



# Total Factor Productivity (TFP) Studies in the Electricity Sector: Methodologies and Best Practices

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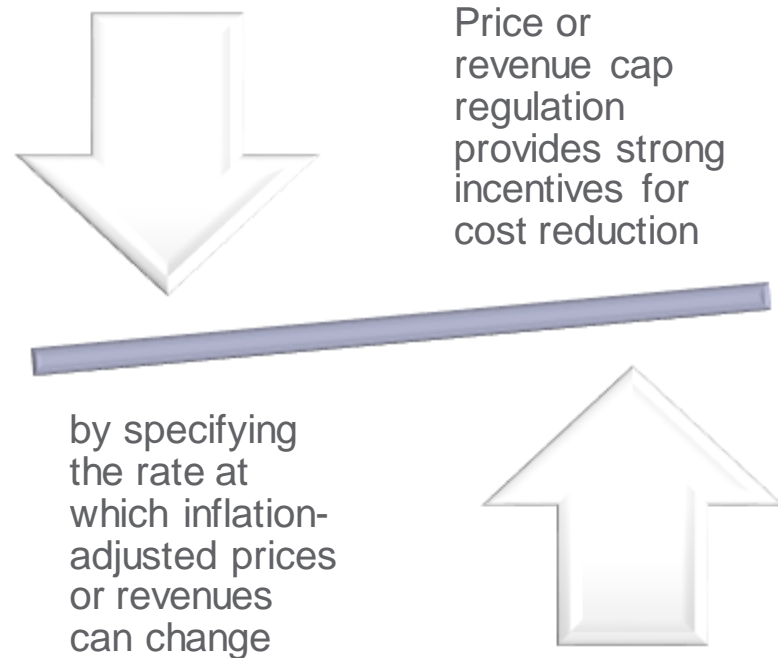
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# Presentation Overview

- Overview of the X Factor
- Common Measurement Approaches for TFP
- Key Challenges for TFP Measurement in the Electricity Sector
  - Output Measurement
  - Input Measurement
  - Data and Sample Selection
  - Weighting Methods
- Biases, Recommendations, and Key Questions
- Evaluation of Eversource and National Grid

## X Factor



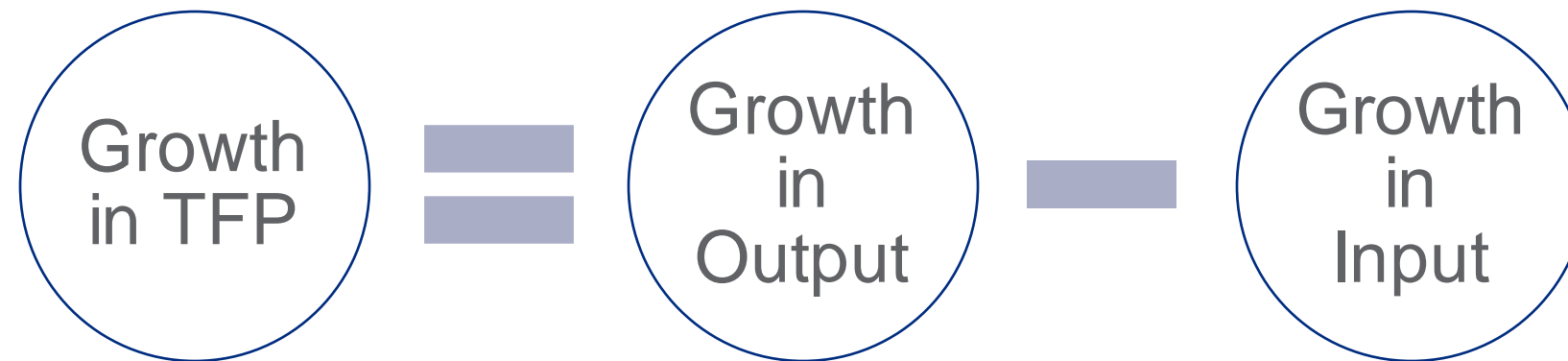
The X factor specifies the rate at which inflation-adjusted prices or revenues should change. It can be positive or negative

