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Total Factor Productivity Studies in the Electricity Sector: Addendum

Review and Evaluation of Methods and Assumptions for Recent TFP Studies in Massachusetts

October 2022

Brittany Tarufelli, PhD and Mark Weimar, PhD
Pacific Northwest National Laboratory

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Summary

In the report “Total Factor Productivity Studies in the Electricity Sector: An Overview of Methodologies and Best Practices” we reviewed the literature and best practices of North American performance-based regulation, provided an overview of potential biases from varied assumptions as well as recommendations to improve total factor productivity (TFP) estimation, and provided several recommendations regarding the methodologies and assumptions underlying TFP studies, including that assumptions should be transparent enough that the study could be reproduced, and sensitivity analysis of key assumptions should be undertaken.

This document is an addendum to the aforementioned report which utilizes the methodologies, assumptions, best practices, and potential biases outlined therein to perform a critical review of past TFP studies from two X-factor proposals in Massachusetts [Eversource (D.P.U. 17-05) and National Grid (D.P.U. 18-150)]. We evaluated the method and assumptions chosen, provided an objective summary of the benefits and drawbacks of that method, provided recommendations for alternative data, methods, and assumptions that would improve the accuracy or reasonableness of the analysis, and provided additional criteria to consider for evaluation of future TFP studies.

We found that the TFP studies were largely in line with best practices but made recommendations in line with our key takeaways: 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.

Acronyms and Abbreviations

AUC	Alberta Utilities Commission
BLS	U.S. Bureau of Labor Statistics
FERC	Federal Energy Regulatory Commission
GDP	Gross domestic product
GDPPI	Gross domestic product price index
O&M	Operations and maintenance
PBR	Performance-based regulation
TFP	Total factor productivity

Contents

1.0 Introduction

This document is an addendum to the “Total Factor Productivity Studies in the Electricity Sector: An Overview of Best Practices and Methodologies” report. We utilize the methodologies, assumptions, best practices, and potential biases outlined in the aforementioned report to perform a critical review of past total factor productivity (TFP) studies from two X-factor proposals in Massachusetts [Eversource (D.P.U. 17-05) and National Grid (D.P.U. 18-150)].

We perform our critical review for several key areas of each TFP study, including sample parameters, inflation measurement, output measurement, input measurement, including capital measurement, and weighting methods. In Section 2.1 we evaluate the TFP study for Eversource, and in Section 2.2 we evaluate the TFP study for National Grid. For each TFP study we evaluate the methods and assumptions of that study, provide an objective summary of the benefits and drawbacks of the selected methods, as well as provide recommendations for alternative data, methods, and assumptions to improve the accuracy or reasonableness of the analysis. We also provide additional criteria to consider for evaluation of future TFP studies in Section 2.3.

2.0 Review and Evaluation of Methods and Assumptions for Recent TFP Studies in Massachusetts

2.1 Eversource

Eversource proposed a PBR mechanism that would adjust base rates annually with a revenue cap formula. In addition, there was a $400 million incremental grid modernization-related capital investment proposed to occur over the next five years. The grid modernization base commitment was initially proposed without a separate cost recovery mechanism, instead it would represent a stretch factor of 1.08% within the PBR formula. The X-factor consisted of the differential in expected productivity growth between the electric distribution industry and the overall economy, and the differential in expected input price growth between the overall economy and the electric distribution industry:

$$X = (\%\Delta TFP_I - \%\Delta \mathrm{TFP_E}) + (\%\Delta W_E - \%\Delta W_I)$$

where $\%\Delta TFP_I$ is the percentage change in electric distribution industry total factor productivity growth. $\%\Delta \mathrm{TFP_E}$ is the percentage change in economy wide total factor productivity growth. $\%\Delta W_E$ is the percentage change in economy wide input price growth. $\%\Delta W_I$ is the percentage change in electric distribution industry input price growth. TFP is the ratio of total output to total input.

Although the resulting negative X-factor was a subject of disagreement among intervenors, recent TFP trends in electric distribution have shown lower productivity growth, driven by slower growth in output and faster growth in inputs (Meitzen et al, 2018; Makholm 2018).

Our approach to reviewing the Eversource TFP study is as follows:

- Review and evaluate the method and assumptions chosen in determining key components of the X-factor
- Provide an objective summary of benefits and drawbacks of that method
- Provide recommendations for alternative data, methods, and assumptions that would improve the accuracy or reasonableness of the analysis.

Our summary of benefits, drawbacks, and recommendations address key factors for measuring TFP and the X-factor, including sample parameters (Section 2.1.1), inflation measurement (Section 2.1.2), output measurement (Section 2.1.3), input measurement (Section 2.1.4), and weighting methods (2.1.5).

As a key takeaway, we find that the Eversource study was largely in line with best practices but provide recommendations for consideration in future X-factor studies. Our overarching recommendations are:

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

2.1.1 Evaluation and Recommendations for Sample Parameters

2.1.1.1 Sample Period

Overview of Method and Assumptions

The selected sample period for the TFP study was from years 2001 to 2015. Although Eversource acknowledged that a longer sample period is a better indicator of future expectations, because post-2007, energy efficiency and other conservation measures created a divergence between electrical use and economic growth, this sample period was selected.

Evaluation of Method and Assumptions

The length of study is likely long enough to uncover long-run productivity trends rather than the trend of an underlying business cycle.

Benefits of Method and Assumptions

The length of this study is chosen to be reflective of the TFP growth trend that is likely to occur during the PBR period.

Drawbacks of Method and Assumptions

Estimating TFP trends for shorter sample lengths can be more volatile due to input price or demand fluctuations, whereas long-run trends can smooth these effects. No statistical tests were provided to evidence that structural breaks occurred in long-run growth trends.

Recommendations

If it is believed that long-run growth trends are unstable, statistical tests (structural break tests) can be used to determine if a structural break has occurred.

