Potential Employment and Output Leakage Under California's Cap-and-Trade Program

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Outline

- Introduction
- Methodology
- Data
- Short- and Long-Run Estimation
- Simulation Results
- Conclusions and Caveats

What is Leakage?

- Movement of emissions (and economic activity) from high to low regulatory cost areas
- Leakage implies economic costs (e.g., lower employment) without reducing global emissions
- Regional programs generally more prone to leakage than national-level ones, although Calif. is world's 7th or 8th largest economy
- **Study goal: to estimate potential leakage (employment, output, and value added) for Calif. industries**

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Literature

- Extensive modeling (Fischer, Fox; Ho et.al., others), limited empirical work
- Kahn and Mansur (2013) model effects of county-specific electricity prices on employment
  - Elasticity (sensitivity) is the percent employment change in response to a 1 percent price increase
  - Their estimates range from -0.15 to -1.17
- Aldy and Pizer (2015) model effects of energy prices on national level output; highest output elasticity = -0.4

Methodological Approach to Complex Problem

- Studying the effect of energy prices on economic activity is one way to model the potential impacts
- Develop statistical model tailored to Calif. program
- Impacts tied to historical changes in Calif. electricity and natural gas price vs non-Calif. prices
- Plant-level analysis at 6-digit NAICS level
- Outcomes: output, employment, value added
- Methodology maps directly to potential effects of Calif. carbon prices on relative energy prices inside and outside Calif.
- Simulate Calif. carbon prices to estimate potential impacts

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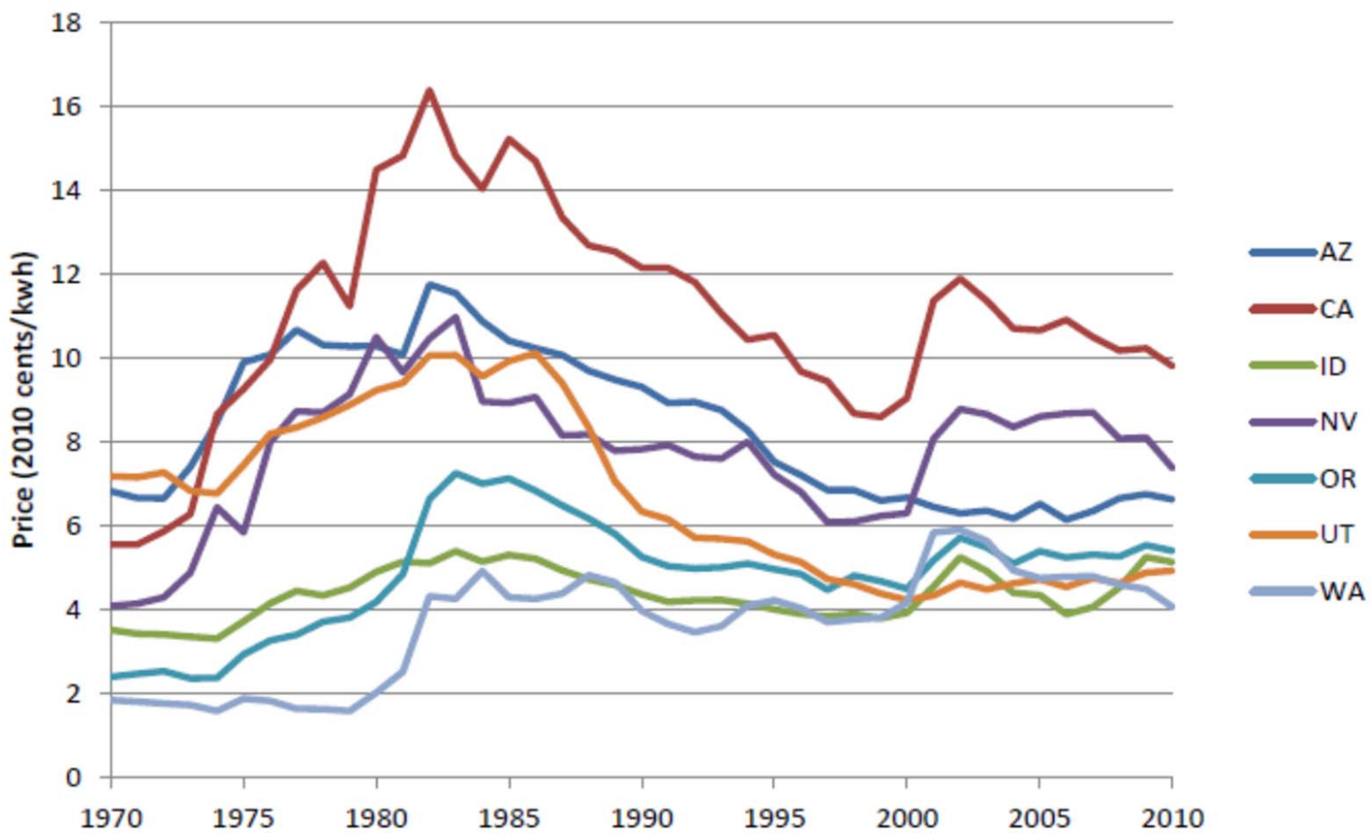
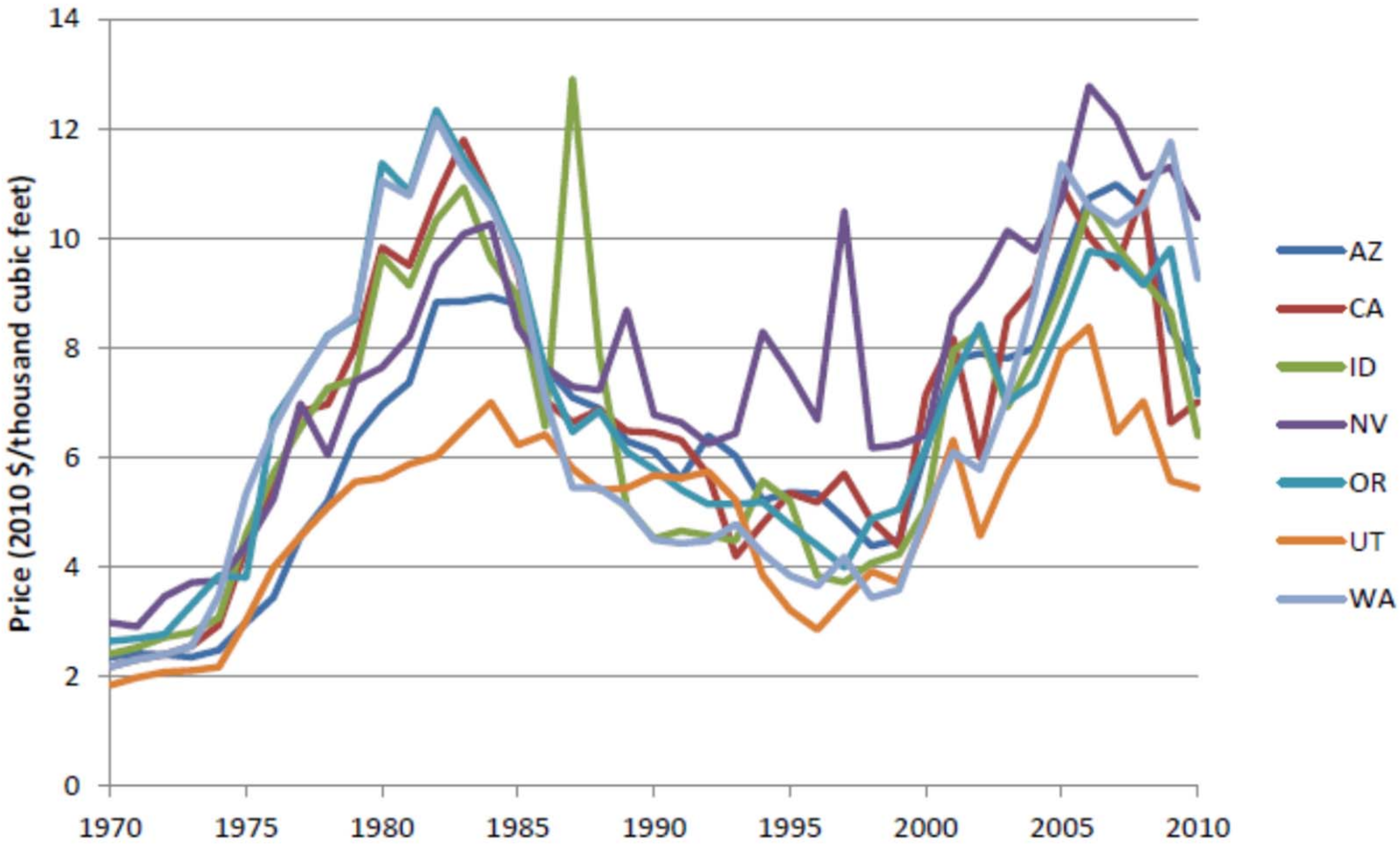
Figure 1: Real Electricity Prices for Industrial Customers



