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Huntington, Hillard

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Hillard Huntington[#], Energy Modeling Forum, Huang Center, 475 Via Ortega, Stanford University, Stanford, CA 94305, hillghunt@gmail.com.

## Forthcoming in Energy Policy

## Abstract

Electrifying household and economic activity remain a cornerstone of the transition towards deep decarbonization. This analysis conducts a cross-country evaluation through a pooled mean-group model based upon 33 OECD nations since 1980. Electrification is defined as electricity's share of the total energy system. The results show that electrification would have decreased by approximately 13 to 31 percent below other countries if the electricity price level had increased above other countries by 100 percent. Additional sensitivities show that symmetry between this response between price increases and price decreases depends upon whether GDP is exogenous. These estimates highlight the critical importance of finding new generation, transmission and distribution technologies that both reduce emissions and remain cost competitive. They also emphasize that any successful transition pathway must price electric power competitively based upon the opportunity costs of providing power. Efforts to bundle costly social programs and other expenses into power prices should be avoided.

## Highlights

- Power prices reshaped electrification in 33 OECD countries since 1980.
- A doubling of power prices would have reduced electrification by 13-31 percent.
- Estimates adjust for two-way causality between electrification and economic growth.
- Successful transition pathways should avoid costly social programs when pricing power.

**Key words:** OECD electrification; electricity prices; cross-country panel analysis

**JEL Codes:**
C23 Panel Data Models
Q41 Energy: Demand and Supply, Prices
Q48 Energy: Government Policy
L94 Electric Utilities
L98 Industry Studies: Government Policy

[#] Data and computer code are available from the author upon request.

## 1. Introduction

High power prices have afflicted electricity customers in many countries in the last several years. These developments have caused policymakers to reconsider electricity market designs to better accommodate high and fluctuating power prices. The post-pandemic recovery of European economies had only just begun when the Russian invasion of Ukraine and western sanctions were imposed. These events disrupted traditional European sources for natural gas supplies and shocked power prices (Pollitt, 2023; Pollitt et al, 2024; Fabra, 2023; Chuliá et al, 2023). In the North American continent, different conditions prevailed. Extreme cold weather combined with freezing natural gas wells and pipelines disrupted power markets in Texas (Levin et al, 2022). These impacts were magnified by the lack of interconnections with other U.S. regions.

Even without these disruptions, policymakers have had a difficult time setting electricity prices efficiently. Many U.S. regions administer prices that distort customer prices from the opportunity costs of providing power when and where it is needed. In states like California, end-use charges for delivered power include the costs of providing subsidies for low-income households, energy efficiency investments or solar panels (Rule, 2024). The customer cost of using additional power can also include massive transmission and distribution expenses for protecting the system from damages incurred by future wildfires and other weather emergencies (Singh et al, 2024). These additional expenses impose costs that exceed the opportunity cost of providing that power by a considerable amount (Borenstein and Bushnell, 2022a).

There has been some concern that high power prices can dampen this electrification process (Borenstein and Bushnell, 2022b). They can discourage the substitution from gasoline to electricity in transportation or the replacement of natural gas by electricity in homes and commercial buildings. This possibility could dampen the drive towards an economy and lifestyle that is built upon cleaner energy sources such as electricity generated by renewables or nuclear.

This analysis provides some basic estimates on the level of electricity prices as a deterrent to electrification of a nation's energy system since 1980. Electrification is defined as the share of total energy use accounted for by electricity. The evaluation draws conclusions from a dynamic panel-data evaluation of 33 different OECD countries. It adopts a macro perspective on the whole power system in order to be more relevant to policymakers who want to focus on overall behavior of a country's power system rather than more detailed evaluations of specific end-uses and sectors.

Since particular interest lies in the long-run responses, the approach applies a pooled mean-group estimator where the long-run responses are uniform across countries.[1] As such, the responses should be viewed as average responses across all nations in the sample rather than as country-specific responses. The approach will also explore whether adjustments for cross-sectional dependence between country effects need to be addressed for electrification as defined above. Finally, an important reason for this effort is the desire to uncover not only the deterrence to electrification but also the ability to unwind these effects by policies that limit the allocation of fixed costs unrelated to the provision of electricity to the marginal prices for

[1] Short-run responses are allowed to vary by country.

end-use power. As a result, additional evaluation explores the extent to which the response to lower electricity prices is symmetric to its counterpart for higher electricity prices.

Section 2 discusses a few related studies that emphasize the importance of pricing in the electrification process. Section 3 describes the adopted methodology in this study of estimating a pooled mean-group regression together with data sources and descriptions. Section 4 highlights the empirical results, focusing upon the relationship between electrification and power prices. Section 5 summarizes the major policy conclusions.

## 2. Policy Context and Related Studies

Electrification has transformed both home life and economic productivity globally over multiple decades. For interesting discussions of the US experience, see Gordon (2016, Chapter4), Lewis and Severnini (2020), and Fiszbein et al (2020). High income countries expanded power by 1.8% over 1971-2014, a good deal faster than the 0.4% growth rate for total energy use. These trends are even more pronounced for nations that are developing their economies. Middle income countries expanded power by 5.7% relative to energy use by 2.7% over 1971-2014.[2]

The discussion in this section will initially explain how the study defines electrification as applied to the 33 relatively wealthy economies evaluated in this study. It will be shown that this definition links directly to policy deliberations and various modeling exercises that consider electrification's role in the strategy to limit future greenhouse gas emissions. In a second subsection, the discussion considers the technique for evaluating whether price increases and

[2] Data provided by World Bank at https://databank.worldbank.org/source/world-development-indicators.

decreases have symmetric responses. Finally, the discussion will consider several ways that electricity prices are distorted by social programs and other expenses that are not directly related to the cost of delivering power to end users.

### 2.1 Electrification

Electrification is the conversion process where energy service demands replace non-electric equipment and systems with electric sources (US Department of Energy, n.d.; International Energy Agency, n.d.). Many alternative measurements exist for electrification, depending upon the issue being addressed. Consistent with the United Nations' Sustainable Development Goal 7, the standard measure for developing countries with many rural households who lack electricity service has been access to the electric system. The World Development Indicators provided by the World Bank reports rural, urban and total access estimates as the percentage of a population with access to electric power. These estimates may understate the growth in electricity access unless they are supplemented with estimates on electricity connections derived from national census data and household surveys that represent the nation's population (Aklin et al, 2018). Moreover, simple estimates of the number of households and firms that have access to electric power fail to capture that the electrification process depends critically upon the quality of electric power (Bhatia and Angelou, 2015; Lee et al, 2020). Household and economic activities depend heavily upon reliable power quality that is not subject to sudden or frequent power disruptions, power availability throughout both the day and night, consistent voltage that will not damage electric equipment, and the system capacity to support multiple uses such as lighting or operating machinery.