When benchmarked to the rest of the economy, the X factor is equal to:

$$X = [\dot{T} - \dot{T}^E] + [\dot{W}^E - \dot{W}]$$

- The X-factor sums the difference in TFP growth rates in the electric industry and the rest of the economy  $[\dot{T} - \dot{T}^E]$  (TFP differential) and the difference in input price growth rates between the rest of the economy and the electric industry  $[\dot{W}^E - \dot{W}]$  (input price differential)

# TFP: difference in growth rates between a company's physical outputs and physical inputs



## Common Measurement Approaches:

	<b>Non-Frontier</b>	<b>Frontier</b>
<b>Non-Parametric</b>	Index Number Methods	Data Envelopment Analysis
<b>Parametric</b>	Ordinary Least Squares and Other Econometric Methods	Stochastic Frontier Methods



## Index Number Methods

- Index number methods combine changes in diverse outputs and inputs into measures of change in total outputs and total inputs
- A common approach: Törnqvist index:

$$\underbrace{\ln A_{it} - \ln A_{it-1}}_{\text{Growth in TFP}} = \underbrace{\ln \frac{Q_{it}}{Q_{it-1}}}_{\text{Growth in Output}} - \underbrace{\left( \frac{s_{it}^L + s_{it-1}^L}{2} \right) \ln \frac{L_{it}}{L_{it-1}} - \left( \frac{s_{it}^K + s_{it-1}^K}{2} \right) \ln \frac{K_{it}}{K_{it-1}}}_{\text{Growth in Input}}$$

- Requires information on output, inputs (labor and capital), and their cost shares

Index number methodologies take a weighted average of the changes in outputs and inputs to calculate TFP

# Key Challenges for TFP Measurement in the Electricity Sector



# Output Measurement Methodology

Outputs can be measured from the perspective of demand or supply:

## Demand Approach:

Output is determined by the amount and value of energy (throughput) provided by distributors to their consumers

A distributor's volume of sales may represent energy throughput and total revenue represents its value

## Supply Approach:

Output is determined by the availability of infrastructure and the condition of that infrastructure

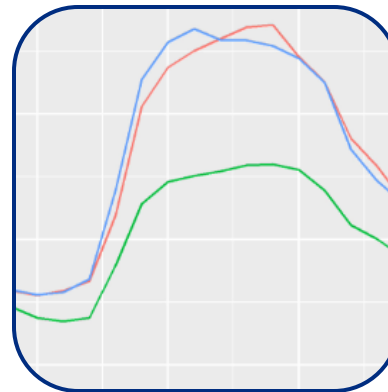
Distributors must also provide and maintain infrastructure for delivering electricity to consumers (and this is not costless)

Reliability and quality of electricity supplied as well as coverage and capacity of the system



## Output Measurement in Practice

Output is typically measured as a combination of demand- and supply-side factors, although experts vary in their choice of which measures to include.



With a price cap a company's revenues are directly affected by how much energy is sold, and a volumetric measure of output such as volume or peak demand is common