Source: EIA

Figure 2: Real Natural Gas Prices for Industrial Customers



Source: EIA

Conceptual Framework

- Plants compete with one another to sell output into regional product markets
- A plant's production or employment depends on energy prices it faces compared to energy prices its competitors face
- We expect a change in relative energy prices to have larger effects on energy-intensive plants

$$\ln(y) = \beta_1 s * \ln(p) + \beta_2 s * \ln(p_R) \qquad (1)$$

y = output, employment, or value added (VA)
s = energy cost share
p = price of energy for Calif. plant
p_R = price of energy for non-Calif. plant
β_1 = Output/empl/VA elasticity with respect to energy price
β_2 = Output/empl/VA elasticity with respect to energy price of competing plants

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Econometric Models

- Generalizing equation (1)
  - Estimate a single regression that includes all plants in continental US
  - Separate energy prices into electricity and natural gas prices, which are directly affected by Calif. carbon price
  - Assign each industry to one of five electricity and natural gas cost share groups
    - Within a group, prices affect outcomes proportionately to industry cost share
    - Effects can vary freely across groups, allowing for (potentially) nonlinear effects of energy prices for the most energy-intensive industries
  - In addition to plant's and competitors' energy prices, we control for local labor costs and product demand, as well as aggregate demand or supply shocks at industry or regional levels
- Estimating short- and long-run models
  - Sample includes all US plants in 49 industries
  - Short-run model uses annual observations
  - Long-run model uses five-year intervals, regressing changes in outcomes on changes in energy prices and other variables

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Addressing Potential Concerns about Energy Prices and Cost Shares

- Energy prices
  - Assume that retail energy prices are uncorrelated with productivity or other features of the plant
  - Energy prices may be correlated with macroeconomic activity or product demand
    - Industry-year and region-year controls address correlation with industry or regional demand
    - Also control for plant-level product demand using input-output relationships between industries
- Energy cost shares
  - Cost shares may be correlated with plant attributes or respond to energy prices
  - We use industry-average cost shares that are computed at the beginning of the sample, both for estimation and simulation

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How Do We Expect Energy Prices to Affect Plant Outcomes?

- Competition among plants suggests that a plant’s energy prices should have a negative effect on activity and competitors’ prices a positive effect
- Expect larger effects for plant-level than national analysis
- Expect larger responses for more energy-intensive industries
  - ➢ Simple production function model suggests that elasticity of output to energy price equals energy cost share
  - ➢ For an industry with a natural gas cost share of 10 percent, a 10 percent natural gas price increase would reduce output by 1 percent
- Long-run responses may be smaller in magnitude than short-run responses
  - ➢ Many plants can respond to an energy price increase by replacing old/inefficient capital equipment
  - ➢ We have also tested potential effects of energy prices on plant exit

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Plant-level Data

- Census of Manufacturers (5 years): 1992-2007
- Annual Survey of Manufacturers: 1989-2009
- Non-Calif. plants compete based on distance from Calif. plants: 250, 500, 100 miles (Longitudinal Business Database)
- Focus on NAICS industries identified by CARB
- Sample sizes:
  - Short-run analysis = 170,000
  - Long-run analysis = 36,000

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Key Definitions

- Labor cost index: Calif. vs non-Calif., industry-specific wage rates (500 mi radius; minus own plant), reflecting local labor market conditions
- Demand growth index: based on ‘using’ industries’ output growth, and reflects local product demand (we separately control for industry-level product demand)
- Industry energy groups: 5 groups of industries, based on electricity or natural gas intensity