2.1.1.2 Selection of Peer Group

Overview of Method and Assumptions

Two different peer groups (samples) were selected:

(1) a sample of 67 firms intended to represent the overall U.S. electric distribution industry.

(2) a sample of 17 firms intended to represent the distribution industry in the Northeast U.S.

Evaluation of Method and Assumptions

Choosing a representative sample of firms that constitutes the electric industry is a commonly used approach to determine the productivity growth for the X-factor in North America. Further, when productivity growth (rather than productivity levels) is the TFP metric, heterogeneity largely vanishes, and it is advisable to use the largest possible sample of firms.

Benefits of Method and Assumptions

The sample selected should result in a TFP trend that represents a reasonable productivity estimate for Eversource.

Drawbacks of Method and Assumptions

If there is reason to believe heterogeneity persists, a sample can be restricted to more comparable firms, so long as care is taken to account for factors that drive productivity differences across firms. However, if productivity trends are dominated by a handful of utilities, TFP may be biased. The sample should also be large enough to determine robust estimates.

Recommendations

As was done in this study, the robustness of the X-factor to sample selection parameters can be examined.

2.1.2 Inflation Measurement

Overview of Method and Assumptions

The Gross Domestic Product Price Index (GDPPI) was used to measure inflation.

Evaluation of Method and Assumptions

The GDPPI is commonly used to measure inflation in TFP studies for the electric industry. Note that the GDPPI and the Gross Domestic Product Implicit Price Deflator (GDPDEF) both measure inflation for the U.S. economy and the indexes are very similar but calculated differently. The difference in the two indexes is that with the GDP implicit price deflator the current nominal-dollar value of GDP is deflated by the chained-dollar value of GDP, that is, the GDPDEF deflates nominal by real GDP. However, the change in the GDPDEF is roughly equivalent to the change in the GDPPI.[1] See section 2.3 for further information on price indexes.

When a macroeconomic inflation index is used, an additional term (the input price differential) must also be estimated to account for the input price trend of the economy (if the input price trend of the economy rises more rapidly than that of the electric distribution industry, the X-factor will be larger). The input price differential was also included in this TFP study.

Benefits of Method and Assumptions

Benchmarking the electricity industry to the rest of the economy recreates the pressures of the competitive market.

Drawbacks of Method and Assumptions

None noted.

Recommendations

None noted.

[1] See https://www.bea.gov/resources/learning-center/what-to-know-prices-inflation and https://www.bls.gov/opub/mlr/2016/article/comparing-the-cpi-with-the-gdp-price-index-and-gdp-implicit-price-deflator.htm for further information.

2.1.3 Output Measurement

Overview of Method and Assumptions

Total number of customers was used as the sole productivity output measure. Two reasons were cited: (1) the number of customers is a primary driver of costs for electricity distribution; and (2) the revenue cap proposed by Eversource is more comparable to a revenue per customer cap than price cap. Customer counts were from FERC Form 1 (average number of customers). Because a few utilities did not report the number of unbundled customers in FERC Form 1, distribution customers from EIA 861 were added to total customers from the FERC form for those utilities.

Evaluation of Method and Assumptions

With a revenue or revenue per customer cap, the number of customers is an important driver for a company's costs (and revenues). However, practitioners also recommend multifactor output measures to reflect changes in output trends. In addition, with regard to the procedure to adjust customer counts, in the EIA Form 861, customer counts are available for residential, commercial, industrial, transportation, and total customers for utilities. Customer accounts are also available for bundled, delivery, or energy only services. Which customer categories and service categories were included in customer counts was not made clear (the authors stated distribution customers, that is not a category of services on the EIA Form 861).

Benefits of Method and Assumptions

The number of customers is an important driver for a distributor's costs (and revenues) (see Lowry and Makos, 2018).

Drawbacks of Method and Assumptions

In the literature, productivity differences among electricity distribution firms can also be driven by energy density, customer density, network density, peak demand, and the customer mix. Combining several output measures can reflect changes in output trends. Lawrence and Diewert (2004) recommend a three variable specification comprised of energy throughput, system capacity, and number of customers to incorporate important density variables that drive distributors' costs. Makholm (2018) notes that TFP studies tend to use a mix of output measures (number of customers, line miles, peak usage, kWh, etc.) to reflect changing output trends due to investment in advanced metering infrastructure or energy efficiency.

Recommendations

Although the number of customers is an important cost driver, future TFP studies could consider different combinations of output measures which incorporate important density variables that drive distributors' costs to examine the sensitivity of TFP growth to different combinations of output measures. Methodologies and assumptions should be transparent enough that the study could be reproduced.

2.1.4 Evaluation and Recommendations for Input Measurement

2.1.4.1 Labor Measurement

Overview of Method and Assumptions

Quantity of labor is the labor cost on the direct payroll distribution booked to electricity distribution operating and maintenance expenses, found in FERC Form 1, divided by the price of labor.

The price of labor is based on the BLS Employment Cost Index for utility industry wages and salaries.

Evaluation of Method and Assumptions

This method is an indirect measurement approach which deflates labor costs by a relevant labor price index, which is an accepted practice in the literature.

Benefits of Method and Assumptions

The benefit of this approach is it circumvents the need to obtain labor quantity data, which may be increasingly difficult to obtain and estimate due to increasing levels of contracted labor.

Drawbacks of Method and Assumptions

It appears this methodology (although an accepted one) deviates from that in Makholm and Ros (2010), the NERA study cited as evidence for the acceptability of this TFP study.

The Makholm and Ros (2010) uses the number of full-time employees (based on full-time equivalents and a methodology to assign employees to distribution).

Recommendations

Due to the reliance on the Makholm and Ros (2010) (NERA) study as an accepted methodology, deviations from that methodology should be clearly documented.

2.1.4.2 Materials Measurement

Overview of Method and Assumptions

Quantity of materials is the materials cost (based on operating and maintenance expense for distribution from FERC Form 1 less direct payroll distribution), divided by the price of materials.

The price of materials is based on the BLS Economic Analysis Gross Domestic Product Price Index.