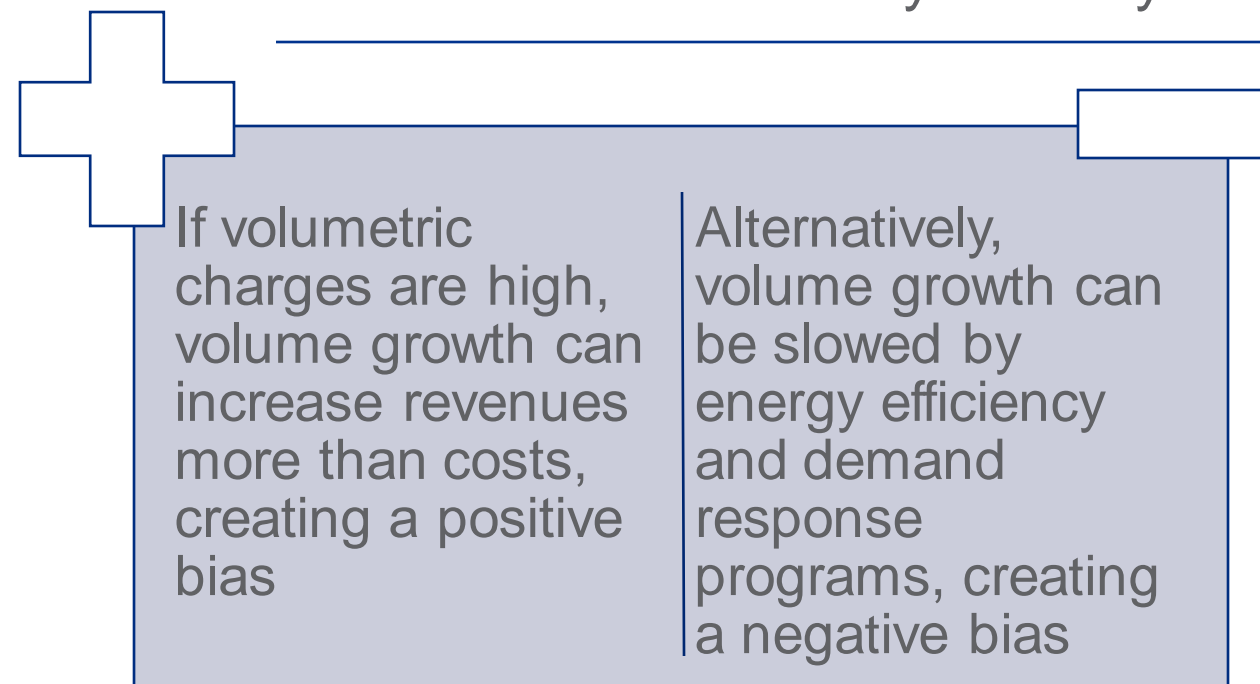
With a revenue cap or a revenue-per-customer cap, the number of customers may be more important drivers for a company's revenues

# Output Measurement Bias, Recommendations, Key Questions to Ask

Biases created by different output measures (such as sales volume or customer count) depend on the trend captured by the output measure

Recommend using a mix of output measures that reflect both customer and sales density measures (number of customers, line miles, peak usage, etc.) to address these and other changing output trends in the electricity industry

A key question regulators need to understand is the sensitivity of TFP to changes in various output measures, which can be uncovered by requesting sensitivity analyses



# Input Measurement

Input indexes are used to capture growth in input quantities and growth in input prices, as both components make up the growth in company costs

- Input indexes are typically comprised of multiple inputs, with distribution systems typically including two broad categories: operations and maintenance expenditure and capital expenditure
  - In North America, operations and maintenance is often separated into labor, materials, and services
- The weights of input indexes are determined by the relative cost share of each input to the total cost of all inputs, with capital subindexes typically being allocated the heaviest weights as distribution systems are capital intensive

# Labor, Materials and Services

Quantity can be measured directly when data permits.

For example, labor quantity can be measured with the number of full-time employees, although labor input data is increasingly difficult to obtain due to contracted labor services

Quantity can be measured indirectly by deflating the value of relevant costs.

For example, labor costs (measured by salary and wage expenses) can be deflated by relevant labor price indexes (measured by a salary and wage price index) to obtain implicit quantity measures.

# Labor, Materials and Services Bias, Recommendations, Key Questions to Ask

## Potential Biases

## Recommendations

## Key Questions

Bias concerns in labor measurement are driven by the accurate measurement of labor quantity (such as number of full-time employees, which may be difficult to ascertain with contracted labor) or selection of relevant price indexes

Recommend that methods be transparent and replicable

Regulators can ask for sensitivity analyses of TFP to various measurement or deflation methods

Bias concerns in materials and services measurement are driven by which expense categories are included, how joint expenses are allocated, and selection of relevant price indexes

Recommend that methods be transparent and replicable

Regulators can ask for sensitivity analyses of TFP to various methods or inclusion/exclusion of expense categories