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Short-Run Estimates

- Most electricity and natural gas cost shares <1%; standard benchmark is that elasticity equals cost share
- Some natural gas cost shares exceed 5%: paperboard, industrial gas, fertilizer, flat glass, glass container, lime, and mineral wool.
- Highest electricity cost share is 5.6% (industrial gas)
- Most energy price elasticities negative and statistically significant
- Short-run elasticities highly correlated across outcomes
- Short-run elasticities similar to Kahn/Mansur; slightly larger than Aldy/Pizer

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Figure 3: Short-Run Electricity Elasticities

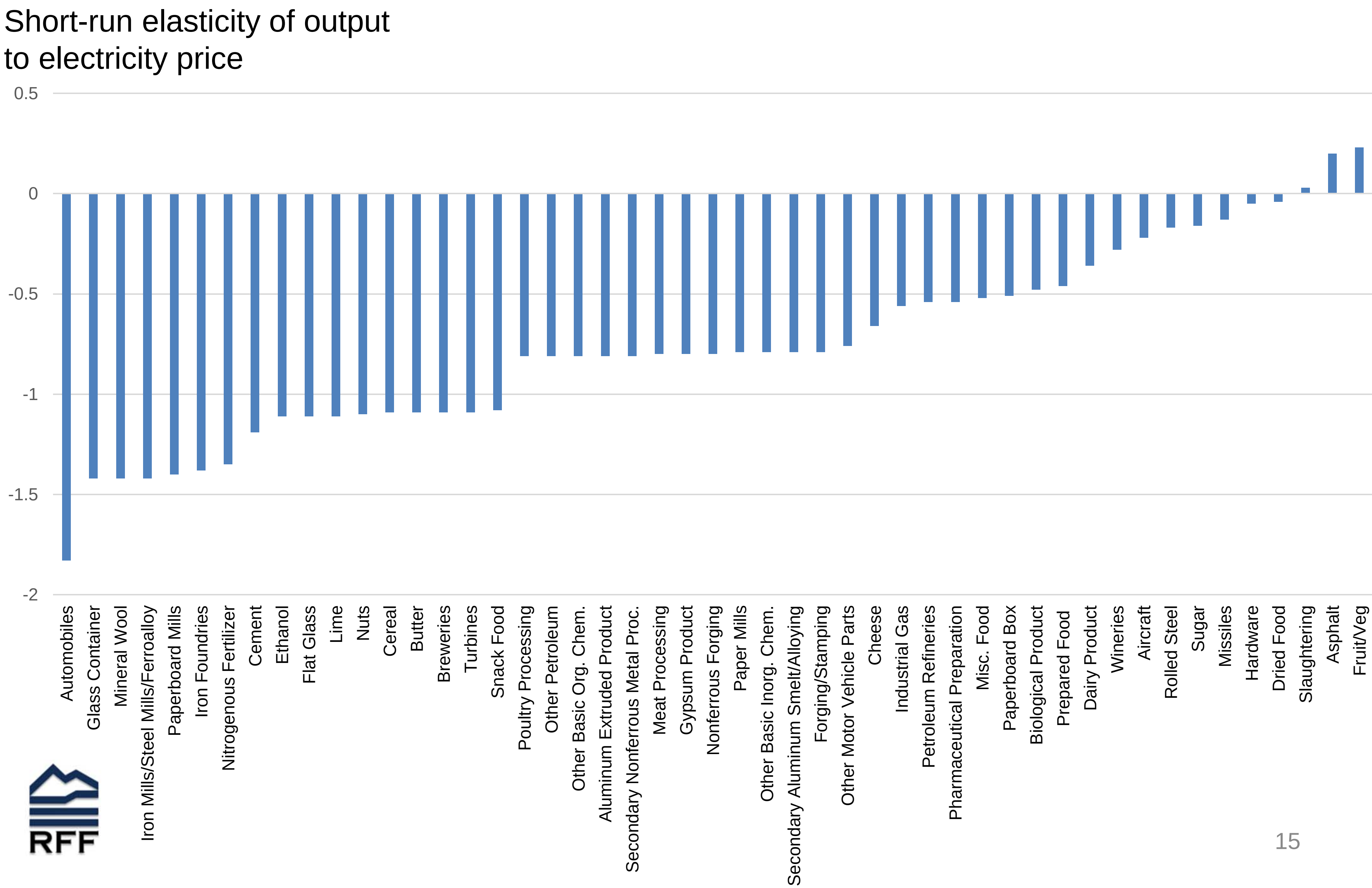

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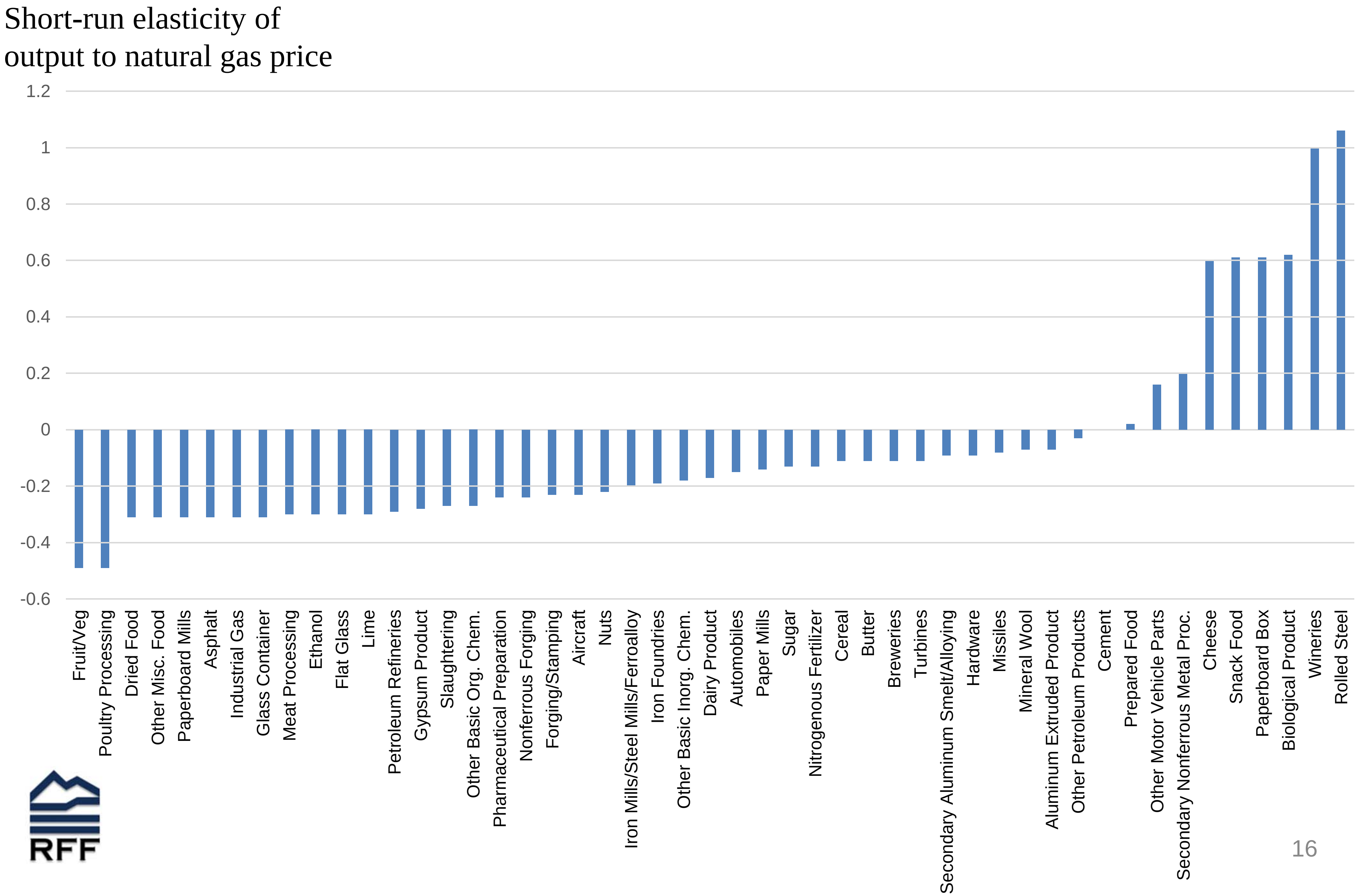
Figure 4: Short-Run Natural Gas Elasticities



