



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

Outline

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



Disclaimer: Opinions expressed in this presentation are those of the authors and do not necessarily represent the views of the California Air Resources Board or the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed.

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**

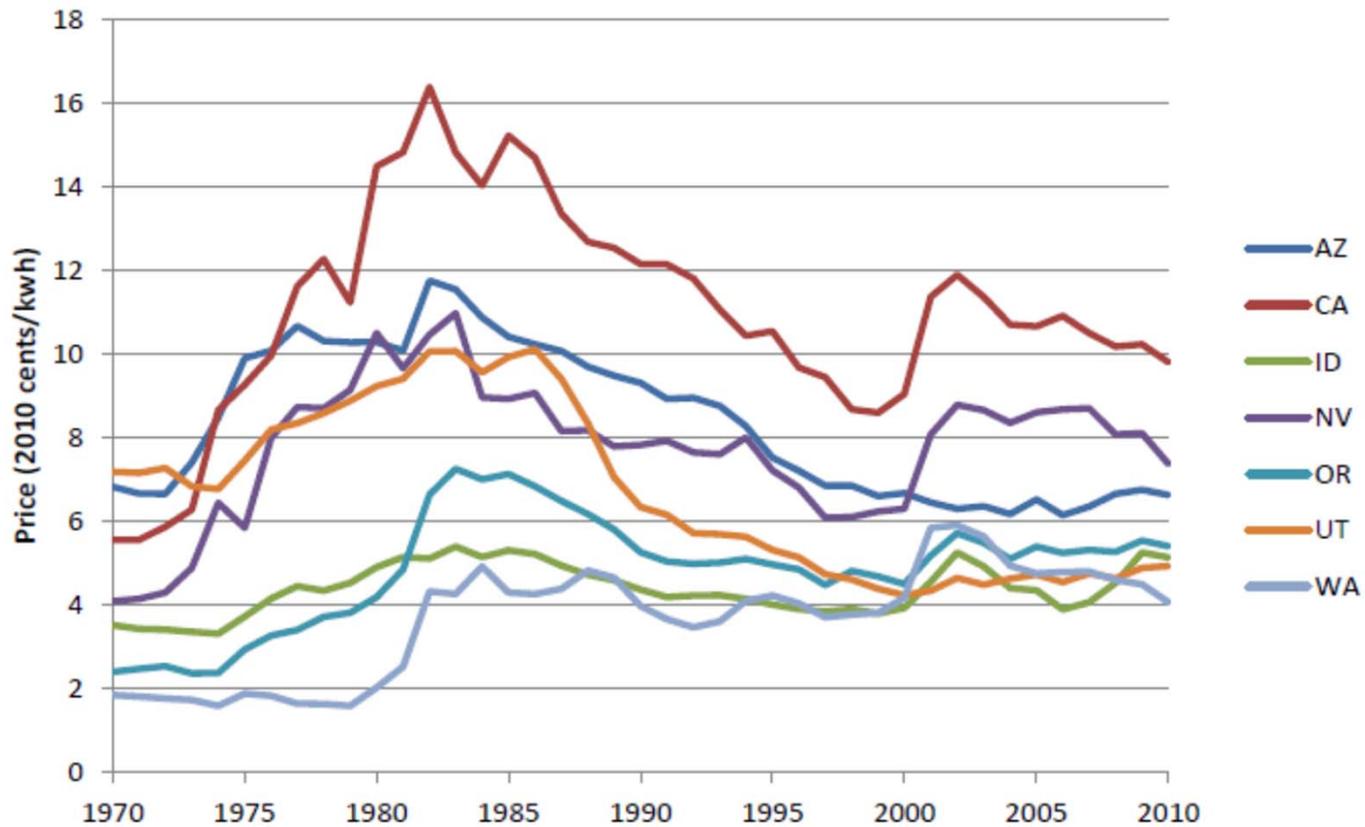
Literature

- 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

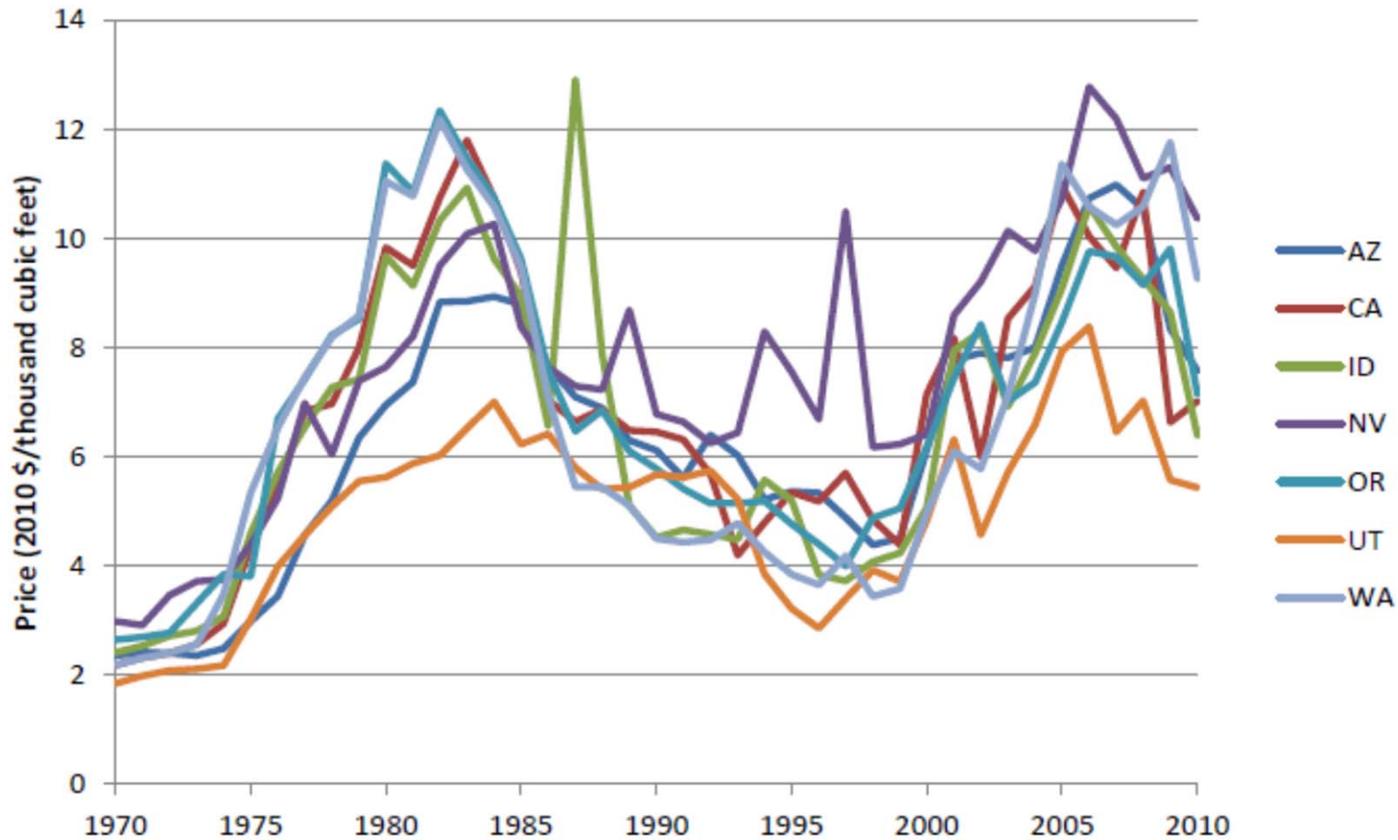
Figure 1: Real Electricity Prices for Industrial Customers