The concern about access-based measurements is even more problematic for the more developed economies because access to electric power systems are now near universal in these countries. In addition, access alone fails to explain electricity's importance to the many different power-using applications in households and industry. For this reason, the study measures the degree of electrification by the share of total energy use contributed by electricity for all applications. As economies grow, they expand the amount and variety of energy service demands that use electricity.

This definition is consistent with a number of exercises (Williams et al, 2012; Barron et al, 2018; Bistline et al 2022; Luderer et al, 2022; Browning et al, 2023) to compare integrated assessment modelling estimates for greenhouse gas emissions covering different regions. The key role for electric power's contribution to total energy use is also widely recognized within the policymaking community (International Energy Agency, 2024). The power sector facilitates a shift towards decarbonized energy systems by providing low-cost carbon-free generation sources, future technologies that can introduce negative emissions, and continued improvement in electrifying end-use applications (Bistline and Blanford, 2021). Electricity's expanding share is critical in evaluations emphasizing deep decarbonization to meet aggressive climate change goals. Studies have also documented that regional and international policy cooperation in the provision and transmission of electric power can significantly reduce the costs of mitigating emissions (Bistline et al, 2020; Joskow, 2020; Davis et al, 2023).

As a system process, electrification differs from electricity demand, which has been modelled extensively in the literature. It seems unnecessary, and perhaps a bit misleading, to review the estimates from the long history of electricity demand studies in the context of the current study on electrification. Electricity demand often focuses upon the private decisions of households and industry, whereas the electrification process requires large pubic investments in not only the transmission and delivery system but also the provision of public services like city street lighting. For this reason, electrification may respond to energy prices and economic activity with different magnitudes than does electricity demand.[3] Electrification may also respond asymmetrically to price increases and decreases even when electricity demand does not.[4] Common factors influencing all countries may not operate for electricity shares, even though techniques for reducing these biases are often used in electricity demand studies.[5]

### 2.2 Asymmetric Price Response

There are no a priori reasons for expecting symmetry in the response to price increases and decreases over the long run. When lower prices stimulate more electrification, households adjust their lifestyles to enjoy new amenities, including improved lighting for evening household activities, new equipment like refrigerators and air conditioners, a home environment relatively free from indoor pollution and health risks, and additional opportunities for information and entertainment through televisions and computers. Although more costly electric power may retard electrification, households may continue to value many of the above benefits and respond differently. Similarly, industrial processes may not change their

[3] Several meta analyses (Labandeira et al, 2017; Zhu et al, 2018) summarize the responses estimated in many articles on the demand for electricity and other energy sources in countries dominated by OECD members. Electricity price estimates provided by the first source are −0.126 for the short run and −0.365 for the long run. Individual estimates can vary widely depending upon regions, time periods, data sources (household survey versus national energy accounts), and empirical methodology. Miller and Alberini (2016) provide an interesting set of estimates on some of these variations as applied to the United States.

[4] A review by Liddle (2023) finds that electricity (and energy) price elasticities are relatively stable and reasonably symmetric over time if the 1970 experience is excluded.

[5] See section 4 for findings related to this topic.

operations simply because electric power is more costly. As electrification expands, firms will find that electric motors are not only more efficient as an energy source but also less costly to maintain. Additionally, more electrification will cause industry to decentralize production operations (David, 1990). For all these reasons, it remains important to consider the extent to which prices have symmetric effects for the electrification process aggregated across the entire system. Policy planners evaluate their needs to build capacity to meet their entire load rather than individual sectors.

The Nonlinear Autoregressive Distributed Lag (NARDL) approach (Shin et al, 2014) has become the standard approach for evaluating the presence of different responses to price increases and decreases. It develops two separate partial sums for price rises and cuts, as explained in section 4 below. The technique is similar to the price decomposition specification used by previous energy researchers (Gately and Huntington, 2002; Adeyemi and Hunt, 2010; and Adeyemi et al, 2014) except that it does not include a third component that measures the response to new price peaks or maximum values. Exclusion of this third component appears reasonable for the particular sample, where the beginning year is 1982 and well after the 1970 energy price shocks. Gately and Huntington (2002) emphasize that maximum price effects in their studies reflect vehicle capital stock adjustments, the near complete replacement of residual oil within electric generation, and other structural changes that dominated the 1970 energy price shocks but did not emerge in later years.

### 2.3 Electricity Price Distortions

Pricing electricity efficiently has been a long-standing issue within the economics community for many years (e.g., see Feldstein 1972). Promoting ancillary services for system reliability, assigning transmission charges to avoid congestion, and recognizing start-up costs for critically placed generation have been a few of the many pricing issues debated by various experts (Chao and Huntington, 2013). Recent attention has shifted towards how to price electricity effectively to limit the pollution and climate change damages associated with fossil generation (Schittekatte et al, 2023). Often, regulators force electricity prices for the end user to rise above the marginal price of using electricity to cover large fixed costs (Borenstein and Bushnell, 2022a). These adjustments may include not only transmission and distribution charges but also a range of other social policies like wildfire protection, subsidies for low-income households, and tax-incentives for energy-efficiency investments and rooftop solar panels. These distortions in pricing power at the margin vary dramatically across regions as well as on an hourly basis.

Even without social marginal cost pricing, future policies will continue to push households into electrifying their homes and vehicles and shift commercial and industrial customers towards electrifying their operations. Given that some regions price electricity well above marginal costs for long durations, these policies may be costly and their benefits difficult to achieve. For example, many local communities advocate proposals to enforce all-electric homes but there exists some concern about their costs. Davis (2023) finds that energy prices are important and can explain more than two-thirds of the increase in electrification in new homes in the United States since 1950. He estimates from his empirical results of electric-homes mandates that colder states where electricity is selected less often for heating experience a welfare loss of $1000, compared to the $350 loss in warmer states. Electricity prices also appear important in other countries. Sahari (2019) concludes that new home builders in Finland install wood heating,  ground source heat pumps, and hydroelectric heating as substitutes for more expensive electric heating.

The analysis in this study complements these more detailed studies focused upon a particular end-use in one sector of a single economy. It attempts to harness the collective experiences of many countries. It also tries to broaden the focus to include the electrical system as an aggregate rather than to evaluate a particular end use or sector. Given international data constraints, the paper focuses upon the average aggregate electricity price level in a country rather marginal cost pricing. Although this topic is somewhat related to the extensive literature on energy demand estimation, the current study focuses upon electrification's share of total energy use rather than the response of the demand for specific fuels for various end-use applications.