Long-Run Estimates

- Similar patterns to short run, although with smaller negative values
- More industries have positive long-run elasticities (most not statistically significant)
- Average long-run elasticities less than -0.10 (in magnitude)

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Figure 5: Long-Run Electricity Elasticities

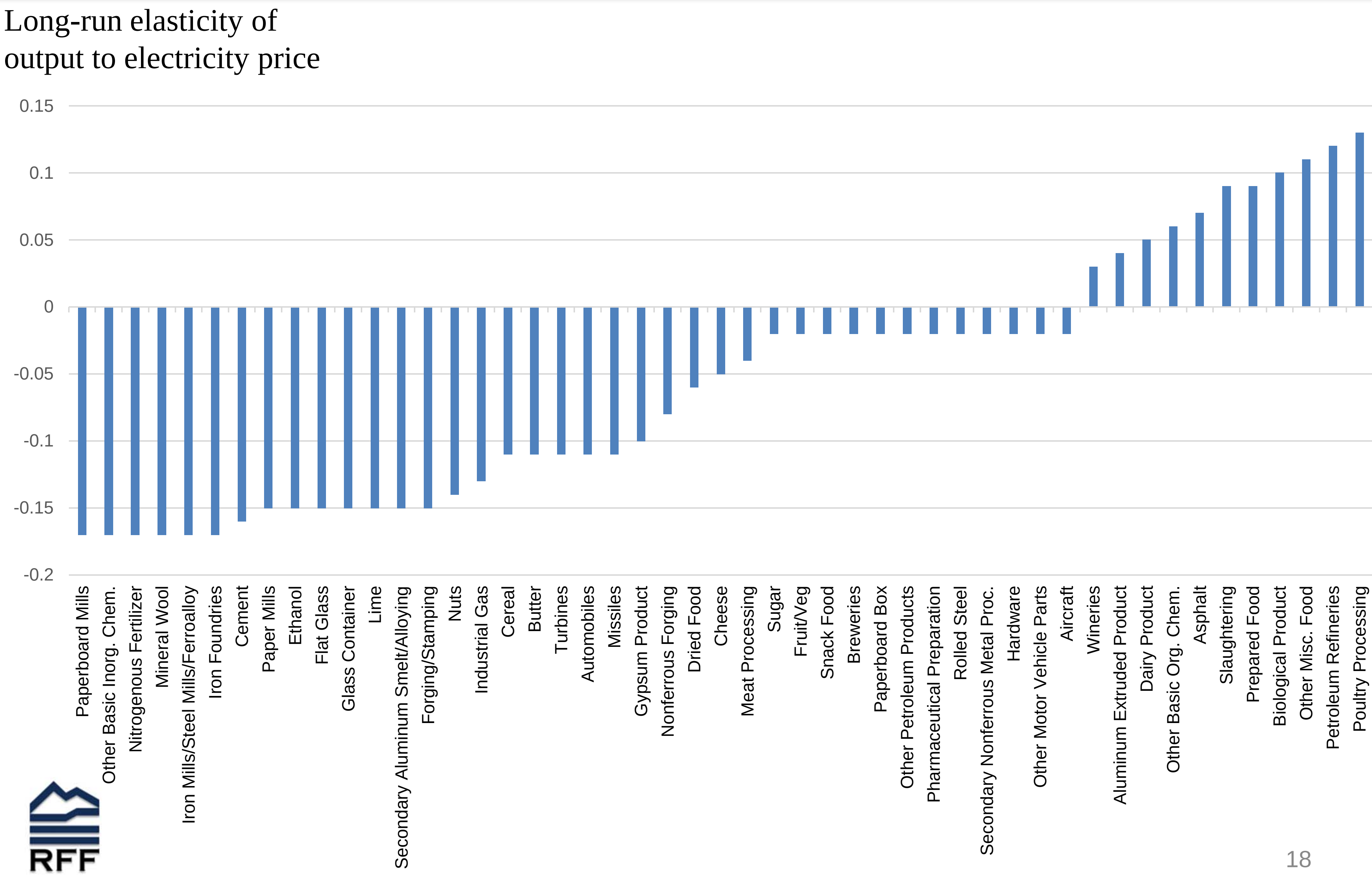

Figure 6: Long-Run Natural Gas Elasticities

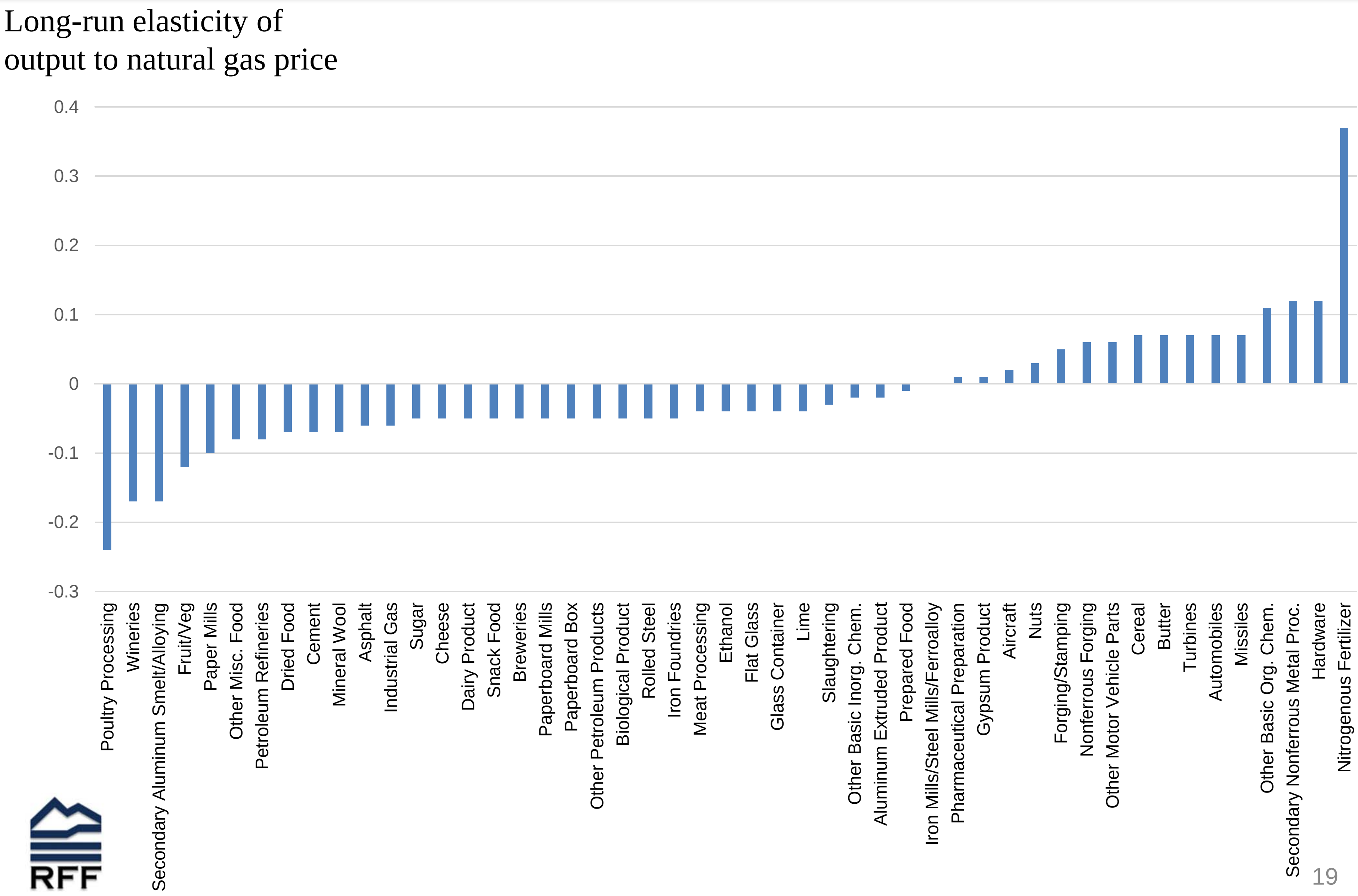

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Figure 7: Short-Run Energy Price Elasticities vs. Energy Cost Shares