# Capital Measurement Approaches

## The capital quantity index measures the flow of services from the acquired capital assets

- Capital quantity can be measured directly.
  - For example, with a measure of line length or transformer capacity.
- Capital quantity can be measured indirectly with the deflated asset value method.
  - For example, capital quantity index is constructed by deflating data on the value of assets—a utility plant value is deflated using a construction cost index

The capital price index measures the prices that would be earned in a competitive market for the rental of capital services

Capital price is often inferred as most capital is owned by the distribution company

# Key Points for Capital Measurement

## Capital Measurement

Total capital stock needs to be inferred from current and past additions

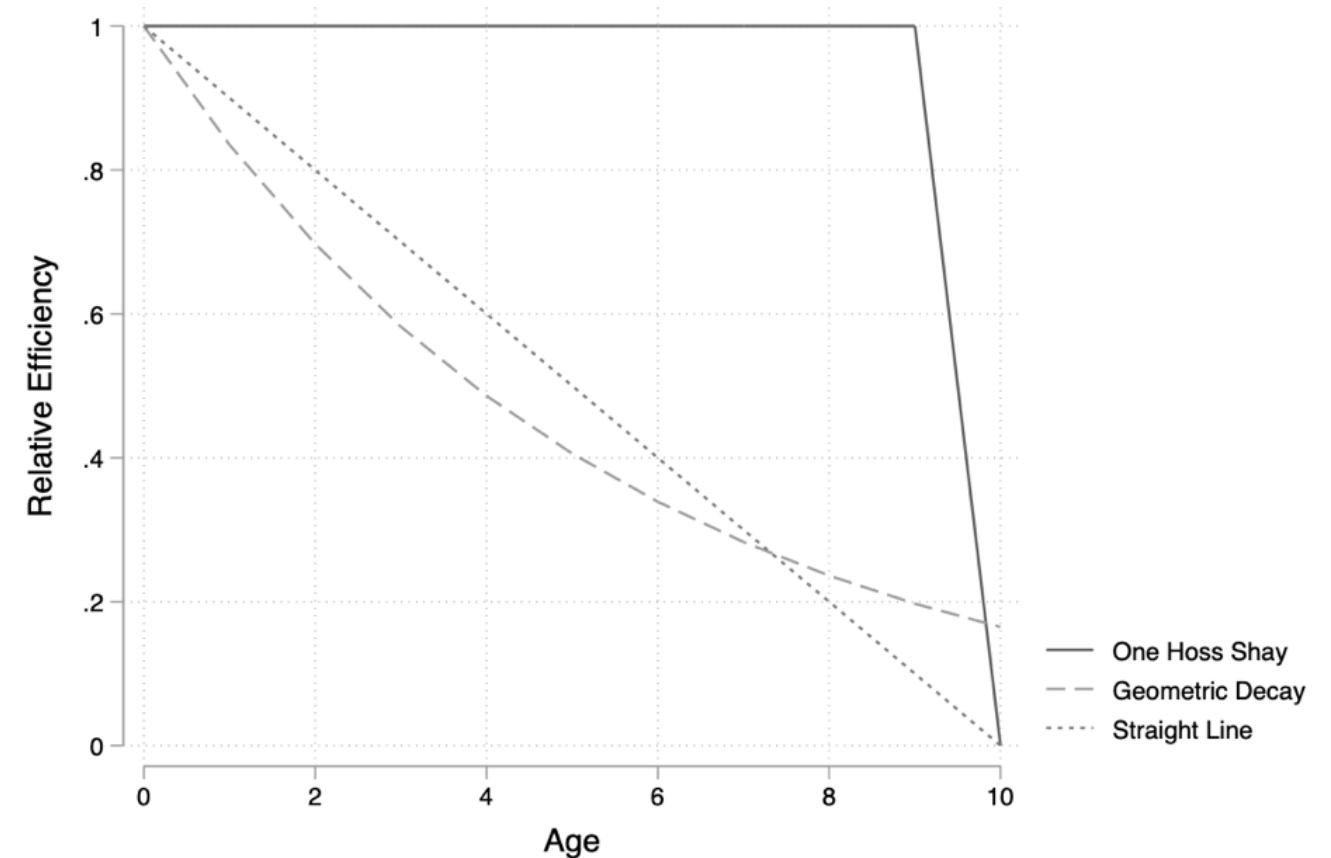
One method for adding up current and past additions is the perpetual inventory method