## 3. Specification and Data

Although expanding electrification is important for economic development in newly industrializing countries (Burke et al, 2018), the speed of the electrification process in more advanced economies will also have major implications for the global transition towards cleaner energy sources. These more developed countries maintain established and more reliable electric systems, but often find it challenging to price power efficiently. Relative to developing countries, regulators in these countries apply more consistent enforcement of policies, rules, and end-use pricing tariffs that appear particularly relevant to the issues described in this analysis. Investments in transmission and distribution infrastructure allow far greater access to power by all citizens.

## 3.1 The Pooled Mean-Group Approach

The approach explores the response of a nation's electrification ($y_{it}$) in any year to variations in its countrywide electricity price over the 1980-2019 period by controlling for other factors. It focuses upon the long-run effects of electricity price by estimating a pooled mean-group model developed by Pesaran, Shin, and Smith (1999), where the long-run coefficients are the same for all panels. Meanwhile, it permits short-run responses, including the error-correction adjustment, to vary across panels. This balance makes it popular for applications involving long-term relationships.[6]

Beginning with an autoregressive distributive lag (ARDL) (1,1) dynamic panel specification, this relationship can be reparameterized into the following error correction equation:

$$\Delta y_{it} = \emptyset_i \left[ y_{i,t-1} - \beta x_{it-1} \right] + \lambda_i \Delta\, y_{i,t-1} + \delta_i \Delta x_{it} + \mu_i + \varepsilon_{it}$$

where

Δ indicates the first difference of either the dependent (y) or independent (x) variable,

$\phi_i$ is the country-specific error correction speed of adjustment parameter to be estimated,

β is a vector of long-run parameters identical for all panels,

$\lambda_i$ and $\delta_i$ are country-specific short-run parameters,

$x_{it}$ is a vector of explanatory variables,

$u_i$ is a set of country-specific intercepts,

and $e_{it}$ is the error term.

[6] See, for example, Baek (2016), Opoku and Boachie (2020), and Raouf (2023).

This analysis will focus upon the long-run coefficient for the electricity price coefficient in the error-correction term, $y_{i,t-1} - \beta x_{i,t-1}$. Expectations should be that it will be negative, if higher than average power prices reduce a country's electrification. It should be noted that the $u_i$ terms control for time-invariant factors that influence a particular country's electrification, such as a its long-term climate that can be an important influence.

### 3.2 Data Sources

Electrification is defined as its share of total energy consumption. The U.S. Energy Information Administration (https://www.eia.gov/international/data/world) provides country data on electricity net consumption (billion kWh), total energy consumption (quadrillion Btu), gross domestic product (billion 2015 dollars at purchasing power parities), and population (thousands). Electricity shares were computed by converting kilowatt hours to quadrillion BTUs by multiplying by 0.003412, prior to dividing by total energy consumption. Per-capita GDP in thousands of dollars person were computed by converting billion dollars to million dollars by multiplying by 1000, prior to dividing by population.

Real price indices for electricity and total energy (2015=100) were accessed from the International Energy Agency (2024), "End-use prices: Energy prices in US dollars", IEA, Paris, https://www.iea.org/data-and-statistics/data-product/oecd-energy-prices-and-taxes-quarterly. They are inflation-adjusted aggregate price indices (2015 values = 100) for the household and industry sectors and are modified to reflect taxes, subsidies, and other levies. The documentation indicates that utility company surveys are often the source for electricity prices and are not computed simply as revenues divided by consumption. This data also serves as the basis of a wider set of aggregate electricity and total energy price data for more countries and for earlier years that extend back to 1960 for some countries (Liddle and Huntington, 2020; Liddle, 2022). The current study uses the IEA data directly because the analysis was restricted to more recent years by data availability limitations on other variables. Additionally, the IEA data set applies the same definitions and standards to every country and avoids inconsistencies that can arise from using merged data that may be based upon different data-collection methodologies.

Economic sector shares for agriculture, construction, industry excluding construction, manufacturing and services were obtained from the Organization for Economic Cooperation and Development (https://data-explorer.oecd.org/). Sector shares are expressed as percentage points or per hundred (20% is 20 pct points or 20 per hundred).[7] They are available in the section titled "NAAG Chapter 4: Production."

The data set is unbalanced because observations are not available for all years for a few countries. The sample that includes real GDP covers the 1980-2019 period, while the sample that includes economic sector shares covers the 1989-2019 period. Table 1 shows the 33 nations included in the data set, along with the country-specific average electrification rates, real electricity price level indices, and real energy price level indices in the first three columns. In the last three columns, the average annual change in these variables is reported for each country.

<Insert Table 1 here>

[7] Corrections were made for the services sector in Switzerland in the 1995-96 period. Reported shares for all sectors in that country exceeded 100% for 1995-96. They were recomputed as 100% minus the shares of the other sectors. Missing service share values for 1990-94 were computed by the same procedure.

Electrification levels range from a low of 8.2% in the Netherlands to a high of 26.1% in Estonia. Both electricity and energy prices are real indices in 2015 prices. They reveal how prices have changed from their country-specific levels in 2015 but cannot be compared across countries. The mean percent changes show the average annual growth rate (per annum) for the three variables in each country. Electrification grows fastest in South Korea at 2.38% per year and slowest in New Zealand at 0.13% per year. Growth in electrification rates depend upon not only the change in electricity prices but also the change in energy prices. The US experience demonstrates the importance of this consideration. While USA electricity prices grow the least at -0.60% per year, they follow a very similar pattern to energy prices. As a result, its electrification rate grows by 1.00% per annum, which is close to the average growth rate for all countries at 1.15% rather than one of the higher electrification rates.

Supporting this conclusion across all countries is a simple regression analysis of the average growth rates in each country for electrification, real electricity prices, and real energy prices based upon the data shown in this table. Both electricity and energy price coefficients are significant. The electricity price coefficient is -0.452 with a t-statistic of 3.04, while the energy price coefficient is 0.382 with a t-statistic of 2.98. Robust estimates are used to correct for heterogeneity. The adjusted R-squared for the equation was 0.197 and its root-mean-squared error was 0.004.

The principal estimates discussed in Section 4, however, extend the analysis to derive results that are based upon the annual data for each country. It employs a mean-group estimator that develops coefficients for each country in separate equations that are then averaged across all countries (or panels). These coefficients reveal the typical response in the countries included in the analysis, but individual countries may respond differently.

The trends in Table 1 happen during a period when renewables and climate change policy have been expanding but at different rates in these countries. Table 2 provides a useful perspective on the electrification process. The first column underscores the wide variation in the average renewable energy penetration (% of total energy) across the countries. The average renewable share of total energy ranges from 1.5% in Korea to 58.6% in Norway. This share grows at disproportionate rates from -2.29% in Turkiye to 9.22% in United Kingdom. The last column emphasizes that most countries have an emissions trading system in place or under development. A few have or had carbon taxes. The ability of these systems to limit carbon emissions varies dramatically across countries depending upon how the revenues are collected and how they are redistributed (Carl and Fedor, 2016.).