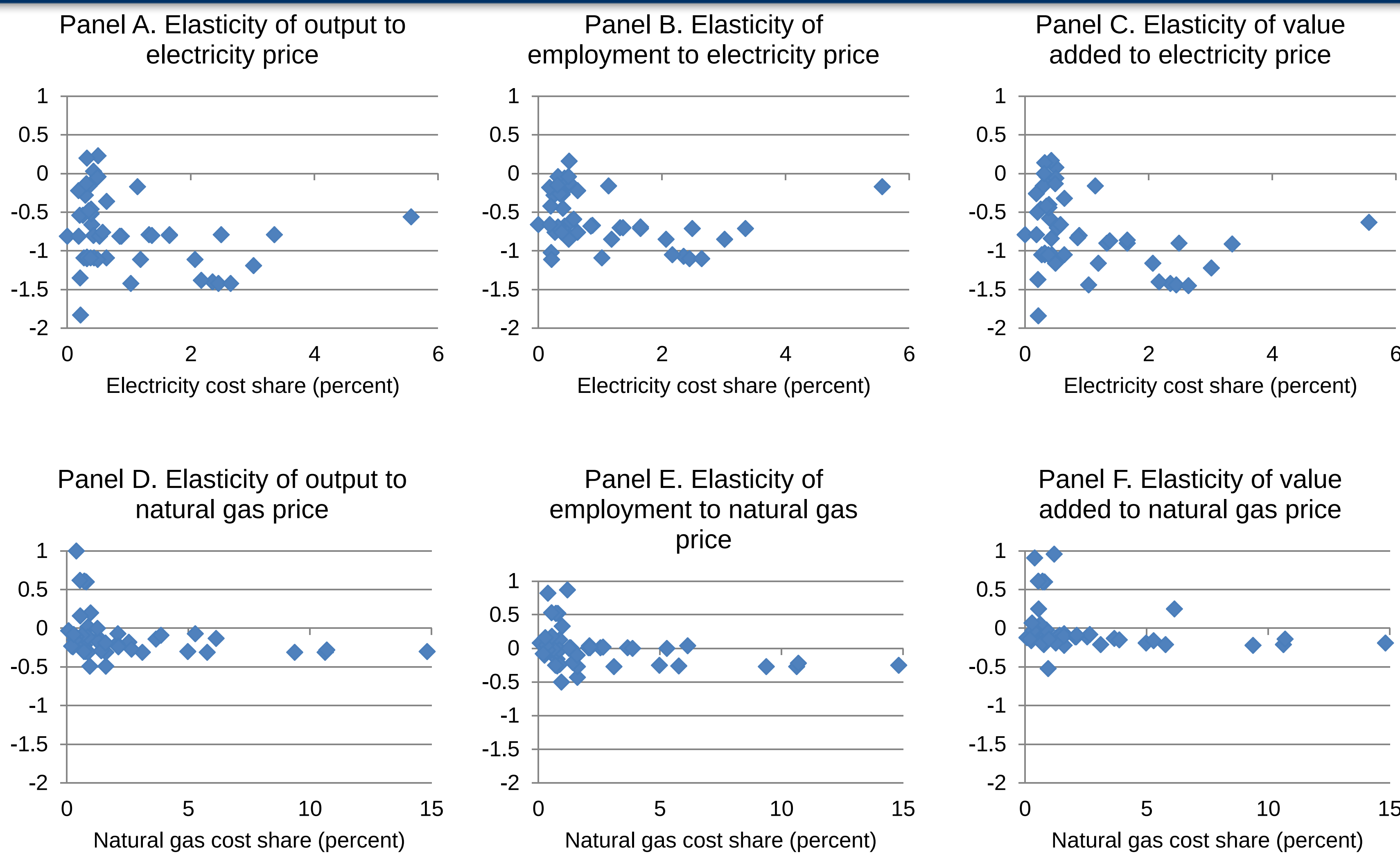

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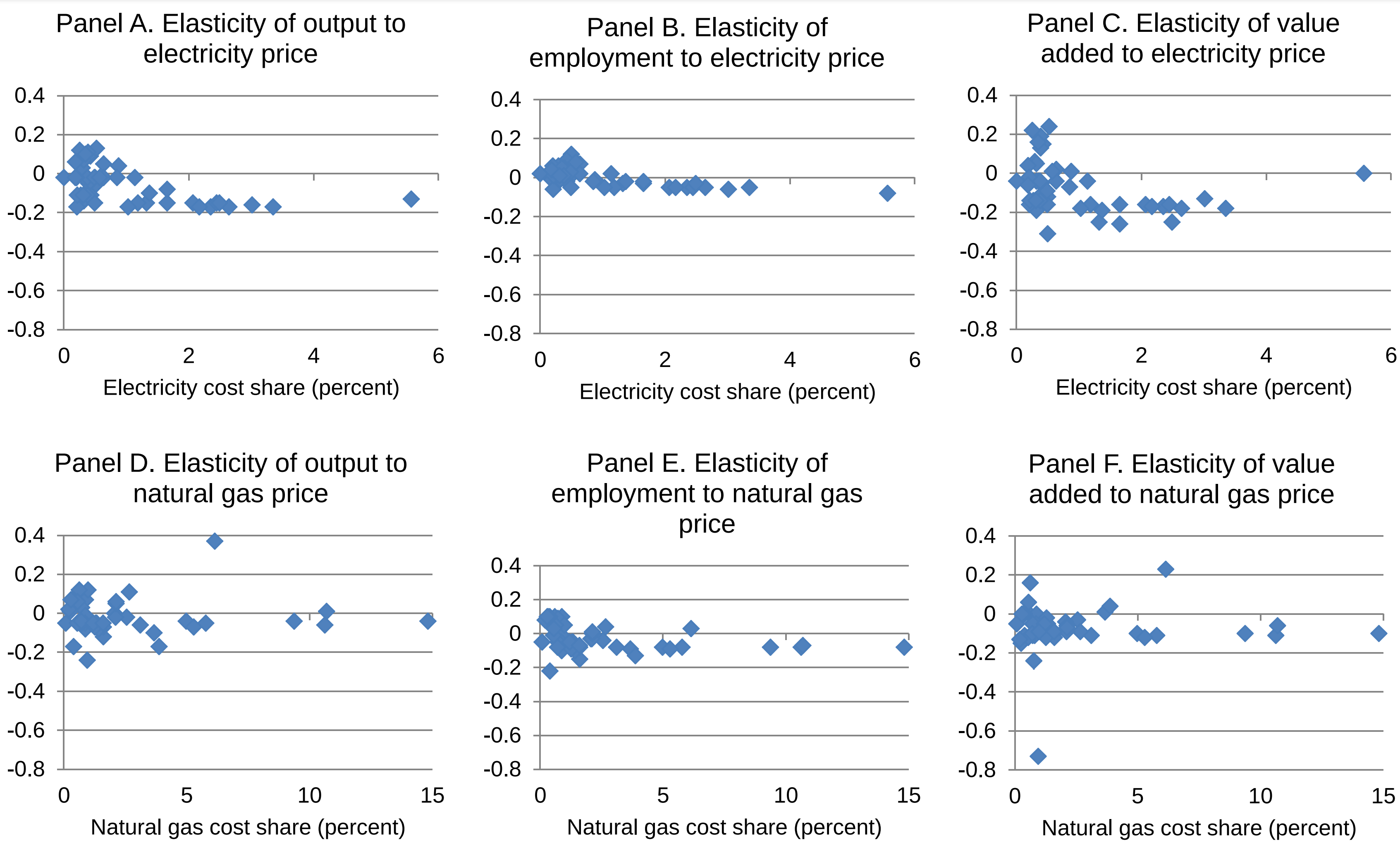
Figure 8: Long-Run Energy Price Elasticities vs. Energy Cost Shares



Simulations

- With \$10/metric ton CO_2 and full pass through, Calif. electricity prices rise 4.2%; natural gas prices rise 8.6%
- Non-Calif. prices held constant at 2009 levels
- Because regressions include year fixed effects, output/empl/VA held constant at 2009 levels
  - ➢ Interpret results as changes in Calif. output/empl/VA *relative to* other regions (not *absolute* changes)
- Simulation with a carbon price based on new energy prices (and no free allocation)
- Simulation without a carbon price based on observed 2009 energy prices
- Aggregate Calif. (and non-Calif.) plants by industry, rescale to maintain national output fixed for both scenarios

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Figure 9: Short-Run Output Results