A specific model of depreciation is chosen to reflect that assets may lose productivity over time:

One Hoss Shay  
Geometric Decay  
Straight Line

Annual capital costs can be measured directly by applying a constant percentage reflecting depreciation, the opportunity cost of capital and the rate of capital gains to the value of assets

(Or indirectly as revenues minus operating costs)



# Capital Measurement Bias, Recommendations, Key Questions to Ask

## Potential Biases

## Recommendations

## Key Questions

The choice of benchmark year affects the starting capital cost and quantity and can create positive or negative bias in TFP estimates.

Recommend a benchmark year that allows for many years of plant additions to minimize measurement error

Does the benchmark year allow for many years of plant additions?

Sensitivity analyses to different benchmark years can be requested

Does TFP change significantly if a different benchmark year is chosen?

Using net plant value (when gross plant value is appropriate) creates downward bias in TFP if net plant value underestimates capital quantity.

In the literature, gross plant value is appropriate for one-hoss-shay, and net plant value for geometric decay, in practice either net or gross plant value are used with either depreciation assumption

Is gross plant value overstating or net plant value understating capital quantity?

Recommend requesting sensitivity analyses if it is believed the choice of gross or net plant value is overstating or understating capital quantity

Does TFP change significantly if gross plant value is used instead of net plant value, or vice versa?

Different depreciation assumptions can result in different capital quantity and price valuations

Recommend regulators determine if the depreciation assumption reflects the underlying depreciation profile of the asset

Does the depreciation assumption reflect the underlying depreciation profile of the asset?

Recommend capital price and quantity indexes have the same depreciation assumption

Do capital price and quantity indexes have the same depreciation assumption?

Sensitivity analyses can be requested to understand the impact of different depreciation assumptions

Does TFP change significantly if different depreciation assumptions are used?

# Data, Sample Selection, Length of Study Bias, Recommendations, Key Questions to Ask

## Potential Biases

## Recommendations

## Key Questions

Index methods are sensitive to measurement error in data

Recommend using publicly available, standardized datasets

Are data sources reputable and do they suffer from measurement error?

Are data sources and any procedures to change the data clearly documented?

Biases can occur if productivity trends are driven by a handful of utilities

Recommend the TFP study sample be based on all companies in the electric industry for which good data are available, or a sub-sample of comparable firms that is large enough to be reliable

Does the peer group selected facilitate a meaningful comparison to the firm in question?

How are exogenous differences between heterogeneous utilities accounted for?

Calculate TFP with different sub-sections of samples to understand their impacts.

X-factor can be calibrated to reflect long- or short-run trends

Recommend using a length of study that is long enough to smooth volatility in outputs and costs, while remaining representative of the TFP growth trend that is likely to occur during the PBR period

Is the TFP growth trend reasonable for the PBR period?

If long-term growth trends are suspected to be unstable, to request statistical tests evidencing a structural break.

# Weighting Methods Bias, Recommendations, Key Questions to Ask

## Potential Biases

## Recommendations

## Key Questions

Index weights can be chained or multilateral

Chain-weighted index weights are calculated for consecutive periods, whereas multilateral indexes are computed relative to the average firm

Is the TFP index chain weighted or multilateral? Is there a reason a particular method was chosen?

The choice of chained or multilateral index can affect TFP as both cost shares and relative growth are computed differently

With TFP growth either method is appropriate

Is the TFP metric TFP growth?

Recommend requesting sensitivity analyses to various weighting methods as necessary

Does TFP change significantly if different weighting methods are used?