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

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

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

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

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

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

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

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

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

Figure 3: Short-Run Electricity Elasticities

Short-run elasticity of output to electricity price

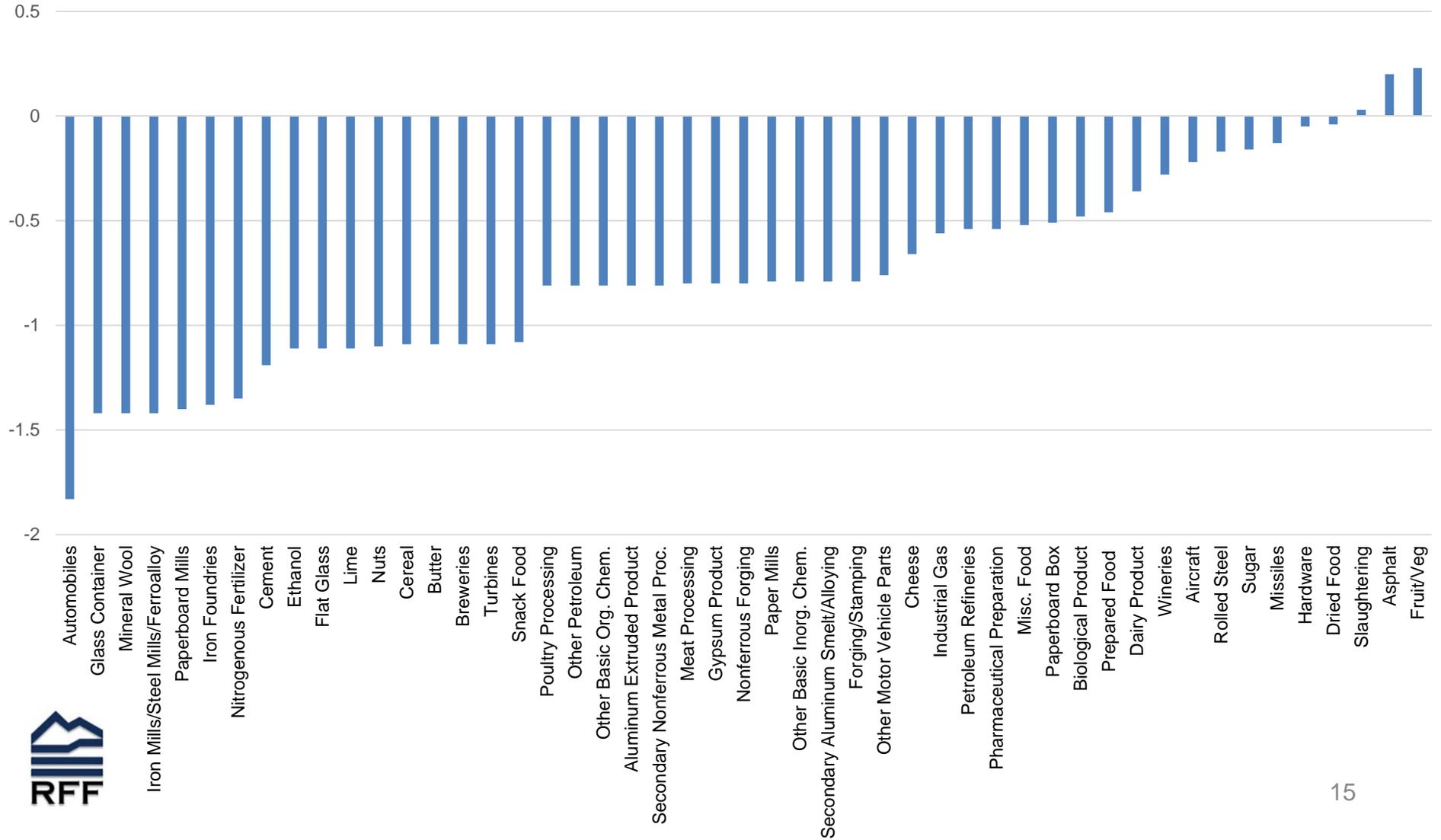
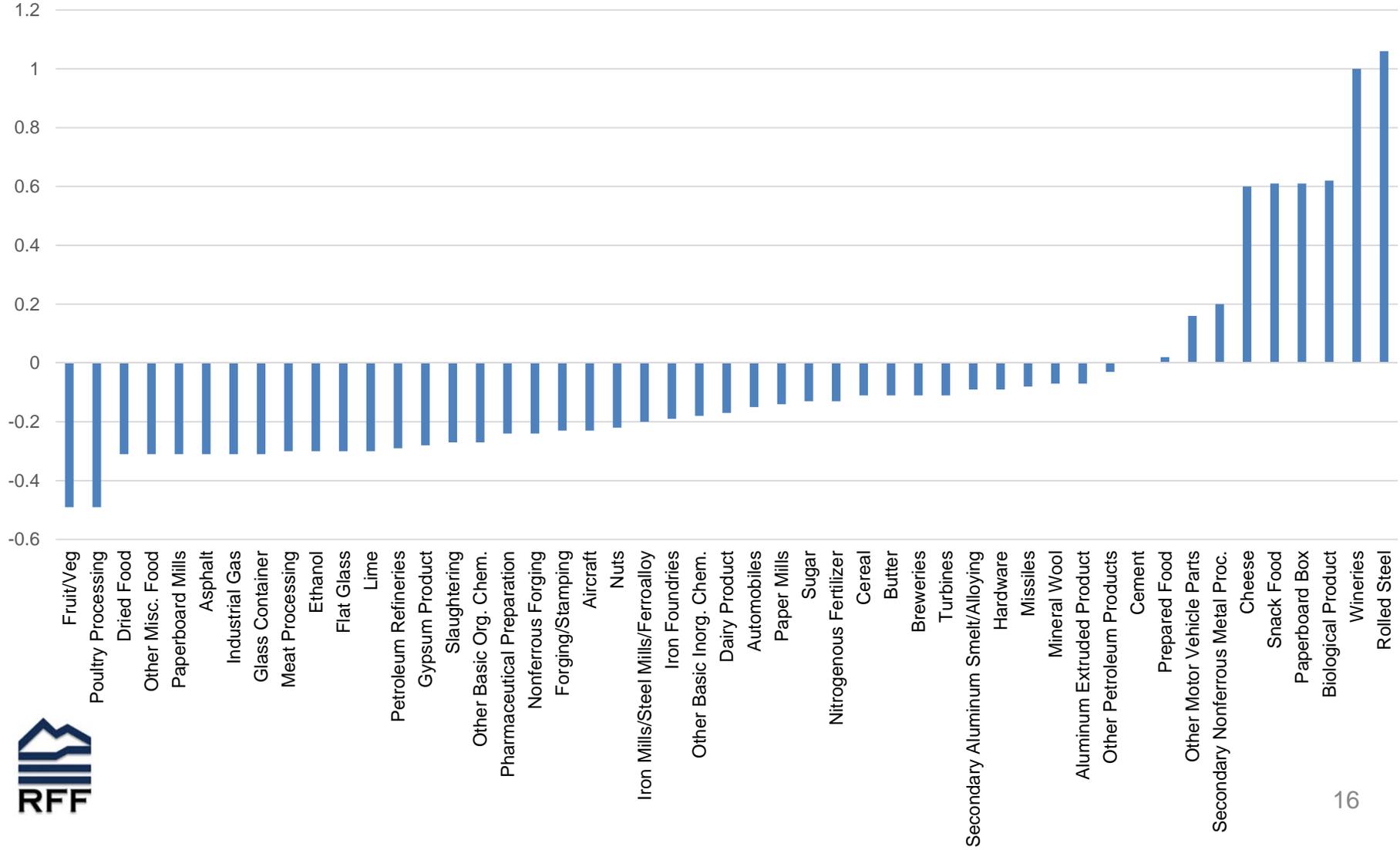