<Insert Table 2 here>

### 3.3 Data Properties

Electrification rates and all exogenous variables in the main results are measured as the difference from the mean value across all nations for each year. Table 3 reports the summary statistics for the demeaned variables. The full panel data set is unbalanced and covers electrification, electricity prices, energy prices and real GDP in 33 countries for the 1980-2019 period. The economic share data is more limited and covers the same 33 countries for the 1989-2019 period. The appendix Table A.1 provides further information about the years covered for each country in both data sets. As reported in Table 3's standard deviation column, the construction share varies the most while the services share varies the least.

<Insert Table 3 here>

Table 4 shows that the Im, Pesaran and Shin (2003) panel unit root test for determining the stationarity of each variable. Unit roots are rejected in favor of stationarity in levels for electrification, real energy price, agriculture, construction, and service. The remaining variables represented by real electricity price, per-capita GDP, and industry appear to be stationary in first differences. Unit roots are rejected when these variables are converted to year-to-year changes, as revealed in the second column. With all variables being stationary in levels or first differences, Bounds F- and t-tests can be applied to explore whether the variables are cointegrated. These results are reported in Tables 5 and 6 below.

<Insert Table 4 here>

# 4. Results

## 4.1 Cointegration and Cross-Sectional Dependence

Before discussing the estimated coefficients, it is useful to evaluate the set of rows at the bottom of Tables 5 and 6. These estimates reveal similar findings for all six equations shown in these two tables. In addition to reporting the number of observations and two goodness-of-fit statistics (the log likelihood ratio and the root mean squared error), the fourth and fifth rows in the bottom section report estimates for the Bounds test for cointegration proposed by Pesaran, Shin, and Smith (2001). Significant coefficients reject the null hypothesis in favor of the alternative that a long-run cointegrating relationship exists between the variables. The F-test indicates whether the explanatory variables in the error-correction term support cointegration. These values are consistently above the upper-bound criterion at the 1% significance level for each equation. The t-test indicates whether the lagged dependent variable supports cointegration. These values are consistently above the upper-bound criterion at the 1% significance level for each equation.

The next two rows emphasize that the panel-data results for the equation explaining the electrification process do not need to be corrected for cross-sectional dependence between the errors of each panel's estimate. The Pesaran (2015) CD test statistic is shown under the coefficients in the table as CD.[8] Insignificant values fail to reject the null hypothesis of weak cross-sectional dependence. The mean absolute correlation coefficients of the residuals (reported as CD_rho in the table) are relatively low and well below the benchmark of 0.5 where one begins to worry about this issue. Hence, cross-sectional dependence between the panels do not appear to be a problem and do not need to be investigated further in this particular example. This condition is fortuitous because removing the bias from cross-sectional dependence along the lines suggested by Chudik and Pesaran ( 2015) would for this application seriously reduce the degrees of freedom and weaken the power of the equations. Each panel with 31 or 40 observations would require three lagged values and one contemporaneous value for the cross-sectional average terms for each variable. These additional terms would need to be included in each panel (country) estimate.[9]

[8] Estimates are based upon the Stata program, pescadf, by Piotr Lewandowski.

[9] The recommended guideline is to add the cubed root of the number of observations in a panel, which in our case is either 31 or 40 observations.

In the absence of cross-sectional dependence, the Pesaran (2007) CIPS test on residuals is reported under the coefficients in the table as the $Z_t$-bar estimates.[10] Significant values indicate the residuals of some of the panel errors are stationary and do not have unit roots.[11]

## 4.2 Symmetric Price Responses

Coefficients and supporting statistics for several versions of the pooled mean-group estimates are displayed in Table 5.[12] These estimates adopt the symmetric price response assumption where the effects of higher and lower power prices are mirror images of each other.

<Insert Table 5 here>

The first two estimates explore the price and GDP responses over the 1980-2019 period by excluding the economic share variables. The *pmgy* specification includes real GDP as well as the real price series for both electricity and total energy. Focus will be on the long-run effects listed under the error-correction term in this equation. Each coefficient indicates the percentage change in a country's electrification that results from a 1 percent change in the price or activity variable. All changes are relative to the average for all countries included in the analysis. For example, the results show that a doubling of the electricity price level above the global average will curtail electrification by 31% below the cross-country mean for electrification. The electrification response includes not only the decline in the residential, commercial, and industrial demands featured frequently in electricity sectoral demand studies, but also electricity used for streetlighting, agriculture, and other purposes. The absolute

[10] Estimates are based upon the Stata program, xtcd, by Markus Eberhardt.
[11] This procedure is not a formal test of cointegration but is consistent with the results from the Bounds testing.
[12] Equation estimates are based upon the Stata program, xtpmg, developed by Blackburne and Frank (2007).

magnitude of this effect is almost 40% more than its counterpart caused by per-capita GDP growth. Electrification is a slow process that changes gradually when energy prices and economic conditions vary.

If the specification drops the real GDP variable, results for the *pmgxy* specification in the second column indicate a considerably smaller effect of 17%, although the two price coefficients for electricity and energy remain significant. The explanatory power of these two specifications appears comparable; the root-mean-square-errors (rmse) are similar. Removal of the per-capita GDP series might be warranted for several reasons. Although per-capita real GDP in this sample appears to be stationary in first differences, there exists an extensive literature claiming different results. A general conclusion appears to emphasize that stationarity is accepted for certain OECD countries after allowing for structural change or breaks (e.g., see Carrion-i-Silvestre et al, 2005; Hegwood and Papell, 2007). A more perplexing problem may be the possibility of reverse causation where the electrification process may create additional economic growth prospects (see e.g., Burke et al, 2018). The estimates for the effect of GDP on electricity consumption in the pmgy specification might be overstated if both per-capita GDP and the electrification process positively influence each other. Under these conditions, some of the additional electrification embodied in the 0.22 response might be caused by the reverse effect of electrification stimulating additional growth.

The *pmgss* specification shown in the third column replaces real GDP in the *pmgy* model by the sectoral share variables. The share variables should be a good proxy for economic growth. At the same time, it appears less likely that electrification will be the primary factor to cause agriculture's share to decrease and service's share to increase.  The share variables for agriculture, construction, other industry (excluding construction) and services reduce the effect of long-run electricity prices on electrification from 31% in the pmgy specification to 12%. Among the share variables, it is not too surprising that construction's impact is insignificant due to its small contribution to the overall economy. However, the service share dominates these responses. Data availability limits this approach to a smaller sample covering the 1989-2019 period for most countries rather than the 1980-2019 period. Despite this smaller coverage, its lower root-mean-square-error (0.025 rather than 0.031) indicates an improved goodness of fit.