TFP trends can also be averaged as a simple arithmetic average or as a weighted average, with more weight given to more similar firms

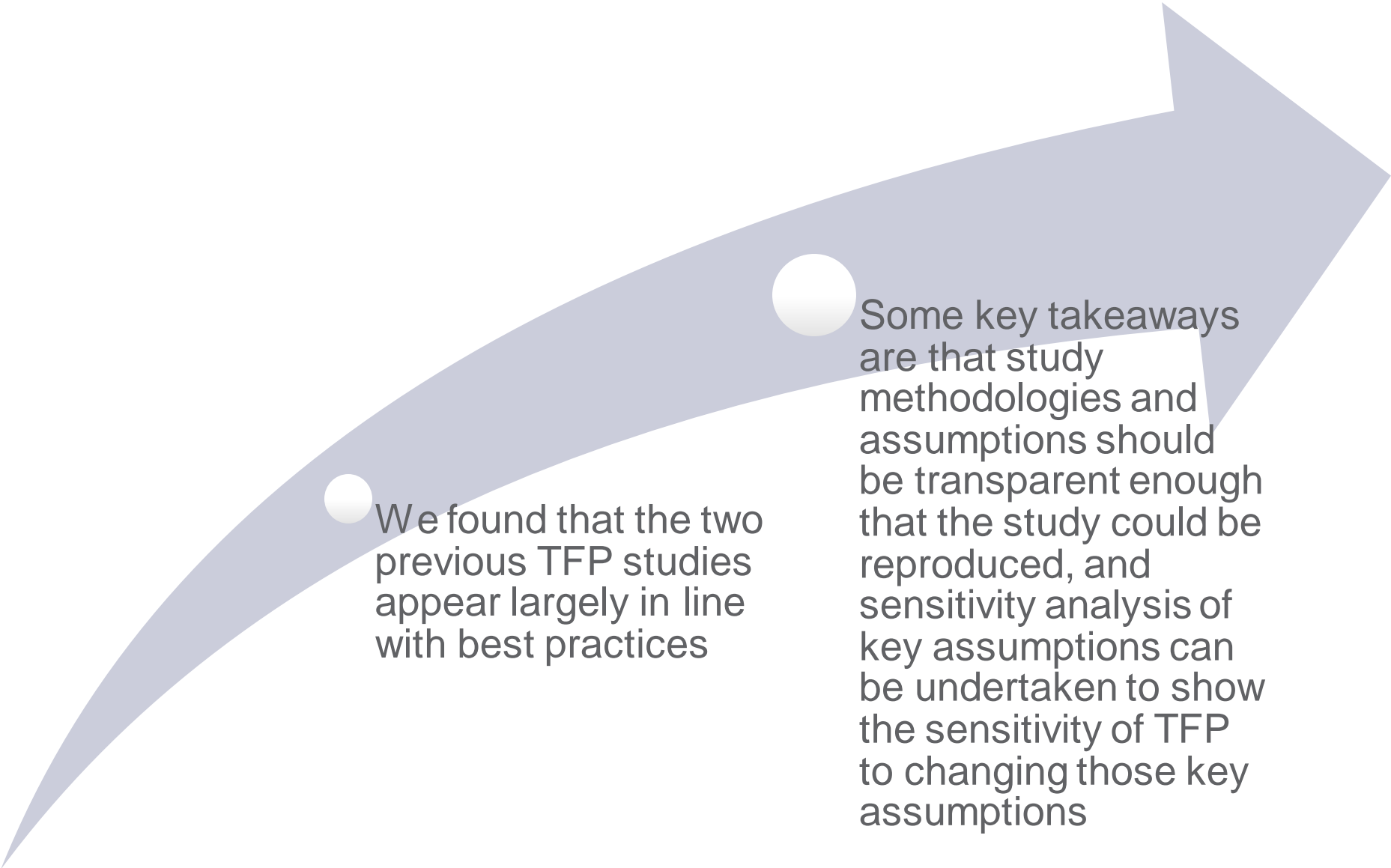
Regulators can request sensitivity analyses to understand the extent to which the averaging method for TFP trends affects the TFP measure

How are TFP trends averaged? Is there a reason why one method is chosen instead of another?