Evaluation of Method and Assumptions

This method is an indirect measurement approach which deflates materials costs by a relevant materials price index. This is the methodology for materials from the NERA study approved in the AUC proceedings (Makholm and Ros, 2010) and is widely used in the literature.

Benefits of Method and Assumptions

The indirect measurement approach circumvents the need to estimate materials quantity directly, as this data may be difficult to obtain from available data.

Drawbacks of Method and Assumptions

Additional materials and services expenses, such as a sensible share of administrative and general expenses (exclusive of those for pension and benefits) are also included in other studies.

Recommendations

Sensitivity analyses can be performed over inclusion or exclusion of various expenses related to distribution materials.

2.1.4.3 Capital Measurement

Overview of Method and Assumptions

Quantity of capital is derived from a perpetual inventory equation:

$$K_t = K_{t-1} + I_t - R_t.$$

Where K_t is the end-of-year capital stock, K_{t-1} is the end of year capital stock from the previous year, I_t are the quantity of capital additions during the year, and R_t the quantity of retirements during the year.

To estimate the quantity of capital additions, distribution additions to plant in service from FERC Form 1 are divided by the Handy-Whitman index for distribution plant. The quantity of Retirements is estimated from dividing distribution retirements from plant in service from FERC Form 1, divided by a lagged value of the Handy-Whitman index (using a lag of 33 years, to represent the average depreciable service life of the distribution plant).

Because the net book value of the plant is not reported in FERC Form 1, the benchmark value of the plant is estimated by taking the ratio of distribution plant in service to total electric plant in service and applying that value to net electric plant in service.

$$K_{1964} = \frac{NetElectricPlantInServ * \left(\frac{DistributionPlantinService}{TotalPlantIn\ Service}\right)}{\sum_{i=1}^{20} \frac{i * HW_{1944}}{\sum_{i=1}^{20} i}}$$

Last, once the end-of-year capital stock is computed, the flow of capital services during a year is based on the quantity of capital stock from the previous year.

$$KS_t = K_{t-1}.$$

The price of capital is derived from an implicit rental price equation that corresponds to the perpetual inventory equation described above:

$$PK_t = \frac{1-uz}{1-u}(r-i)\left[1-\left(\frac{1+i}{1+r}\right)^{33}\right]^{-1} HW_{t-1}.$$

Where u is corporate profits tax rate, z the present value of tax depreciation on one dollar of investment in distribution plant and equipment, r is the forward-looking cost of capital, and i the forward-looking inflation rate.[1] The number 33 represents the asset life used in the perpetual inventory equation.

[1] Note that to smooth the input price series, the average cost of capital rate and the average inflation rate over the 2001 – 2015 period was used. The average cost of capital is based on Moody's seasoned AAA bond yield and the average inflation rate is based on the Consumer Price Index for All Urban Consumers.

Evaluation of Method and Assumptions

The depreciation assumption should best reflect the underlying depreciation profile of the asset. In this case, both the Department and Eversource agreed that these capital assets' contribution to Eversource's productivity remain relatively constant until they are retired, which is in line with the underlying depreciation profile of one-hoss-shay.

The capital quantity and price indexes reflect the same depreciation assumption, which is also in line with best practices.

The capital cost index was smoothed to reduce capital cost volatility. The underlying assumption is that the investor's forward looking real rate of return (cost of capital less the inflation rate) is constant through time (based on Diewert, 2005, p.491). This assumption is applied by computing the average cost of capital rate and the average inflation rate over the 2001 – 2015 period. This assumption is based on a recommended methodology in the literature.

The choice of benchmark year (1964) allows for many years of plant additions to minimize measurement error

Benefits of Method and Assumptions

The methods and assumptions chosen are largely in line with the literature, with the exception of the choice to use the net plant value rather than the gross plant value, however TFP studies do not always align with the literature in their choice of gross or net plant value for the benchmark value.

Drawbacks of Method and Assumptions

The one-hoss-shay method is more sensitive to the useful life of the asset than the geometric decay assumption because the value of the capital stock is entirely determined by the useful life.

With this TFP study, the benchmark value of the plant was constructed from estimating the net book value of the plant rather than the gross plant value, which can create a downward bias in the TFP trend if net plant value underestimates capital quantity. In the literature, the gross plant value is appropriate for the one-hoss-shay depreciation assumption and net plant value for the geometric decay depreciation assumption (see Diewert and Lawrence, 2000; Lowry and Makos 2018).

Recommendations

Sensitivity analyses can be performed to determine the impacts to TFP from using gross or net plant value.

Sensitivity analyses can be performed to determine the impacts to TFP from smoothing the capital cost volatility.

Sensitivity analyses can also be performed to different depreciation assumptions if the underlying depreciation profile of the asset is in question.

2.1.4.4 Supplemental Capital

Overview of Method and Assumptions

The $400 million grid modernization base commitment investment (representing an implicit stretch factor of 1.08%) was removed from the X-factor and a capital cost tracker was used instead.

Evaluation of Method and Assumptions

Capital trackers are increasingly common as it is challenging to recover capital expenditures, however, capital trackers can distort incentives for cost containment.

Benefits of Method and Assumptions

Capital trackers are administered in a manner similar to cost-of-service regulation.

Drawbacks of Method and Assumptions

Capital trackers can weaken incentives for capex cost containment. Further capital trackers can discourage a utility from optimizing its resources across all inputs (for example, avoiding inefficient substitution between labor and capital).

Recommendations

Consider the effective X-factor ($X' = X - K$), 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 (Meitzen et al., 2017). 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).[1]

[1] Available at: https://www2.auc.ab.ca/h007/Proceeding20414/ProceedingDocuments/20414-D01-2016Errata2018-2022PBRPlansfor_0712.pdf (accessed 8/26/2022). See also https://www.regulatorylawchambers.ca/blog/2018/12/9/rebasing-for-the-2018-2022-pbr-plans-for-alberta-electric-and-gas-distribution-utilities-first-compliance-proceeding-decision-22394-d01-2018 for a summary of suggested refinements.