The fourth specification (*pmgyi*) in this table replaces the sector share variables with instrumental variables for real per-capita GDP that are based upon the shares of agriculture, construction and services.[13] One can conclude that these were sufficiently strong instruments by excluding the instrumental variables from the first-stage estimation of GDP. The weak identification test (Cragg-Donald Wald F statistic) of 38.14 exceeded the common benchmark of 10 as well as the Stock-Yogo weak ID test critical value of 13.91 at 5% significance. In addition, the three instrumental variables appear valid. The Sargan statistic for overidentification of all instruments equaled 5.07, which did not significantly reject the validity of the instrumental variables at the 5% level.

This specification reduced the role for per-capita GDP from the *pmgy* model where GDP was exogenous, as expected. It also reduced the magnitude of the electricity price responses from -0.31 to -0.16. Although both estimates are smaller than when GDP is exogenous, the importance of electricity prices relative to GDP in shaping electrification appears larger. The

[13] Electricity prices are most likely exogenous because regulatory authorities rather than market conditions set end-user prices. IEA data on electricity prices are usually derived from utility samples on end-use prices and are not computed simply as revenues divided by consumption.

absolute magnitude of the electricity price response now exceeds its GDP counterpart by 108% rather than 40% in the previous pmgy specification.

The countries represented in this analysis tend to be wealthier with more advanced electric power systems than global averages. Although the evidence on the bi-causality between electrification and economic growth (which causes which) tends to be mixed, there exists some reasons for supporting the conclusion that economic growth causes electrification for the richer nations (Tran et al, 2022; Aydin, 2019). In that case, one might favor the pmgy specification in the second column indicating a 17% response to electricity prices when per-capita GDP is exogenous. For robustness purposes, however, the table also reports estimates for the pmgyi specification (column 4) that allows per-capita GDP to be endogenous.

### 4.3 Asymmetric Price Responses

Exploring the asymmetry in responses to price requires that the variable is decomposed into two series for price increases and decreases. Shin el al (2014) proposed that the ARDL approach can be modified to incorporate this nonlinearity. In their Nonlinear Autoregressive Distributed Lag (NARDL) approach, price increases are defined as the iterative accumulation of all subsequent price increases, beginning with the price level in the initial year of the sample. Similarly, price decreases are defined as the accumulation of all subsequent price decreases over this same period. When *p* is defined as the logarithm of the power price, the two partial sums can be represented as the following:

$$p_t^+ = \sum_{j=1}^{t} \max(\Delta p_j, 0)$$

$$p_t^- = \sum_{j=1}^{t} \min(\Delta p_j, 0)$$

Figure 1 displays these two partial sums for each country. Price rises and cuts are considerably larger for Turkiye than for other nations.

<insert Figure 1 here>

Results for the asymmetric price response hypothesis are presented in Table 6 for the pmgy and pmgyi specifications reported in Table 5. They are labeled pmgya and pmgyia, respectively, in Table 6. In the first case where per-capita GDP is exogeneous, the responses to electricity price increases are statistically no different from those to price decreases. The Wald test was 1.11 and therefore could not reject the hypothesis of symmetric effects. Similar tests appeared quite different when per-capita GDP was instrumented. Here, the Wald test was 24.47 and therefore could reject symmetric effects in favor of asymmetric effects. Price cuts expanded the electrification process somewhat less than price rises slowed down the electrification process. Results were very similar when the equation ignores the Turkiye experience where the price rises and cuts were substantially larger than for the other countries.

<Insert Table 6 here>

## 5. Conclusions and Policy Implications

The overall policy objective in electricity market design for multiple decades has been to establish electricity prices that incorporate the additional costs of generating, transmitting, and distributing electric power to potential users of the power system. Pricing will be governed by the various energy mixes available to the system operators and include operating costs, sufficient reserve capacity, and infrastructure upgrades for ensuring reliable power quality.

Pricing will also differ according to when and where consumers want to purchase power in order to work around limits on peak generation capacity and congested transmission and distribution lines. Of critical importance will be the need to incorporate any social costs associated with air and water pollution as well as climate change damages into electricity prices.

Both policymaking and climate policy modelling have emphasized the role of increasing electrification as a key dimension in the transition towards cleaner energy systems. Many governments have implemented carbon pricing either in the form of carbon taxes or carbon emissions trading systems. Although these programs raise electricity prices, the relative consideration should be whether electricity prices increase more than the prices paid by direct users of fossil fuels. In many instances when generation has relatively low carbon intensity, electricity prices will tend to increase by less. Moreover, the easier substitution of renewables for fossil fuels within electric power generation will dampen the increase in electricity prices relative to fuel prices in the non-electric sectors.

In addition to the above private and social costs, electricity policymaking and planning have frequently incorporated other policy objectives such as making electricity affordable for low-income consumers through lower end-use tariffs, subsidizing the cost of energy-efficiency improvements and rooftop solar panel installations, and massive transmission and distribution expenses that might exceed the benefits from protecting the system from damages incurred by future wildfires and other weather emergencies. Although policymakers may be committed to pursuing many of these objectives, these programs are often financed by raising electricity rates above the private and environmental costs of supplying the power. Under these conditions, electricity becomes less competitive with other energy products and the penetration rate of electrification may decline. This situation can operate against other policy efforts like the mandates for all-electric homes, which have become very expensive in California and other regions where electricity prices have outstripped their social costs.

Based upon these interests, this analysis has focused on a relatively straightforward measure of the electrification process: the share of total energy consumption in a nation's economy attributable to electricity. To provide a macro perspective, conclusions are derived from a cross-country empirical evaluation from 33 countries with relatively advanced electric power systems. When the price of electricity increases relative to the price of direct fossil fuel usage, the evidence from this analysis suggests that electricity's penetration will be less than in other nations. Prices in this analysis are inflation-adjusted aggregate price indices for the household and industry sectors. Price adjustments include not only direct operating costs but also taxes, subsidies, and other levies.

The analysis estimates the long-run response of electrification to different electricity price levels by holding constant economic conditions like per-capita GDP or major economic shares. When GDP is considered as an exogenous factor, electrification declines by 31 percent below the mean value for all countries in the long run for each 100 percent increase in inflation-adjusted electricity prices. Although initial reactions may be that this estimate appears relatively small, its absolute magnitude is nearly 40 percent higher than electrification's response to higher GDP levels. Thus, the short answer for the policymaking community appears to be that they may dampen the electrification process in the long run if electricity prices are held artificially high by the inclusion of subsidies to some users and other social programs unrelated to the costs of providing power.

Alternative estimates allow some reverse causality between electrification and GDP, where electrification can stimulate economic growth. Under these conditions, all responses are lower than in the initial estimates. Electrification now declines by 16 percent (rather than 31 percent) below the mean value for all countries in the long run for each 100 percent increase in inflation-adjusted electricity prices. However, the response of electrification to GDP drops more precipitously, causing the absolute magnitude of the electricity price response to be 108 percent higher than the GDP response.