Does TFP change significantly if different averaging methods are used?



# Key Takeaways – Eversource and National Grid



We found that the two previous TFP studies appear largely in line with best practices

Some key takeaways are that study methodologies and assumptions should be transparent enough that the study could be reproduced, and sensitivity analysis of key assumptions can be undertaken to show the sensitivity of TFP to changing those key assumptions

# Summary of Recommendations – Eversource and National Grid

Method or Assumption	Recommendation	Applies to Eversource & National Grid
Sample Period	If it is believed that long-term growth trends are unstable, statistical tests can be used to determine if a structural break has occurred	✓
Selection of Peer Group	The robustness of the X-factor to sample selection parameters can be examined	✓
Output Measurement	Future TFP studies could consider different combinations of output measures which incorporate important density variables (energy density, customer density, network density, peak demand, and the customer mix) that drive distributors' costs to examine the sensitivity of TFP growth to different combinations of output measures	✓
Labor Measurement	Methodology should be clearly documented  Sensitivity analyses can be performed over the sensitivity of TFP to inclusion or exclusion of various joint or common costs for labor expenses (National Grid)	✓
Materials Measurement	Sensitivity analyses can be performed over inclusion or exclusion of various expenses related to distribution materials	✓

# Summary of Recommendations – Eversource and National Grid

Method or Assumption	Recommendation	Applies to Eversource & National Grid
Capital Measurement	<p>Sensitivity analyses can be performed to determine the impacts to TFP from using gross or net plant value.</p> <p>Sensitivity analyses can be performed to determine the impacts to TFP from smoothing the capital cost volatility.</p> <p>Sensitivity analyses can also be performed to different depreciation assumptions if the underlying depreciation profile of the asset is in question.</p>	✓
Supplemental Capital	<p>Consider the effective X-factor (<math>X' = X - K</math>), as supplemental capital can lead to overall increases in prices or revenues when these factors add on to the PBR plan. Consider also designing superior incentives for supplemental capital plans. See for example, the K-bar capital mechanism adopted in the 2018 – 2022 Performance-Based Regulation Plans for Alberta Electric and gas Distribution Utilities (Errata to Decision 20414-D01-2016).</p>	Eversource
Weighting Methods	<p>Methodologies for determining revenue or cost shares should be clearly documented and make sense based on the data used to determine the shares.</p> <p>Sensitivity analyses on the weighting method can be performed if there are concerns that the weighting method is biasing TFP growth.</p>	✓

# Special Considerations – Inflation Measurement

Indexes show how prices are changing in the United States. By looking at the price indexes more narrowly the individual components of electricity costs can be evaluated

Overall inflation in the economy is best represented by the Gross Domestic Product (GDP) implicit price deflator

A good place to find the most current value and history is at the [Federal Reserve Economic Database \(FRED\)](#)

The consumer price index also measures changes in prices monthly, but the GDP implicit price deflator is more comprehensive (even though it is only reported quarterly)

Other key indexes that support evaluation of change in input prices include energy prices, construction costs, commodity prices such as copper, and wage and price indexes

- Although several of the indexes are available at FRED, some are only available at the Bureau of Labor Statistics (BLS)

## Conclusion

- In this webinar, we provided an overview of common methods for estimating TFP, including index number methods, approaches to measuring outputs and inputs when using index number methods, as well as a review of potential biases, recommendations, and key questions that can be asked
- From our in-depth review of Eversource and National Grid TFP Studies we found that the two previous proposals appeared largely in line with best practices, but provided recommendations for consideration in future X factor studies

Some key takeaways are:

- ✓ Study methodologies and assumptions should be transparent enough that the study could be reproduced;
- ✓ Sensitivity analysis of key assumptions can be undertaken to show the sensitivity of TFP to changing those key assumptions



**Questions?**

# Contact



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Energy and Environment Directorate  
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**Thank you**