Figure 4: Short-Run Natural Gas Elasticities

Short-run elasticity of output to natural gas price



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)

Figure 5: Long-Run Electricity Elasticities

Long-run elasticity of output to electricity price

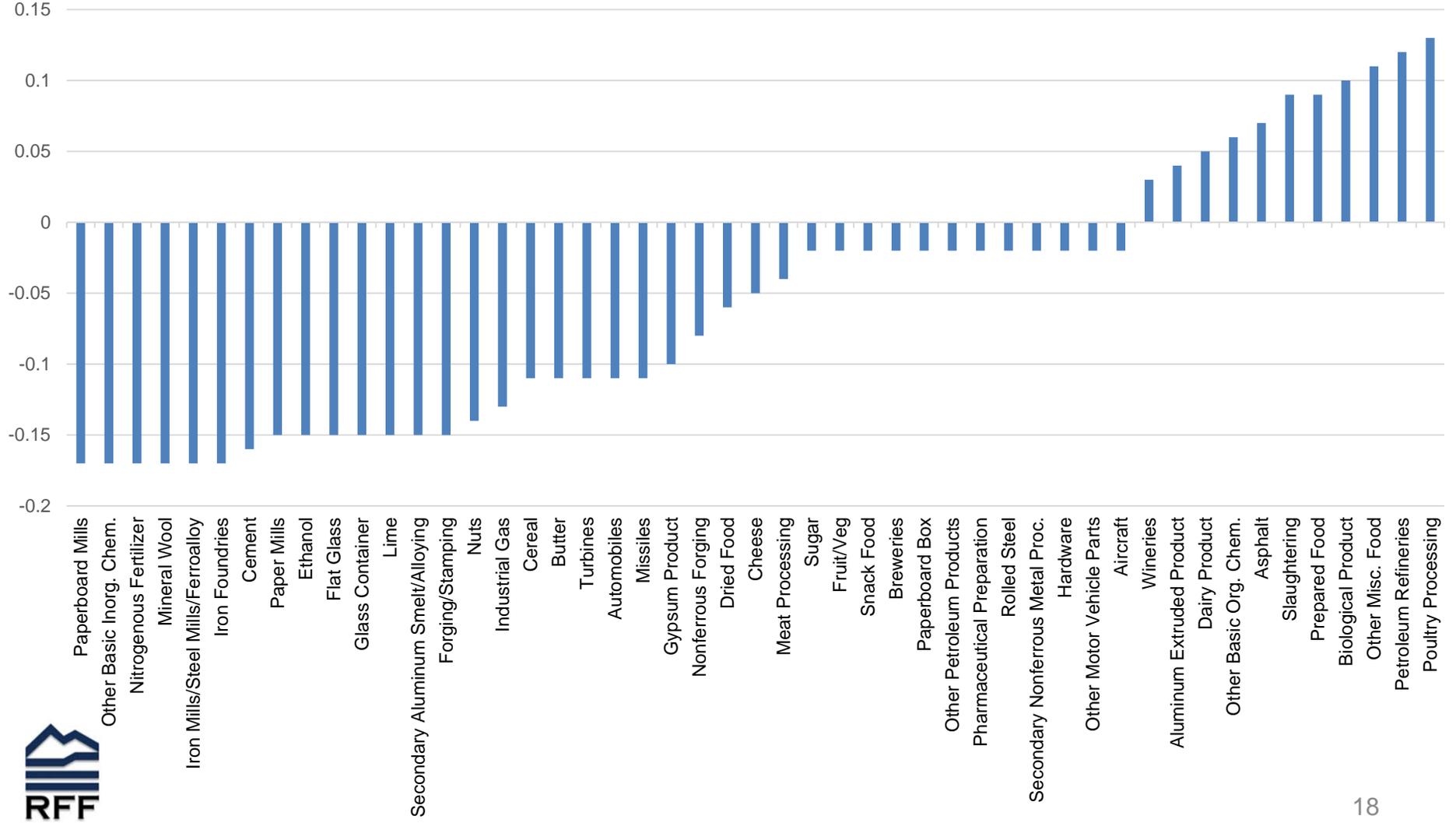


Figure 6: Long-Run Natural Gas Elasticities

Long-run elasticity of output to natural gas price

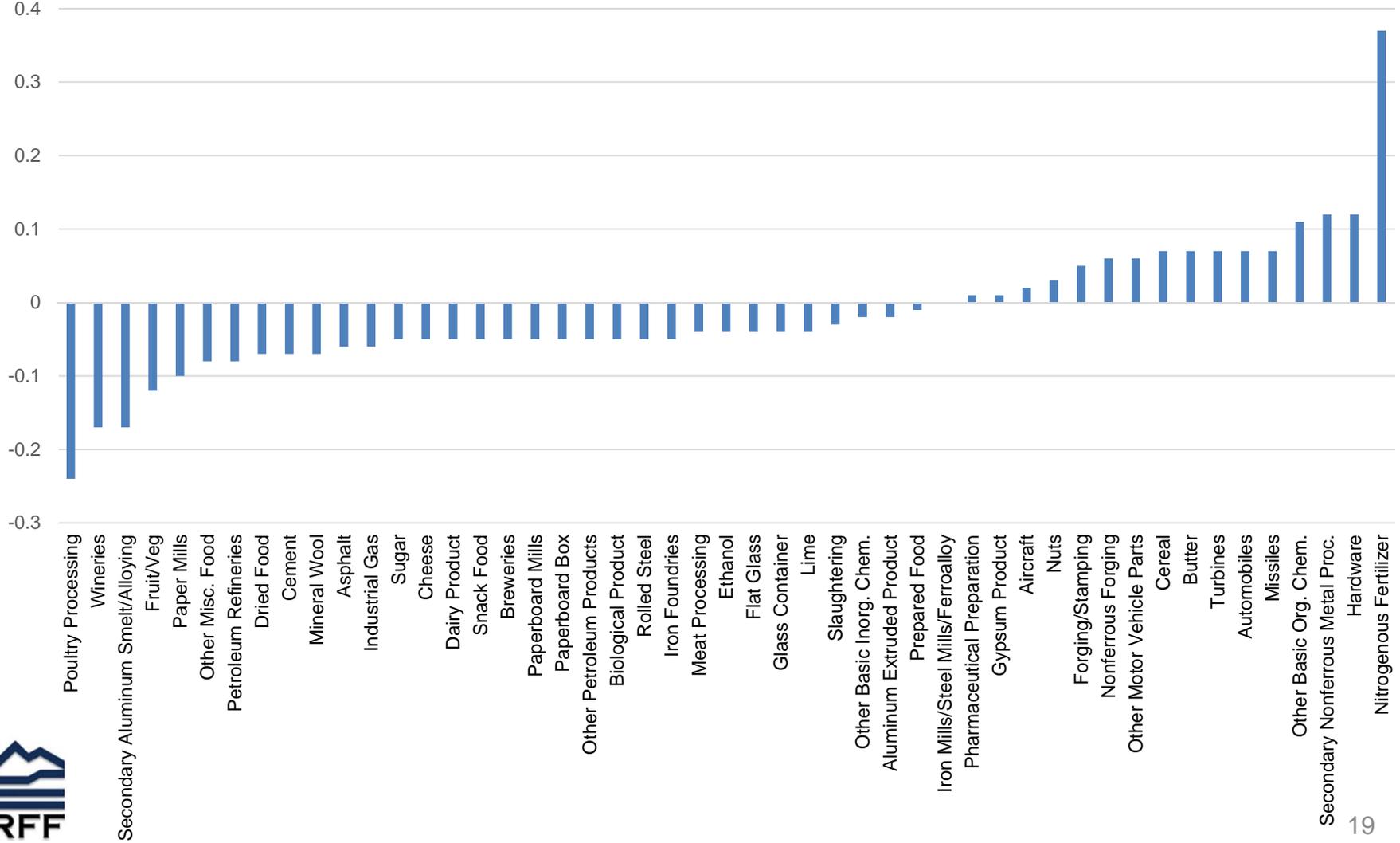
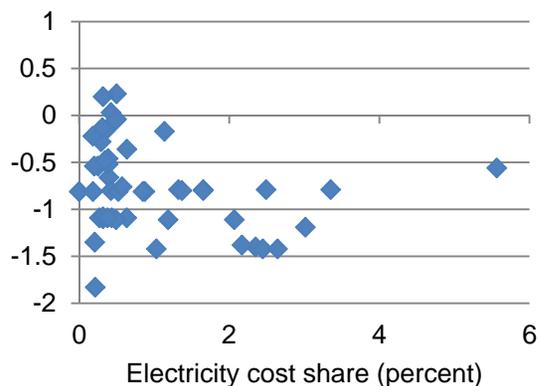
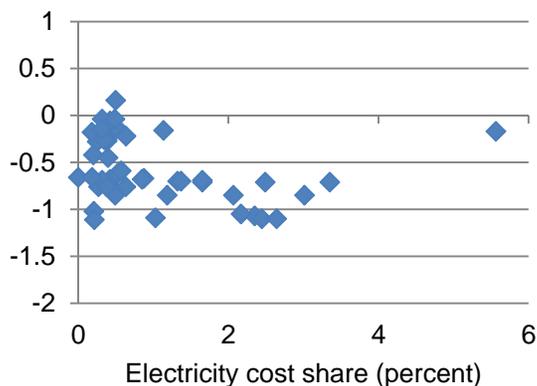