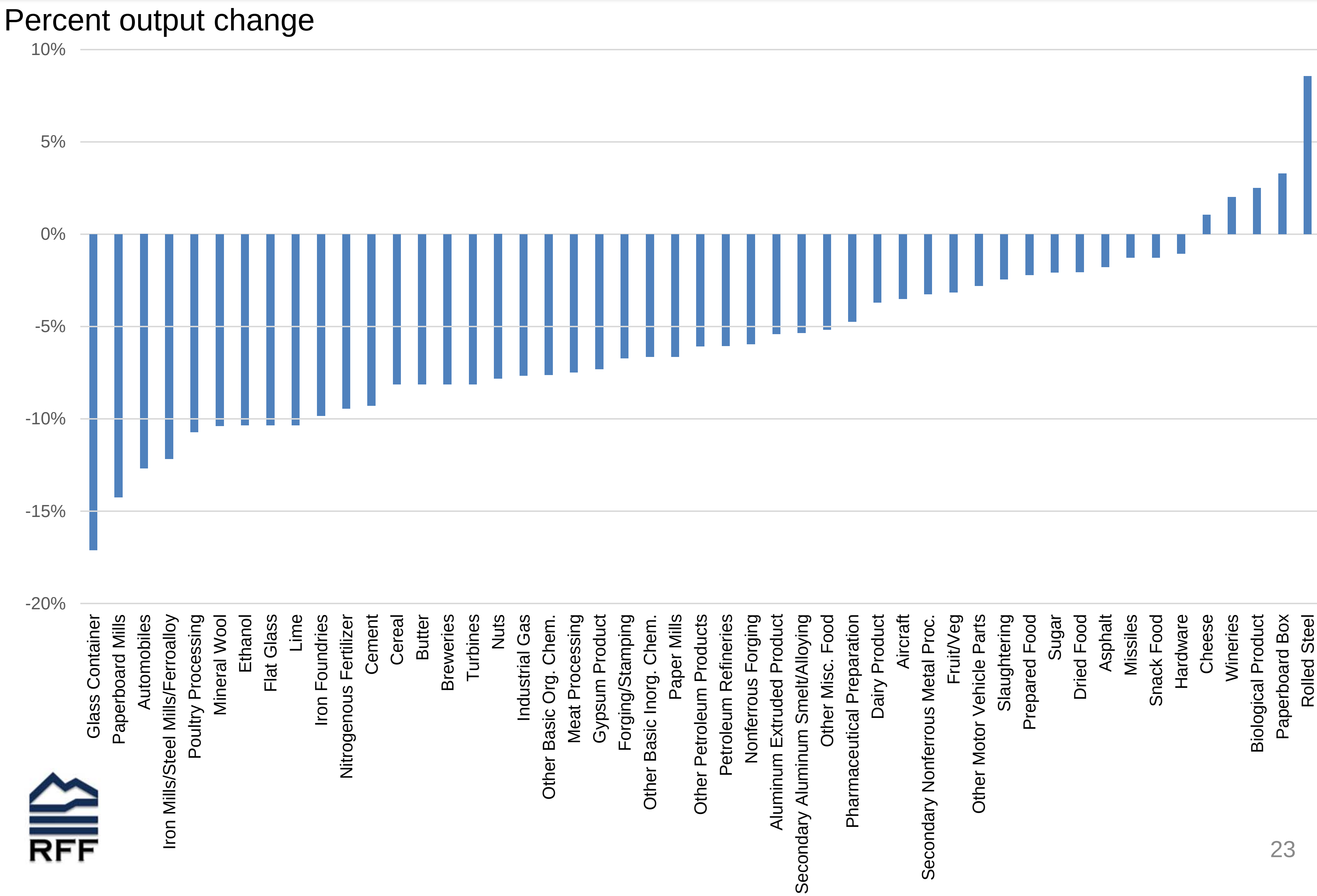

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Figure 10: Long-Run Output Results