2.1.5 Weighting Methods

2.1.5.1 Quantity Index of Total Input

Overview of Method and Assumptions

The quantity index of total input is constructed for each firm using the multilateral Törnqvist indexing procedure with the form:

$$\ln\left(X_{i,t}\right) = \frac{sk_{it} + \overline{sk}}{2}\left(lnKS_{it} - \overline{lnKS}\right) + \frac{sl_{it} + \overline{sl}}{2}\left(lnL_{it} - \overline{lnL}\right) + \frac{sm_{it} + \overline{sm}}{2}\left(lnM_{it} - \overline{lnM}\right).$$

Where the variable X represents the quantity of total input, KS the quantity of capital input, denotes, L the quantity of labor, and M the quantity of materials input, sk is the cost share of capital, sl the cost share of labor, and sm the cost share of materials, and a bar above the variable represents the average value over all firms and all years.

The price index of total input is computed similarly for the price of capital, materials, and labor:

$$\ln\left(P_{i,t}\right) = \frac{sk_{it} + \overline{sk}}{2}\left(lnPK_{it} - \overline{lnPK}\right) + \frac{sl_{it} + \overline{sl}}{2}\left(lnPL_{it} - \overline{lnPL}\right) + \frac{sm_{it} + \overline{sm}}{2}\left(lnPM_{it} - \overline{lnPM}\right).$$

Where P is the price of total input, PK the price of capital input, PL the price of labor input, and PM the price of materials input.

Evaluation of Method and Assumptions

The multilateral Törnqvist index is a common methodology where weights are computed relative to the average firm.

Benefits of Method and Assumptions

The multilateral Törnqvist index allows for comparisons that are bilateral and transitive, and it is widely used in the literature.

Drawbacks of Method and Assumptions

The derivation of the cost share of capital, labor, and materials was not explicitly discussed.

Recommendations

Methodologies for determining revenue or cost shares should be clearly documented and make sense based on the data used to determine the shares.

2.1.5.2 Overall TFP Index Weighting Method

Overview of Method and Assumptions

To determine industry rates of growth, each firm was weighted by its relative number of customers:

$$s_i = \frac{CUST_{it}}{\sum_i CUST_{it}}.$$

Where s_i is the weighting factor for each firm.

The industry rate of total output growth is then:

$$\ln {}^{Y_t}/_{Y_{t-1}} = \sum_i s_i \left({}^{CUST_{it}}/_{CUST_{i,t-1}} \right).$$

The industry rate of total input growth is:

$$\ln {}^{X_t}/_{X_{t-1}} = \sum_i s_i \left({}^{X_{it}}/_{X_{i,t-1}} \right).$$

The industry rate of total input price growth is:

$$\ln {}^{P_t}/_{P_{t-1}} = \sum_i s_i \left({}^{P_{it}}/_{P_{i,t-1}} \right).$$

The industry rate of TFP growth is:

$$\ln {}^{TFP_t}/_{TFP_{t-1}} = \ln {}^{Y_t}/_{Y_{t-1}} - \ln {}^{X_t}/_{X_{t-1}}.$$

Evaluation of Method and Assumptions

Indexes were weighted by the relative number of customers to provide more weight to more similar (larger) firms, which is an accepted practice in the literature.

Benefits of Method and Assumptions

TFP trends are more representative of those for larger firms.

Drawbacks of Method and Assumptions

Different weighting methods can result in different measures of TFP growth.

Recommendations

Sensitivity analyses on the weighting method can be performed if there are concerns that the weighting method is biasing TFP growth.

2.2 National Grid

National Grid proposed a PBR mechanism that would adjust base distribution rates annually through an adjustment to its revenue decoupling mechanism with a revenue cap formula. The X-factor consisted of the differential in expected productivity growth between the electric distribution industry and the overall economy, and the differential in expected input price growth between the overall economy and the electric distribution industry:

$$X = (\%\Delta TFP_I^R - \%\Delta \mathrm{TFP_E}) + (\%\Delta W_E - \%\Delta W_I)$$

where $\%\Delta TFP_I^R$ is the percentage change in electric distribution industry total factor productivity growth. $\%\Delta \mathrm{TFP_E}$ is the percentage change in economy wide total factor productivity growth. $\%\Delta W_E$ is the percentage change in economy wide input price growth. $\%\Delta W_I$ is the percentage change in electric distribution industry input price growth. TFP is the ratio of total output to total input.

Our approach to reviewing the National Grid TFP study is as follows:

- Review and evaluate the method and assumptions chosen in determining key components of the X-factor.
- Provide an objective summary of benefits and drawbacks of that method.
- Provide recommendations for alternative data, methods, and assumptions that would improve the accuracy or reasonableness of the analysis.

Our summary of benefits, drawbacks, and recommendations address key factors for measuring TFP and the X-factor, including sample parameters (Section 2.2.1), inflation measurement (Section 2.2.2), output measurement (Section 2.2.3), input measurement (Section 2.2.4), and weighting methods (Section 2.2.5).

As a key takeaway, we find that the National Grid TFP study was largely in line with best practices but provide recommendations for consideration in future X-factor studies. Our overarching recommendations are:

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

2.2.1 Evaluation and Recommendations for Sample Parameters

2.2.1.1 Sample Period

Overview of Method and Assumptions

The selected sample period for the TFP study was from years 2002 to 2016. This time period was chosen to balance the most recent, relevant information within a long enough period to overcome transient, short-term occurrences that could inappropriately skew the results of the TFP study.

Evaluation of Method and Assumptions

The length of study is likely long enough to uncover long-run productivity trends rather than the trend of an underlying business cycle.

Benefits of Method and Assumptions

The length of this study is chosen to be reflective of the growth trend that is likely to occur during the PBR period. Further, years prior to 2002 were excluded to avoid the sample including the effects of technological advancements (computerization and automation) that are now fully incorporated into National Grid's operations.