Figure 7: Short-Run Energy Price Elasticities vs. Energy Cost Shares

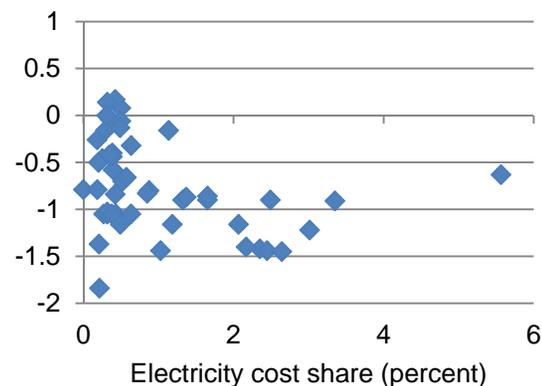
Panel A. Elasticity of output to electricity price



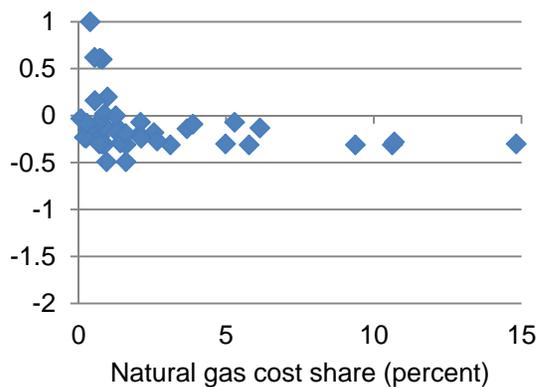
Panel B. Elasticity of employment to electricity price



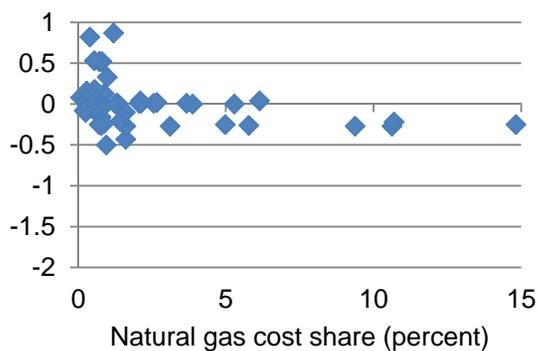
Panel C. Elasticity of value added to electricity price



Panel D. Elasticity of output to natural gas price



Panel E. Elasticity of employment to natural gas price



Panel F. Elasticity of value added to natural gas price

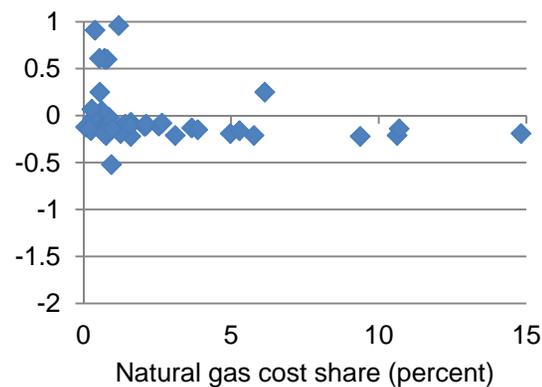
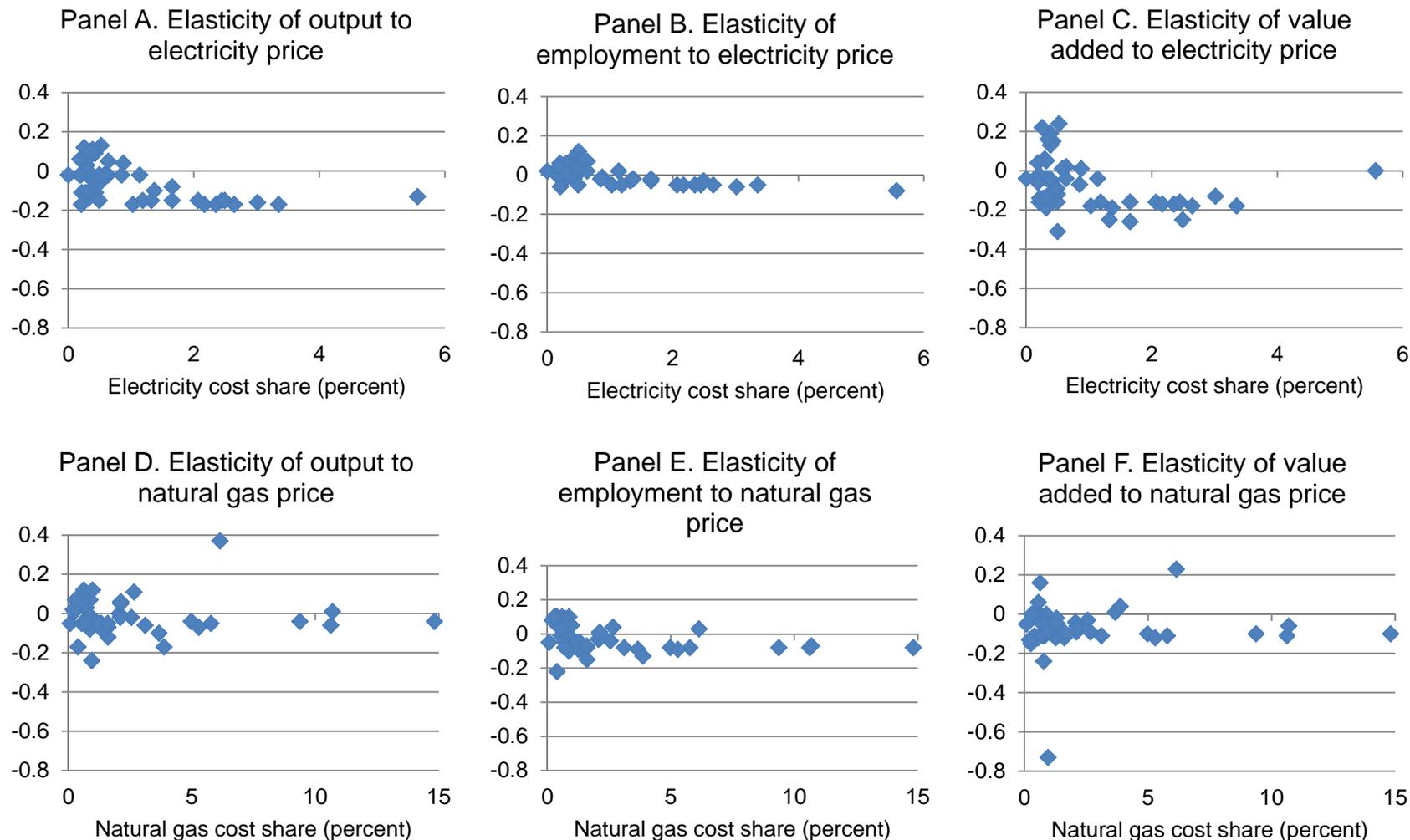