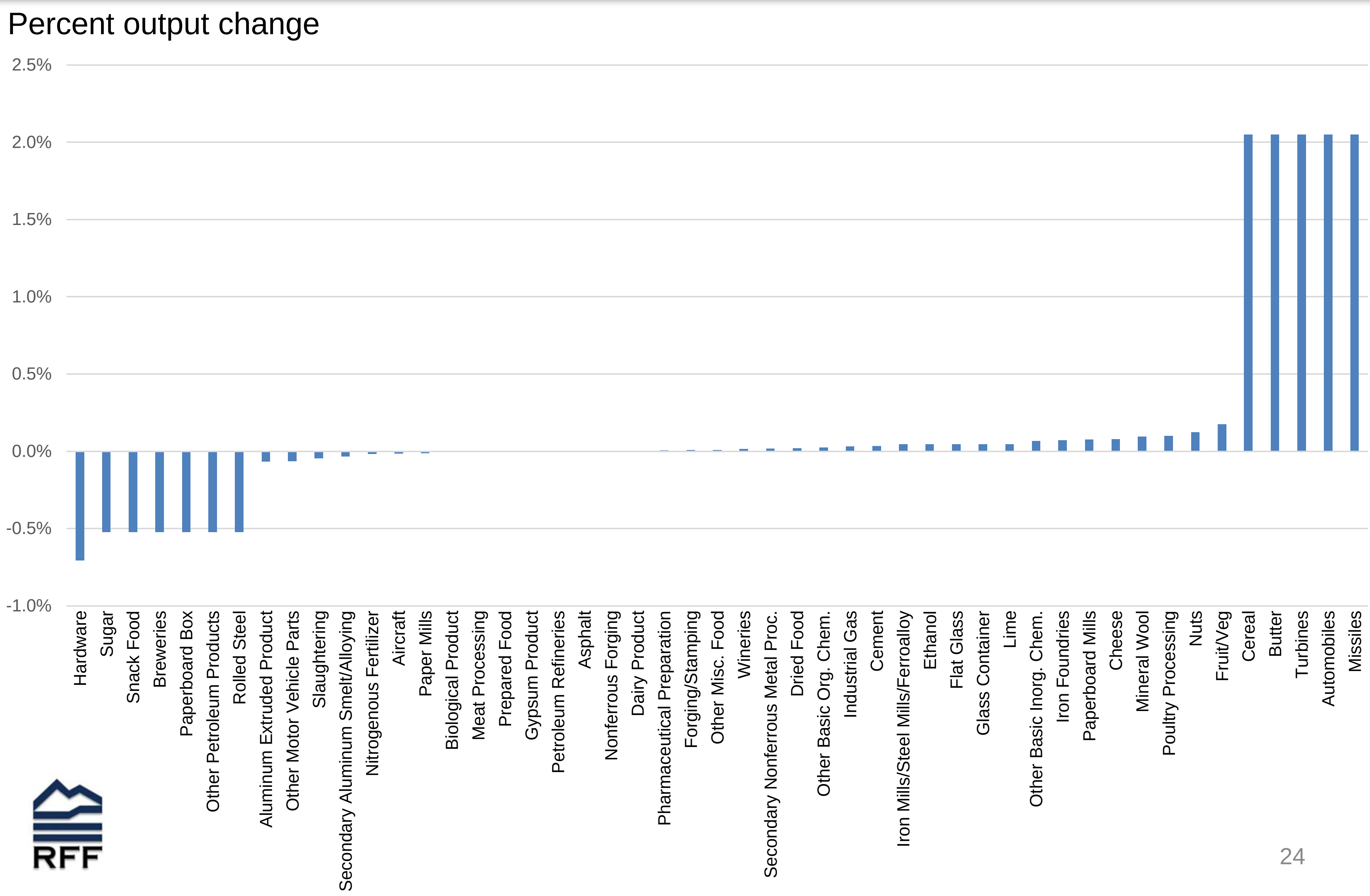

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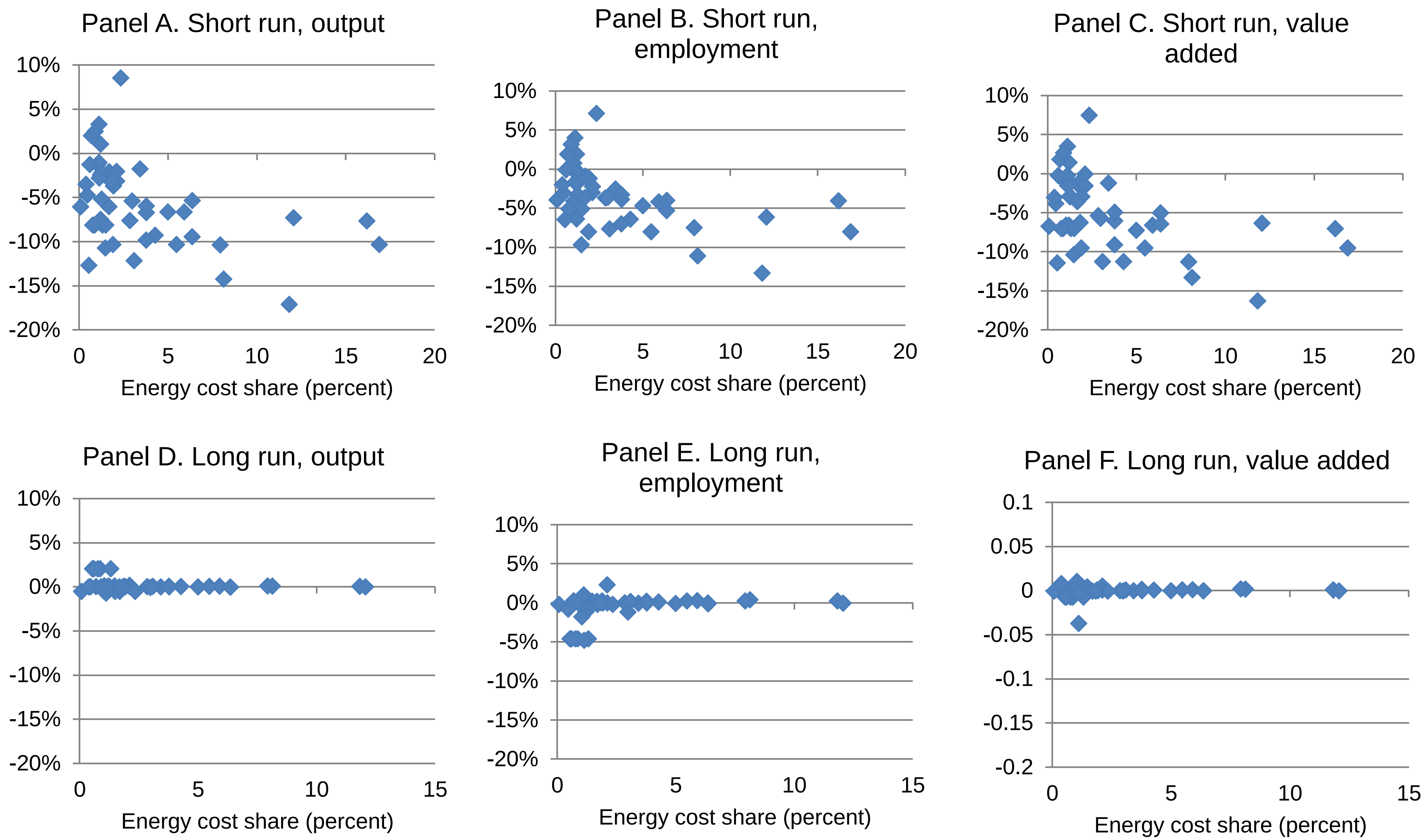
Figure 11: Simulated Short- and Long-Run Percent Changes vs. Energy Cost Shares



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Sensitivity Analysis

- Variations of estimation model based on number of industry groups, definition of cost shares, and distance of competing plants
- Small differences and high correlations across short-run models; larger differences across long-run models

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Exit Analysis

- Estimate linear probability model using long-run data set
  - Average exit of 0.5 plants per industry with \$10/metric ton CO_2
  - Expressed as percentages, impact of exit on output/empl/VA below 1% for most industries; never more than 3%
  - Elasticity of exit rate with respect to electricity prices positive in most cases for electricity; often negative for natural gas

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Conclusions

- Historical sensitivity of Calif. facilities to differences between Calif. and non-Calif. energy prices is one means of studying complex effects of Calif. Cap-and-Trade Program
- $10/metric ton CO_2 price in Calif. and zero elsewhere with no rebates will likely result in short-run (one-year) losses in output, employment and value added of 4-6 percent among Calif. industries; but up to 3x that average in the most affected industries
- For CO_2 allowance prices up to $22.62, losses are larger, approximately in proportion to carbon price
- Short-run results for a few industries are much larger than expected, suggesting caution for those industries

Conclusions and Caveats

- Long-run impacts are smaller, although we offer additional caution compared to short run when interpreting industry-specific long-run results
- Caveats
  - Impacts overstated if compliance costs not fully passed through to end users
  - Impacts understated if national output levels decline with Calif. reductions
  - Impacts understated for industries with large amounts of process non CO_2 emissions, such as fertilizer, lime, industrial gases, non-ferrous smelting

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Thank You

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