Drawbacks of Method and Assumptions

Estimating TFP trends for shorter sample lengths can be more volatile due to input price or demand fluctuations, whereas long-run trends can smooth these effects. No statistical tests were provided to evidence structural breaks occurred in long-run growth trends.

Recommendations

If it is believed that long-run growth trends are unstable, statistical tests (structural break tests) can be used to determine if a structural break has occurred.

2.2.1.2 Selection of Peer Group

Overview of Method and Assumptions

Two different peer groups (samples) were selected:

(1) a sample of 66 firms intended to represent the overall U.S. electric distribution industry

(2) a sample of 18 firms intended to represent the distribution industry in the Northeast U.S.

Evaluation of Method and Assumptions

Choosing a representative sample of firms that constitutes the electric industry is a commonly used approach to determine the productivity growth for the X-factor in North America. Further, when productivity growth (rather than productivity levels) is the TFP metric, heterogeneity largely vanishes, and it is advisable to use the largest possible sample of firms. It was noted that although the largest sample of firms was not used, the sample was of sufficient size to be representative of the industry.

Benefits of Method and Assumptions

The sample selected should result in a TFP trend that represents a reasonable productivity estimate for National Grid.

Drawbacks of Method and Assumptions

If there is reason to believe heterogeneity persists, a sample can be restricted to more comparable firms, so long as care is taken to account for factors that drive productivity differences across firms. However, if productivity trends are dominated by a handful of utilities, TFP may be biased. Sample should also be large enough to determine robust estimates.

Recommendations

As was done in this study, the robustness of the X-factor to sample selection parameters can be examined.

2.2.2 Inflation Measurement

Overview of Method and Assumptions

The Gross Domestic Product Price Index (GDPPI) was used to measure inflation.

Evaluation of Method and Assumptions

The GDPPI is commonly used to measure inflation in TFP studies for the electric industry. Note that the GDPPI and the Gross Domestic Product Implicit Price Deflator (GDPDEF) both measure inflation for the U.S. economy and the indexes are very similar but calculated differently. The difference in the two indexes is that with the GDP implicit price deflator the current nominal-dollar value of GDP is deflated by the chained-dollar value of GDP, that is, the GDPDEF deflates nominal by real GDP. However, the change in the GDPDEF is roughly equivalent to the change in the GDPPI. See section 2.3 for further information on price indexes.

When a macroeconomic inflation index is used, an additional term (the input price differential) must also be estimated because if the input price trend of the economy rises more rapidly than that of the electric distribution industry, the X-factor will be larger, and this input price differential was included in this TFP study.

Benefits of Method and Assumptions

Benchmarking the electricity industry to the rest of the economy recreates the pressures of the competitive market.

Drawbacks of Method and Assumptions

None noted.

Recommendations

None noted.

2.2.3 Output Measurement

Overview of Method and Assumptions

Total number of customers was the sole productivity output measure. Two reasons were cited: (1) the number of customers is a primary driver of costs for electricity distribution; and (2) the revenue cap proposed by Eversource is more comparable to a revenue per customer cap than a price cap.

Customer counts were from EIA 861 "Sales to Ultimate Customers" bundled and delivery customers were included. Note that in the EIA 861 data, "bundled" customer counts include full-service energy and delivery data, energy-only service customer counts include customers for which a utility provides only the energy consumed, not delivery service, and delivery-only service includes customers for which a utility provides only billing and related energy delivery services.

Evaluation of Method and Assumptions

With a revenue or revenue per customer cap, the number of customers is an important driver for a company's costs (and revenues). However, practitioners also recommend multifactor output measures to reflect changes in output trends.

Including both bundled and delivery customers appears reasonable based on the EIA 861 data.

Benefits of Method and Assumptions

The number of customers is an important driver for a distributor's costs (and revenues) (see Lowry and Makos, 2018).

Drawbacks of Method and Assumptions

In the literature, productivity differences among electricity distribution firms can also be driven by energy density, customer density, network density, peak demand, and the customer mix. Combining several output measures can reflect changes in output trends. Lawrence and Diewert (2004) recommend a three variable specification comprised of energy throughput, system capacity, and number of customers to incorporate important density variables that drive distributors' costs. Makholm (2018) notes that TFP studies tend to use a mix of output measures (number of customers, line miles, peak usage, kWh, etc.) to reflect changing output trends due to investment in advanced metering infrastructure or energy efficiency.

Recommendations

Although the number of customers is an important cost driver, future TFP studies could consider different combinations of output measures which incorporate important density variables that drive distributors' costs to examine the sensitivity of TFP growth to different combinations of output measures.

2.2.4 Evaluation and Recommendations for Input Measurement

2.2.4.1 Labor Measurement

Overview of Method and Assumptions

Quantity of labor is the labor cost on the direct payroll distribution booked to electricity distribution operating and maintenance expenses, found in FERC Form 1, divided by the price of labor.

The price of labor is based on the BLS Employment Cost Index for utility industry wages and salaries.

Evaluation of Method and Assumptions

This is an indirect measurement approach which deflates labor costs by a relevant labor price index, which is an accepted practice in the literature.

Benefits of Method and Assumptions

The benefit of this approach is it circumvents the need to obtain labor quantity data, which may be increasingly difficult to obtain and estimate due to increasing levels of contracted labor.

Drawbacks of Method and Assumptions

None noted.

Recommendations

None noted.

2.2.4.2 Materials Measurement

Overview of Method and Assumptions

Quantity of materials is the materials cost (based on operating and maintenance expense for distribution from FERC Form 1 less direct payroll distribution), divided by the price of materials

The price of materials is based on the BLS Economic Analysis Gross Domestic Product Price Index.

National Grid also produced X-factors which omitted any plant-apportioned administrative and general expenses.

Evaluation of Method and Assumptions

This is an indirect measurement approach which deflates materials costs by a relevant materials price index. This is the methodology for materials from the AUC proceedings and is widely used in the literature.