Policymaking may also include efforts to reduce electricity prices by removing subsidies or social programs that do not influence the marginal costs of generating and delivering power to the end user. The analysis finds that the effects of electricity price cuts are symmetric with the effects of electricity price rises, if one can assume that real GDP is an exogenous economic control. It is not unreasonable to expect that these conditions will hold for the wealthier economies evaluated in this study. If reverse causation between electrification and GDP levels is allowed, these two responses appear asymmetric. Electrification declines by 19 percent in the long run for each 100 percent increase in inflation-adjusted electricity prices, but expands by 13 percent in the long run for each 100 percent decrease in electricity prices.

It is hoped that this macro perspective will stimulate other more disaggregated efforts to evaluate individual power systems where costs exceed the marginal costs of providing power. Another useful extension would be to develop refinements in defining and measuring electrification that relies upon voltage capacity and other physical attributes of the electric power system and is less dependent upon electricity and energy consumption.

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Table 1. Electrification and Real Price Indices for Covered Countries

| | | Mean Levels | | | Mean Percent Changes | | |
|---|---|---|---|---|---|---|---|
| Country Code | Country | Electrifi-cation | Electricity Price | Energy Price | Electrifi-cation | Electricity Price | Energy Price |
| AUS | Australia | 12.2% | 81.8 | 89.2 | 0.98% | 1.33% | 0.66% |
| AUT | Austria | 13.3% | 94.8 | 91.5 | 0.97% | -0.03% | -0.06% |
| BEL | Belgium | 9.8% | 92.7 | 89.4 | 0.99% | 0.24% | 0.34% |
| CAN | Canada | 13.2% | 91.4 | 91.8 | 0.36% | 1.46% | 1.23% |
| CHE | Switzerland | 13.9% | 100.8 | 95.4 | 1.08% | -0.05% | -0.24% |
| CZE | Czech Republic | 11.2% | 74.4 | 74.3 | 0.88% | 1.49% | 2.56% |
| DEU | Germany | 11.6% | 72.9 | 80.8 | 1.02% | 1.00% | 0.52% |
| DNK | Denmark | 12.9% | 93.8 | 91.6 | 1.56% | 0.36% | 0.40% |
| ESP | Spain | 12.1% | 80.8 | 87.2 | 0.83% | 1.11% | 0.45% |
| EST | Estonia | 26.1% | 75.0 | 87.2 | 1.31% | 4.64% | 5.18% |
| FIN | Finland | 19.9% | 87.9 | 81.1 | 1.53% | 0.24% | 0.81% |
| FRA | France | 12.8% | 84.1 | 84.8 | 1.23% | 0.28% | 0.55% |
| GBR | United Kingdom | 11.3% | 79.1 | 80.7 | 0.92% | 0.88% | 0.85% |
| GRC | Greece | 12.2% | 83.1 | 82.6 | 1.25% | 0.08% | 0.07% |
| HUN | Hungary | 10.7% | 82.3 | 81.8 | 1.34% | 1.52% | 1.80% |
| IRL | Ireland | 12.1% | 76.6 | 83.2 | 1.30% | 1.02% | 0.62% |
| ITA | Italy | 12.2% | 80.3 | 83.7 | 1.26% | 1.18% | 0.84% |
| JPN | Japan | 14.5% | 92.3 | 90.5 | 1.06% | -0.15% | -0.24% |
| KOR | South Korea | 10.3% | 88.3 | 79.9 | 2.38% | -0.58% | -0.09% |
| LTU | Lithuania | 9.9% | 93.6 | 100.8 | 2.19% | 0.20% | 0.10% |
| LUX | Luxembourg | 10.9% | 115.0 | 90.5 | 0.89% | 0.05% | 0.34% |
| LVA | Latvia | 11.8% | 78.2 | 93.3 | 1.00% | 2.20% | 1.68% |
| MEX | Mexico | 8.3% | 95.9 | 75.2 | 2.20% | 1.24% | 2.76% |
| NLD | Netherlands | 8.2% | 101.0 | 85.9 | 1.29% | -0.19% | 0.90% |
| NOR | Norway | 20.3% | 118.2 | 101.8 | 0.47% | 1.14% | 1.10% |
| NZL | New Zealand | 15.1% | 77.6 | 90.1 | 0.13% | 0.92% | -0.01% |
| POL | Poland | 9.6% | 54.6 | 57.0 | 1.30% | 3.35% | 4.23% |
| PRT | Portugal | 13.2% | 92.0 | 89.1 | 0.86% | 0.38% | 0.19% |
| SVK | Slovak Republic | 11.1% | 66.0 | 69.4 | 1.22% | 2.82% | 3.42% |
| SVN | Slovenia | 14.2% | 97.5 | 94.6 | 0.75% | 0.75% | 1.40% |
| SWE | Sweden | 19.5% | 78.4 | 76.0 | 0.91% | 1.36% | 1.93% |
| TUR | Republic of Türkiye | 10.3% | 97.6 | 78.5 | 1.56% | -0.31% | 1.08% |
| USA | United States | 12.1% | 105.0 | 101.7 | 1.00% | -0.60% | -0.67% |
| | Mean | 12.9% | 87.4 | 85.8 | 1.15% | 0.89% | 1.05% |
| | High | 26.1% | 118.2 | 101.8 | 2.38% | 4.64% | 5.18% |
| | Low | 8.2% | 54.6 | 57.0 | 0.13% | -0.60% | -0.67% |

Notes: Electrification rates are electricity's share of total energy used (%).
Real price indices are in 2015 prices (=100).
Mean percent changes are average over full period (% per annum)

