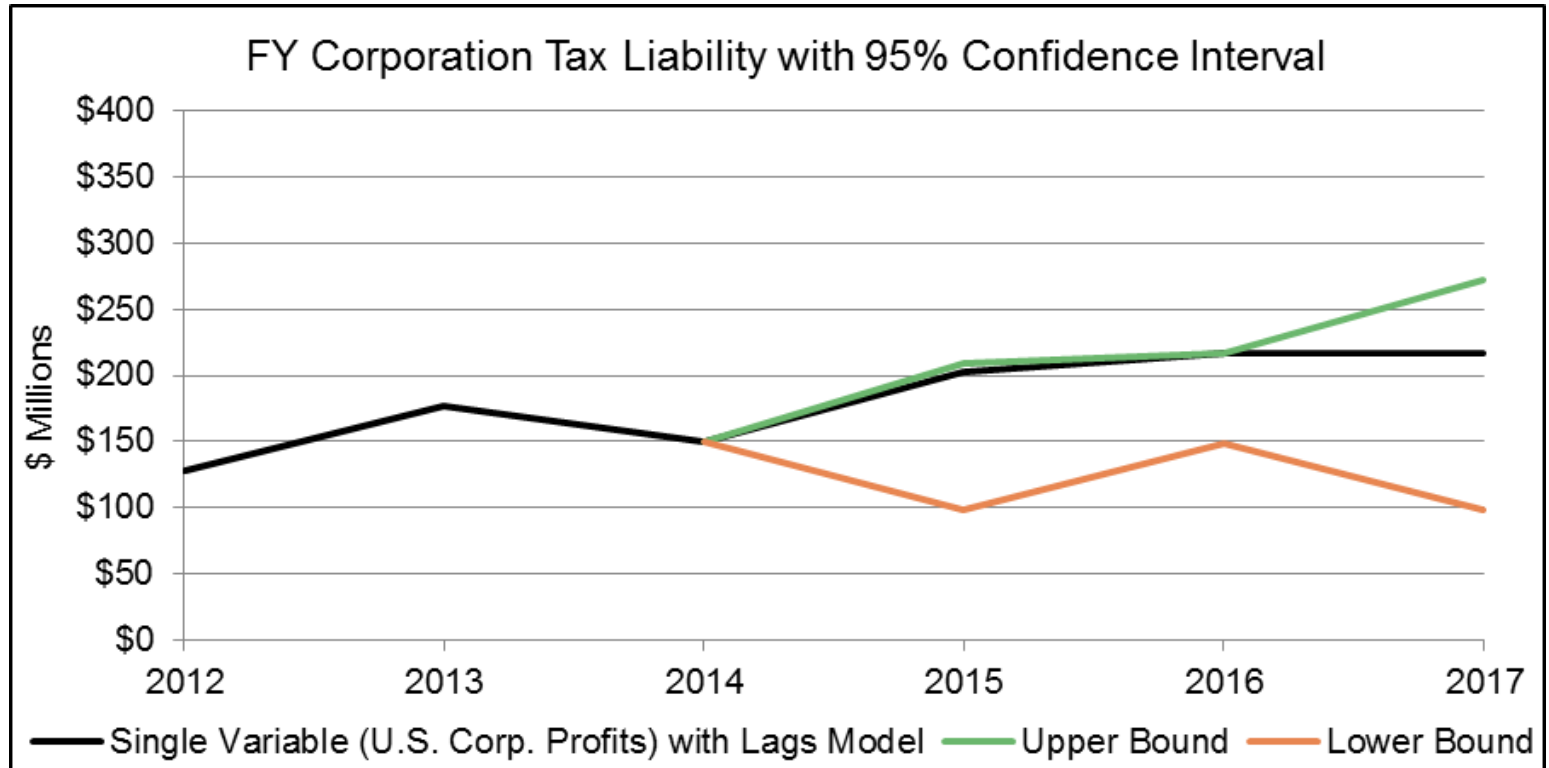FY Corporation Tax Liability Using 95% Confidence Intervals

Single Variable Model: WTI

FY Corporation Tax Liability with 95% Confidence Interval

Single Variable Model: Personal Income

FY Corporation Tax Liability with 95% Confidence Interval

Legend: Single Variable (Personal Income) Model, Upper Bound, Lower Bound

Single Variable Model: US Corporate Profits

Lagged Corporate Profits Model

FY Corporation Tax Liability with 95% Confidence Interval

Future Work

- Continue peer-review process.
  - Statewide Economists
  - Past professors
  - Past colleagues
  - PEW center for the states
- Incorporate relevant suggestions.
- Apply methodology to other large or volatile revenue sources.