Benefits of Method and Assumptions

The indirect measurement approach circumvents the need to estimate materials quantity directly, as this data may be difficult to obtain from available data.

Drawbacks of Method and Assumptions

None noted.

Recommendations

Sensitivity analyses can be performed over inclusion or exclusion of various expenses related to distribution materials.

2.2.4.3 Customer Accounts and Sales Labor Index

Overview of Method and Assumptions

Customer accounts and sales expenses were included in O&M expenses. The labor expense portions are line items in FERC Form 1, the price of labor is based on the BLS Employment Cost Index for utility industry wages and salaries, with the quantity of labor derived by dividing the cost of labor by its price.

Evaluation of Method and Assumptions

A portion of customer accounts and sales expenses were included in total input to capture additional costs typically considered in ratemaking contexts. Labor expense portions of customer accounts and sales were determined were based on the labor expense line items for those categories in FERC Form 1 (distribution of wages and salaries are separate line items from O&M expenses).

Practitioners can vary in their choice of whether or not it is appropriate to include shared costs that are not explicitly labeled as distribution costs in FERC Form 1,[1] and it is important that the method to allocate the joint or common costs be transparent and replicable, and attribute relevant costs to labor, as was done in this case.

Benefits of Method and Assumptions

Relevant labor expenses may be included in developing labor quantity indexes.

Drawbacks of Method and Assumptions

There is no universally accepted method for allocating shared costs (see paragraph 122, AUC, 2017).

Recommendations

Sensitivity analyses can be performed over the sensitivity of TFP to inclusion or exclusion of various joint or common costs for labor expenses.

[1] See for example Paragraph 122 of the AUC proceeding for 2018 – 2022 PBR plans where a similar allocation issue is discussed (AUC, 2017).

2.2.4.4 Customer Accounts and Sales Materials Index

Overview of Method and Assumptions

Customer accounts and sales expenses were included in O&M expenses. The materials expenses for customer accounts and sales expenses are total O&M expenses for these accounts less the direct payroll distribution for these accounts. The price of materials is based on the BLS Gross Domestic Product Price Index, with the quantity of materials derived by dividing the cost of materials by its price.

Evaluation of Method and Assumptions

A portion of customer accounts and sales expenses were included in total input to capture additional costs typically considered in ratemaking contexts. The materials expenses are net of any labor expenses (payroll distribution).

Practitioners can vary in their choice of whether or not it is appropriate to include shared costs that are not explicitly labeled as distribution costs in FERC Form 1,[1] and it is important that the method to allocate the joint or common costs be transparent and replicable, and attribute relevant costs to materials, as was done in this case.

Benefits of Method and Assumptions

Relevant materials expenses may be included in developing materials quantity indexes.

Drawbacks of Method and Assumptions

There is no universally accepted method for allocating shared costs (see paragraph 122, AUC, 2017).

Recommendations

Sensitivity analyses can be performed over the sensitivity of TFP to inclusion or exclusion of various joint or common costs for materials expenses.

[1] See for example Paragraph 122 of the AUC proceeding for 2018 – 2022 PBR plans where a similar allocation issue is discussed (AUC, 2017).

2.2.4.5 Administrative and General (A&G) Labor Index

Overview of Method and Assumptions

Because A&G expenses are comprised of joint and common costs that pertain to activities that span distribution, transmission, and production (rather than just distribution) functions. To assign these costs to the distribution function, the portion of joint and common A&G expenses allocated to the distribution function was determined by multiplying a firm's total A&G expenses for each year in the sample by the annual average across all firms in the sample of the percent of distribution plant relative to total plant.

The labor expense portions are line items in FERC Form 1. The price of labor is based on the BLS Employment Cost Index for utility industry wages and salaries, with the quantity of labor derived by dividing the cost of labor by its price.

Evaluation of Method and Assumptions

Practitioners can vary in their choice of whether or not it is appropriate to include shared costs that are not explicitly labeled as distribution costs in FERC Form 1,[1] and it is important that the method to allocate the joint or common costs be transparent and replicable, and attribute relevant costs to labor, as was done in this case.

Benefits of Method and Assumptions

Relevant labor expenses may be included in developing labor quantity indexes.

Drawbacks of Method and Assumptions

There is no universally accepted method for allocating shared costs (see paragraph 122, AUC, 2017).

Recommendations

Sensitivity analyses can be performed over the sensitivity of TFP to inclusion or exclusion of various joint or common costs for labor expenses.

[1] See for example Paragraph 122 of the AUC proceeding for 2018 – 2022 PBR plans where a similar allocation issue is discussed (AUC, 2017).

2.2.4.6 Administrative and General (A&G) Materials Index

Overview of Method and Assumptions

Because A&G expenses are comprised of joint and common costs that pertain to activities that span distribution, transmission, and production (rather than just distribution) functions. To assign these costs to the distribution function, the portion of joint and common A&G expenses allocated to the distribution function was determined by multiplying a firm's total A&G expenses for each year in the sample by the annual average across all firms in the sample of the percent of distribution plant relative to total plant.

The materials expenses for A&G expenses are the total expenses for these accounts less the direct payroll distribution for these accounts. The price of materials is based on the BLS Gross Domestic Product Price Index, with the quantity of materials derived by dividing the cost of materials by its price.

Evaluation of Method and Assumptions

Practitioners can vary in their choice of whether or not it is appropriate to include shared costs that are not explicitly labeled as distribution costs in FERC Form 1,[1] and it is important that the method to allocate the joint or common costs be transparent and replicable, and attribute relevant costs to materials, as was done in this case.

Benefits of Method and Assumptions

Relevant materials expenses may be included in developing materials quantity indexes.

Drawbacks of Method and Assumptions

There is no universally accepted method for allocating shared costs (see paragraph 122, AUC, 2017).

Recommendations

Sensitivity analyses can be performed over the sensitivity of TFP to inclusion or exclusion of various joint or common costs for materials expenses.