Table 2. Renewable intensity, Growth and Major Carbon Policies by Country

| Country Code | Country Name | Renewable (%) Percent | Growth (% p.a.) | Carbon Policies |
|---|---|---|---|---|
| AUS | Australia | 8.5% | 1.39% | No carbon tax; emissions trading for large users |
| AUT | Austria | 29.0% | 1.15% | EU ETS |
| BEL | Belgium | 4.7% | 7.09% | EU ETS |
| CAN | Canada | 21.9% | 0.17% | c tax (British Columbia), ets (Quebec), or hybrid |
| CHE | Switzerland | 20.1% | 1.61% | linked to EU ETS |
| CZE | Czechia | 9.5% | 5.05% | EU ETS |
| DEU | Germany | 8.6% | 6.86% | EU ETS |
| DNK | Denmark | 18.9% | 5.58% | EU ETS |
| ESP | Spain | 11.8% | 1.88% | EU ETS |
| EST | Estonia | 21.0% | 7.69% | EU ETS |
| FIN | Finland | 33.9% | 2.31% | EU ETS |
| FRA | France | 11.4% | 1.40% | EU ETS |
| GBR | United Kingdom | 3.7% | 9.22% | UK ETS; Carbon Price Support |
| GRC | Greece | 11.2% | 3.27% | EU ETS |
| HUN | Hungary | 9.4% | 4.41% | EU ETS |
| IRL | Ireland | 5.1% | 5.51% | EU ETS |
| ITA | Italy | 9.8% | 4.93% | EU ETS |
| JPN | Japan | 4.9% | 2.31% | c tax; regional ETS |
| KOR | Korea, Rep. | 1.5% | 2.62% | K-ETS; no formal c tax |
| LTU | Lithuania | 19.3% | 7.65% | EU ETS |
| LUX | Luxembourg | 6.2% | 8.03% | EU ETS |
| LVA | Latvia | 34.7% | 2.96% | EU ETS |
| MEX | Mexico | 11.1% | -0.33% | c tax; ets in progress |
| NLD | Netherlands | 3.8% | 7.48% | EU ETS |
| NOR | Norway | 58.6% | 0.12% | EU ETS |
| NZL | New Zealand | 27.7% | 0.10% | NZ ETS; no formal c tax |
| POL | Poland | 8.6% | 5.82% | EU ETS |
| PRT | Portugal | 24.8% | 0.58% | EU ETS |
| SVK | Slovak Republic | 8.1% | 6.76% | EU ETS |
| SVN | Slovenia | 17.3% | 2.07% | EU ETS |
| SWE | Sweden | 41.8% | 1.71% | EU ETS |
| TUR | Turkiye | 16.7% | -2.29% | establishing ets; no c tax |
| USA | United States | 6.8% | 3.08% | Regional ETS (Calif., RGGI for northeast); no c tax |
| | Average | 16.1% | 3.58% | |
| | High | 58.6% | 9.22% | |
| | Low | 1.5% | -2.29% | |

Source for Renewable Data is World Bank (2023).
Carbon policy notes: “ets” denotes emissions trading system; “c tax” denotes carbon tax.

Table 3. Summary Statistics for Demeaned Variables (logarithms)

| | Observations | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Electrification | 1174 | 0.000 | 0.073 | -0.328 | 0.265 |
| Electricity Price | 1174 | 0.000 | 0.146 | -0.944 | 0.414 |
| Energy Price | 1174 | 0.000 | 0.107 | -1.134 | 0.334 |
| Per-capita GDP | 1174 | 0.000 | 0.129 | -0.933 | 0.479 |
| Agriculture | 881 | 0.000 | 0.157 | -0.722 | 0.961 |
| Construction | 881 | 0.000 | 0.201 | -1.304 | 0.815 |
| Industry | 881 | 0.000 | 0.088 | -0.332 | 0.399 |
| Manufacturing | 881 | 0.000 | 0.106 | -0.403 | 0.449 |
| Services | 881 | 0.000 | 0.028 | -0.137 | 0.125 |

Notes: Each variable shows logarithmic level minus cross-sectional average across all countries for each year.

Table 4. Unit Root Tests for Variables

| Variable | Level | Difference | Lags |
|---|---|---|---|
| Electrification | -2.331*** | #N/A | 1 |
| Electricity Price | -0.585 | -14.546*** | 1 |
| Energy Price | -3.042*** | #N/A | 1 |
| Per-capita GDP | 1.204 | -13.696*** | 1 |
| Agriculture | -4.964*** | #N/A | 1 |
| Construction | -2.094** | #N/A | 2 |
| Industry | -0.205 | -13.788*** | 1 |
| Service | -3.766*** | #N/A | 1 |

Notes:
Im-Pesaran-Shin (2003) panel unit root test (W-t-bar statistics).
** $p < 0.05$, *** $p < 0.01$.
All variables are in logarithms.
Cross-sectional dependence adjustments are unnecessary as shown in Tables 5 and 6 below.

Table 5. Coefficients and Statistics for Symmetric Pooled Mean-Group Estimates

| | pmgy | pmgxy | pmgss | pmgyi |
|---|---|---|---|---|
| Error Correction (ec) | | | | |
| Per-Capita GDP | 0.225*** | | | 0.076** |
| | (0.020) | | | (0.027) |
| Electricity Price | -0.314*** | -0.168*** | -0.117*** | -0.158*** |
| | (0.024) | (0.030) | (0.028) | (0.030) |
| Energy Price | 0.303*** | 0.227*** | -0.147 | 0.097 |
| | (0.039) | (0.046) | (0.084) | (0.063) |
| Agriculture | | | 0.092*** | |
| | | | (0.023) | |
| Construction | | | -0.042 | |
| | | | (0.032) | |
| Industry | | | -0.390*** | |
| | | | (0.108) | |
| Services | | | -0.738* | |
| | | | (0.342) | |
| Short Run | | | | |
| ec term | -0.288*** | -0.273*** | -0.269*** | -0.330*** |
| | (0.045) | (0.032) | (0.051) | (0.049) |
| D.Per-Capita GDP | -0.016 | | | -0.049 |
| | (0.055) | | | (0.134) |
| D.Electricity Price | 0.076* | 0.040 | 0.083* | 0.096** |
| | (0.030) | (0.031) | (0.037) | (0.033) |
| D.Energy Price | -0.067 | -0.057 | -0.035 | -0.065 |
| | (0.052) | (0.049) | (0.060) | (0.059) |
| D.Agriculture | | | -0.061* | |
| | | | (0.028) | |
| D.Construction | | | -0.058 | |
| | | | (0.039) | |
| D.Industry | | | -0.093 | |
| | | | (0.130) | |
| D.Services | | | -0.267 | |
| | | | (0.405) | |
| Constant | 0.014 | 0.007 | -0.003 | 0.004 |
| | (0.017) | (0.016) | (0.017) | (0.019) |
| Observations | 1141 | 1141 | 848 | 829 |
| Log Likelihood | 2528.5 | 2501.4 | 2080.6 | 1977.4 |
| rmse | 0.031 | 0.032 | 0.025 | 0.027 |
| Bounds F-test | 15.24*** | 5.79*** | 11.35*** | 6.23*** |
| Bounds t-test | -6.36*** | -5.62*** | -5.24*** | -6.72*** |
| Ztbar | -23.164*** | -23.150*** | -19.146*** | -23.164*** |
| CD | 1.182 | 1.534 | 0.778 | 0.449 |
| CD_rho | 0.162 | 0.165 | 0.169 | 0.171 |

Notes:
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Estimates have not been adjusted for cross-sectional correlated errors because CD does not reject weak CS dependence and CD_rho is well below 0.5.