[1] See for example Paragraph 122 of the AUC proceeding for 2018 – 2022 PBR plans where a similar allocation issue is discussed (AUC, 2017).

2.2.4.7 Capital Measurement

Overview of Method and Assumptions

Quantity of capital is derived from a perpetual inventory equation:

$$K_t = K_{t-1} + I_t - R_t$$

Where K_t is the end-of-year capital stock, K_{t-1} is the end of year capital stock from the previous year, I_t are the quantity of capital additions during the year, and R_t the quantity of retirements during the year.

To estimate the quantity of capital additions, distribution additions to plant in service from FERC Form 1 are divided by the Handy-Whitman index for distribution plant. The quantity of Retirements is estimated from dividing distribution retirements from plant in service from FERC Form 1, divided by a lagged value of the Handy-Whitman index (lag of 33 years, to represent the average depreciable service life of the distribution plant).

Because the net book value of the plant is not reported in FERC Form 1, the benchmark value of the plant is estimated by taking the ratio of distribution plant in service to total electric plant in service and applying that value to net electric plant in service.

$$K_{1964} = \frac{NetElectricPlantInServ * \left(\frac{DistributionPlantinService}{TotalPlantIn\,Service}\right)}{\sum_{i=1}^{20} \frac{i * HW_{1944+i}}{\sum_{i=1}^{20} i}}.$$

Last, once the end-of-year capital stock is computed, the flow of capital services during a year is based on the quantity of capital stock from the previous year.

$$KS_t = K_{t-1}.$$

The price of capital is derived from an implicit rental price equation that corresponds to the perpetual inventory equation described above:

$$PK_t = \frac{1-uz}{1-u}(r-i)\left[1 - \left(\frac{1+i}{1+r}\right)^{33}\right]^{-1} HW_{t-1}\,.$$

Where u is corporate profits tax rate, z the present value of tax depreciation on one dollar of investment in distribution plant and equipment, r is the forward-looking cost of capital, and i the forward-looking inflation rate.[1] The number 33 represents the asset life used in the perpetual inventory equation.

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[1] Note that to smooth the input price series, the average cost of capital rate and the average inflation rate over the 2002 – 2016 period was used. The average cost of capital is based on Moody's seasoned AAA bond yield and the average inflation rate is based on the Consumer Price Index for All Urban Consumers.

Evaluation of Method and Assumptions

The depreciation assumption should best reflect the underlying depreciation profile of the asset. With the one-hoss-shay the level of services of the asset remains relatively constant until it is retired. In this case the Department noted that this method best reflected the pattern of service flow observed in the electric distribution industry.

The capital quantity and price indexes reflect the same depreciation assumption, as is recommended in the literature.

The capital cost index was smoothed to reduce capital cost volatility. The underlying assumption is that the investor's forward looking real rate of return (cost of capital less the inflation rate) is constant through time (based on Diewert, 2005, p.491). This assumption is applied by computing the average cost of capital rate and the average inflation rate over the 2002 – 2016 period. This assumption is based on a recommended methodology in the literature.

The choice of benchmark year (1964) allows for many years of plant additions to minimize measurement error. The asset useful life was based on the Makholm and Ros (2010) study as well as the Eversource TFP study.

Benefits of Method and Assumptions

The methods and assumptions chosen are largely in line with the literature, with the exception of the choice to use the net plant value rather than the gross plant value, however TFP studies do not always align with the literature in their choice of gross or net plant value for the benchmark value.

Drawbacks of Method and Assumptions

The one-hoss-shay method is more sensitive to the useful life of the asset than the geometric decay assumption because the value of the capital stock is entirely determined by the useful life.

With this TFP study, the benchmark value of the plant was constructed from estimating the net book value of the plant rather than the gross plant value, which can create a downward bias in the TFP trend if net plant value underestimates capital quantity. In the literature, the gross plant value is appropriate for the one-hoss-shay depreciation assumption and net plant value for the geometric decay depreciation assumption (see Diewert and Lawrence, 2000; Lowry and Makos 2018).

Recommendations

Sensitivity analyses can be performed to determine the impacts to TFP from using gross or net plant value.

Sensitivity analyses can be performed to determine the impacts to TFP from smoothing the capital cost volatility.

Sensitivity analyses can also be performed to different depreciation assumptions if the underlying depreciation profile of the asset is in question.

2.2.5 Weighting Methods

2.2.5.1 Quantity Index of Total Input

Overview of Method and Assumptions

The quantity index of total input is constructed for each firm using the multilateral Törnqvist indexing procedure with the form:

$$\ln(X_{i,t}) = \frac{1}{2}\sum_{j=1}^{7}(sy_{jit} + \overline{sy_j})(lnX_{jit} - \overline{lnX_j})$$

Where i = firm ($i = 1, \ldots, 66$), t = period ($t = 2002, \ldots, 2016$), j = input ($j = 1, \ldots, 7$) to represent distribution labor, distribution materials, customer accounts and sales labor, customer accounts and sales materials, A&G labor, A&G materials, and capital. X_{it} is the quantity of total input for firm i in period t, X_{jit} is the quantity of input j for firm i in period t, and sy_{jit} the cost share of input j for firm i in period t. A bar above a variable represents the average value over all firms and all years.

The Price Index of Total Input is computed similarly for the prices of individual inputs:

$$\ln(P_{i,t}) = \frac{1}{2}\sum_{j=1}^{7}(sy_{jit} + \overline{sy_j})(lnP_{jit} - \overline{lnP_j}).$$

Where P_{it} is the price of total input for firm i in period t, P_{jit} is the price of input j for firm i in period t.

Evaluation of Method and Assumptions

The multilateral Törnqvist index is a common methodology where weights are computed relative to the average firm.

Benefits of Method and Assumptions

The multilateral Törnqvist index allows for comparisons that are bilateral and transitive, and it is widely used in the literature.

Drawbacks of Method and Assumptions

The derivation of the cost share of capital, labor, and materials was not explicitly discussed.

Recommendations

Methodologies for determining revenue or cost shares should be clearly documented and make sense based on the data used to determine the shares.

2.2.5.2 Overall TFP Index Weighting Method

Overview of Method and Assumptions

To determine industry rates of growth, each firm was weighted by its relative number of customers:

$$s_i = \frac{CUST_{it}}{\sum_i CUST_{it}}.$$

Where s_i is the weighting factor for each firm.

The industry rate of total output growth is then:

$$\ln {}^{Y_t}/_{Y_{t-1}} = \sum_i s_i \left({}^{CUST_{it}}/_{CUST_{i,t-1}} \right).$$

The industry rate of total input growth is:

$$\ln {}^{X_t}/_{X_{t-1}} = \sum_i s_i \left({}^{X_{it}}/_{X_{i,t-1}} \right).$$

The industry rate of total input price growth is:

$$\ln {}^{P_t}/_{P_{t-1}} = \sum_i s_i \left({}^{P_{it}}/_{P_{i,t-1}} \right).$$

The industry rate of TFP growth is:

$$\ln {}^{TFP_t}/_{TFP_{t-1}} = \ln {}^{Y_t}/_{Y_{t-1}} - \ln {}^{X_t}/_{X_{t-1}}.$$

Evaluation of Method and Assumptions

Indexes were weighted by the relative number of customers to provide more weight to more similar (larger) firms, which is an accepted practice in the literature.

Benefits of Method and Assumptions

TFP trends are more representative of those for larger firms.

Drawbacks of Method and Assumptions

Different weighting methods can result in TFP growth. The Department noted that the difference in results was not significant enough as to warrant a change in the TFP study.

Recommendations

Sensitivity analyses on the weighting method can be performed if there are concerns that the weighting method is biasing TFP growth.

2.3 Additional Criteria for Consideration: Price Indices

Indices can help evaluate changes in costs in the economy as a whole and point to how changes in prices are affecting a utility's rate structure. The indices show how prices are changing in the United States and by looking at the price indices more narrowly the individual components of electricity costs can be evaluated. In the following paragraphs we provide an overall measure for evaluating price change in the U.S. economy as well as indices that may pinpoint more clearly where the price increases are occurring in the electricity industry.

Overall inflation in the economy is best represented by the Gross Domestic Product (GDP) implicit price deflator. The index measures how the prices in the economy changed while the same quantity of goods and services were provided. 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. A good place to find the most current value and history is at the Federal Reserve Economic Database (FRED). The following URL (https://fred.stlouisfed.org/series/GDPDEF) provides a graphic of the data, but the data can be downloaded from the website if more long-term analysis is required. The remaining indices below can be downloaded as well.

Other key indices that support evaluation of change in input prices include energy prices, construction costs, commodity prices such as copper, and wage and price indices. Although several of the following indices are available at FRED, some are only available at the Bureau of Labor Statistics (BLS).

The "Unit Labor Costs for Utilities: Electric Power Generation, Transmission and Distribution (NAICS 2211) in the United States" index is provided annually and can be found at https://fred.stlouisfed.org/series/IPUCN2211U101000000. The composition of the information aggregated in the FRED database comes from the Bureau of Labor Statistics website and the newest data can be found at https://www.bls.gov/oes/current/naics4_221100.htm. The top line provides the weighted average of the actual wages paid by the NAICS code 221100-Electric Power Generation, Transmission and Distribution. A regional version of the index was searched for but couldn't be found for Massachusetts or New England.

The "Producer Price Index by Commodity: Nonmetallic Mineral Products: Construction Sand, Gravel, and Crushed Stone (WPS1321)" provides information on some input prices for construction of substations, switch stations, and footers for poles and towers as well as concrete poles if they are used (https://fred.stlouisfed.org/series/WPS1321). The "Producer Price Index by Commodity: Metals and Metal Products: Copper Wire and Cable (WPU10260314)" offers a basis for changes in conductor prices (https://fred.stlouisfed.org/series/WPU10260314). The "Producer Price Index by Commodity: Machinery and Equipment: Power and Distribution Transformers, Except Parts (WPU11740999)" affords an index for another major utility cost item (https://fred.stlouisfed.org/series/WPU11740999). The "Producer Price Index by Industry: Electric Power Generation (PCU221110221110)" provides price change for generators of electricity (https://fred.stlouisfed.org/series/PCU221110221110). The index measures the change in prices for the first major commercial transaction by generators. The Electric Bulk Power Transmission and Control, NAICS 221121 measures changes in fees and charges in the movement of electricity from generation to distribution centers. Currently the index (https://data.bls.gov/timeseries/PCU221121221121) is only available at BLS. The two indices along with the “PPI industry data for Electric power distribution, not seasonally adjusted” (https://data.bls.gov/timeseries/PCU221122221122) provide a complete array of the costs generation, transmission, and distribution of electricity.

Employment for Utilities: Electric Power Generation, Transmission and Distribution (NAICS 2211) in the United States (IPUCN2211W200000000), https://fred.stlouisfed.org/series/IPUCN2211W200000000, provides not an index but the actual number of jobs provided by the electricity industry. The number of jobs could be a measure of improved productivity.

3.0 Conclusion and Next Steps

We utilized the methodologies, assumptions, best practices, and potential biases outlined in "Total Factor Productivity Studies in the Electricity Sector: An Overview of Methodologies and Best Practices" to perform a critical review of past TFP studies from two X-factor proposals in Massachusetts [Eversource (D.P.U. 17-05) and National Grid (D.P.U. 18-150)]. We evaluated the method and assumptions chosen, provided an objective summary of the benefits and drawbacks of that method, provided recommendations for alternative data, methods, and assumptions that would improve the accuracy or reasonableness of the analysis, and provided additional criteria to consider for evaluation of future TFP studies.

We found that the reviewed TFP studies were largely in line with best practices but made several recommendations with two overarching themes: 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.

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