Table 6. Coefficients and Statistics for Asymmetric Pooled Mean-Group Estimates

| | pmgya | pmgyia |
|---|---|---|
| Error Correction (ec) | | |
| Per-Capita GDP | 0.230*** | 0.108*** |
| | (0.023) | (0.025) |
| Price Rises | -0.299*** | -0.192*** |
| | (0.024) | (0.026) |
| Price Cuts | -0.285*** | -0.132*** |
| | (0.027) | (0.027) |
| Energy Price | 0.275*** | 0.150** |
| | (0.041) | (0.052) |
| SR | | |
| ec term | -0.291*** | -0.358*** |
| | (0.046) | (0.055) |
| D.Per-Capita GDP | -0.027 | -0.021 |
| | (0.057) | (0.148) |
| D.Price Rises | 0.046 | 0.084 |
| | (0.041) | (0.045) |
| D.Price Cuts | 0.108* | 0.139 |
| | (0.045) | (0.074) |
| D.Energy Price | -0.080 | -0.080 |
| | (0.059) | (0.058) |
| constant | 0.022 | 0.028 |
| | (0.021) | (0.022) |
| Observations | 1141 | 829 |
| Log Likelihood | 2548.3 | 2004.8 |
| rmse | 0.031 | 0.026 |
| Bounds F-test | 14.38*** | 8.81*** |
| Bounds t-test | -6.31*** | -6.53*** |
| Ztbar | -22.686*** | -19.672*** |
| CD | 1.097 | 1.168 |
| CD_rho | 0.159 | 0.175 |

Notes:

* p < 0.10, ** p < 0.05, *** p < 0.01.

Estimates have not been adjusted for cross-sectional correlated errors because CD does not reject weak CS dependence and CD_rho is well below 0.5.

Table A.1. Country Coverage in Each Data Set

| | Without Sectors | | With Sectors | |
|---|---|---|---|---|
| Country | Begin | End | Begin | End |
| Australia | 1980 | 2019 | 1989 | 2019 |
| Austria | 1980 | 2019 | 1989 | 2019 |
| Belgium | 1980 | 2019 | 1995 | 2019 |
| Canada | 1980 | 2019 | 1997 | 2019 |
| Czechia | 1993 | 2019 | 1993 | 2019 |
| Denmark | 1980 | 2019 | 1989 | 2019 |
| Estonia | 1997 | 2019 | 1997 | 2019 |
| Finland | 1980 | 2019 | 1989 | 2019 |
| France | 1980 | 2019 | 1989 | 2019 |
| Germany | 1991 | 2019 | 1991 | 2019 |
| Greece | 1980 | 2019 | 1995 | 2019 |
| Hungary | 1991 | 2019 | 1995 | 2019 |
| Ireland | 1980 | 2019 | 1995 | 2019 |
| Italy | 1980 | 2019 | 1990 | 2019 |
| Japan | 1980 | 2019 | 1994 | 2019 |
| Latvia | 1997 | 2019 | 1997 | 2019 |
| Lithuania | 2007 | 2019 | 2007 | 2019 |
| Luxembourg | 1988 | 2019 | 1995 | 2019 |
| Mexico | 1980 | 2019 | 1993 | 2019 |
| Netherlands | 1980 | 2019 | 1989 | 2019 |
| New Zealand | 1980 | 2019 | 1989 | 2019 |
| Norway | 1980 | 2019 | 1989 | 2019 |
| Poland | 1989 | 2019 | 1995 | 2019 |
| Portugal | 1980 | 2019 | 1995 | 2019 |
| Slovakia | 1993 | 2019 | 1995 | 2019 |
| Slovenia | 2000 | 2019 | 2000 | 2019 |
| South Korea | 1980 | 2019 | 1989 | 2019 |
| Spain | 1980 | 2019 | 1995 | 2019 |
| Sweden | 1980 | 2019 | 1989 | 2019 |
| Switzerland | 1980 | 2019 | 1990 | 2019 |
| Turkiye | 1980 | 2019 | 1998 | 2019 |
| United Kingdom | 1980 | 2019 | 1990 | 2019 |
| United States | 1980 | 2019 | 1997 | 2019 |

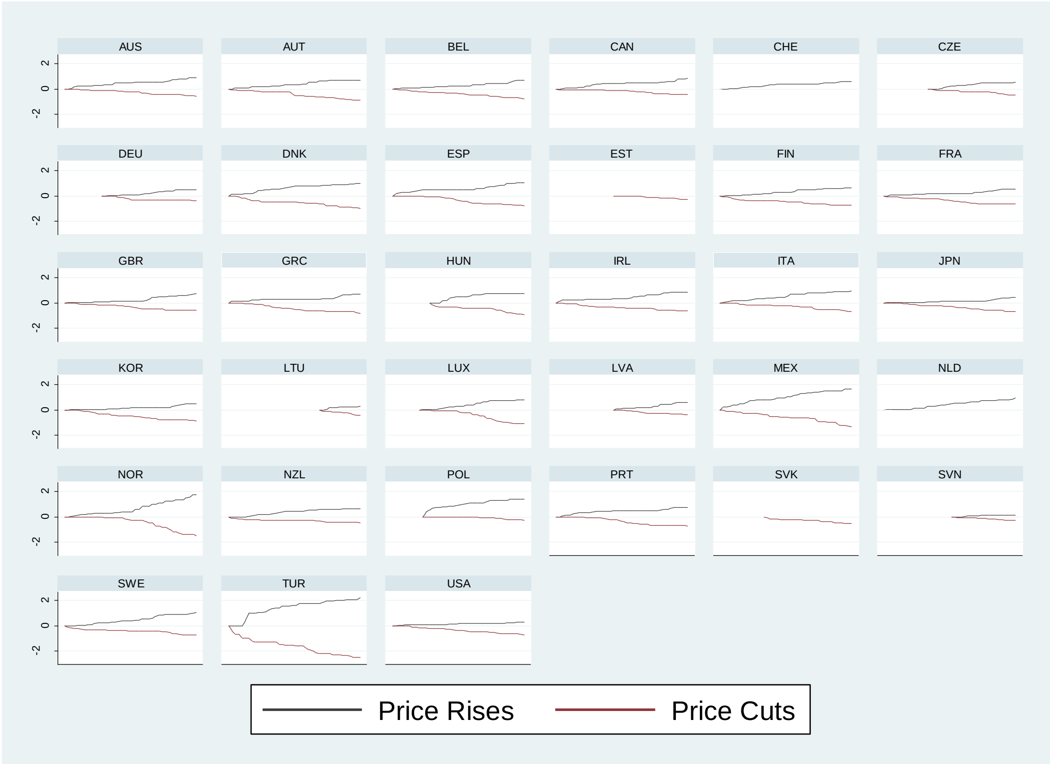


Figure 1. Price Rises and Cuts Over Years by Country