Figure 8: Long-Run Energy Price Elasticities vs. Energy Cost Shares



Simulations

- With \$10/metric ton CO₂ 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

Figure 9: Short-Run Output Results

Percent output change

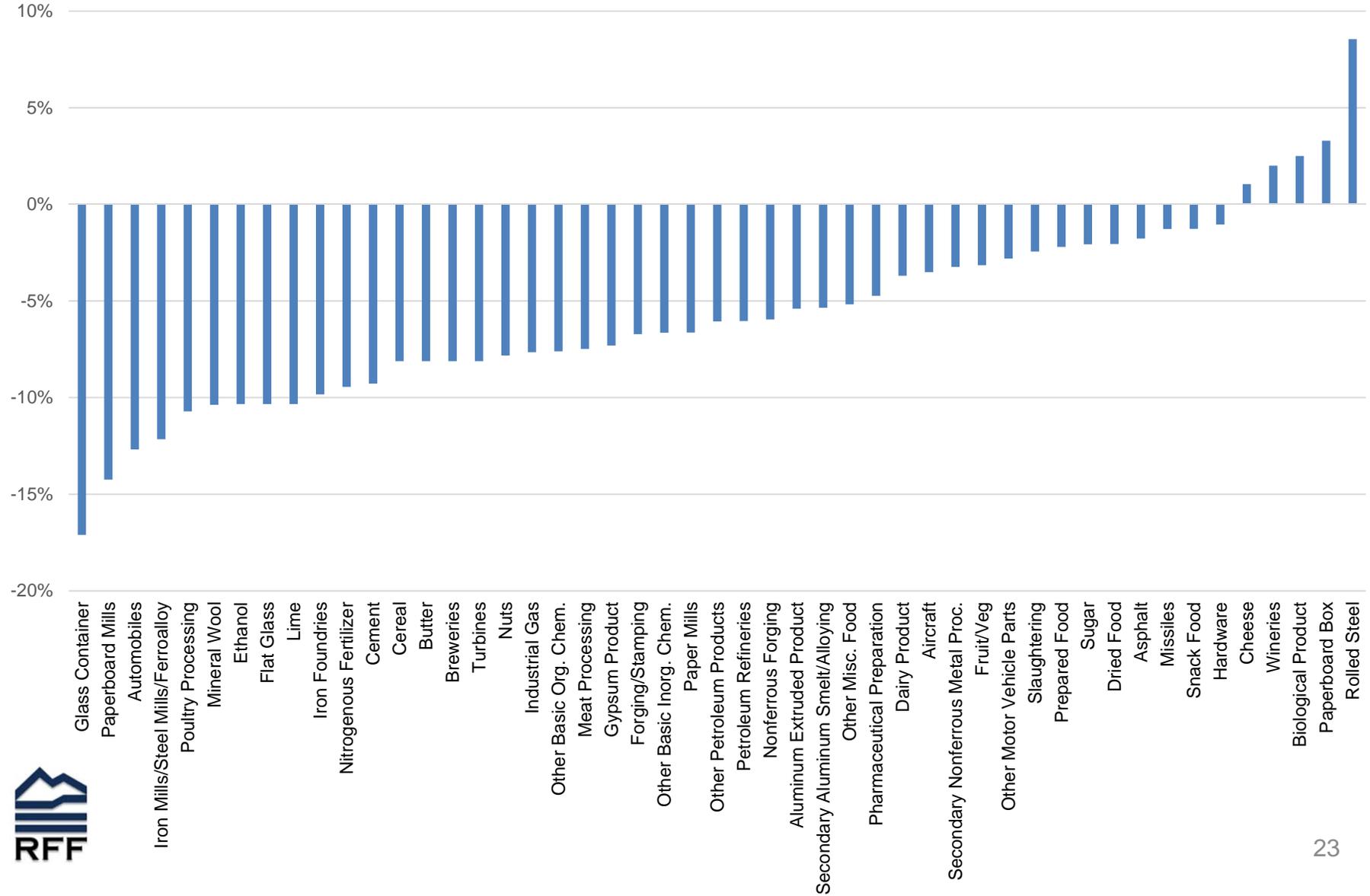


Figure 10: Long-Run Output Results

Percent output change

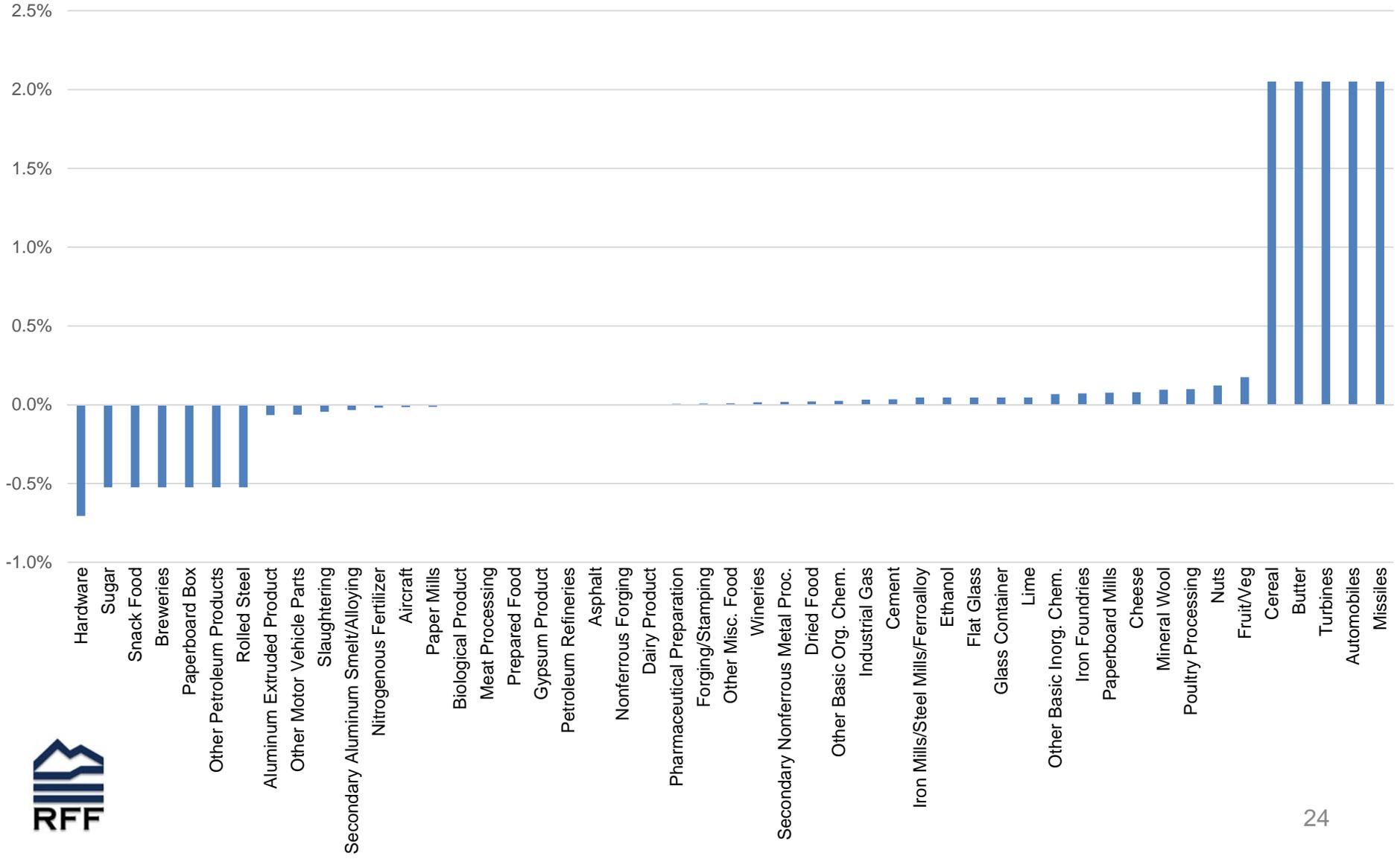
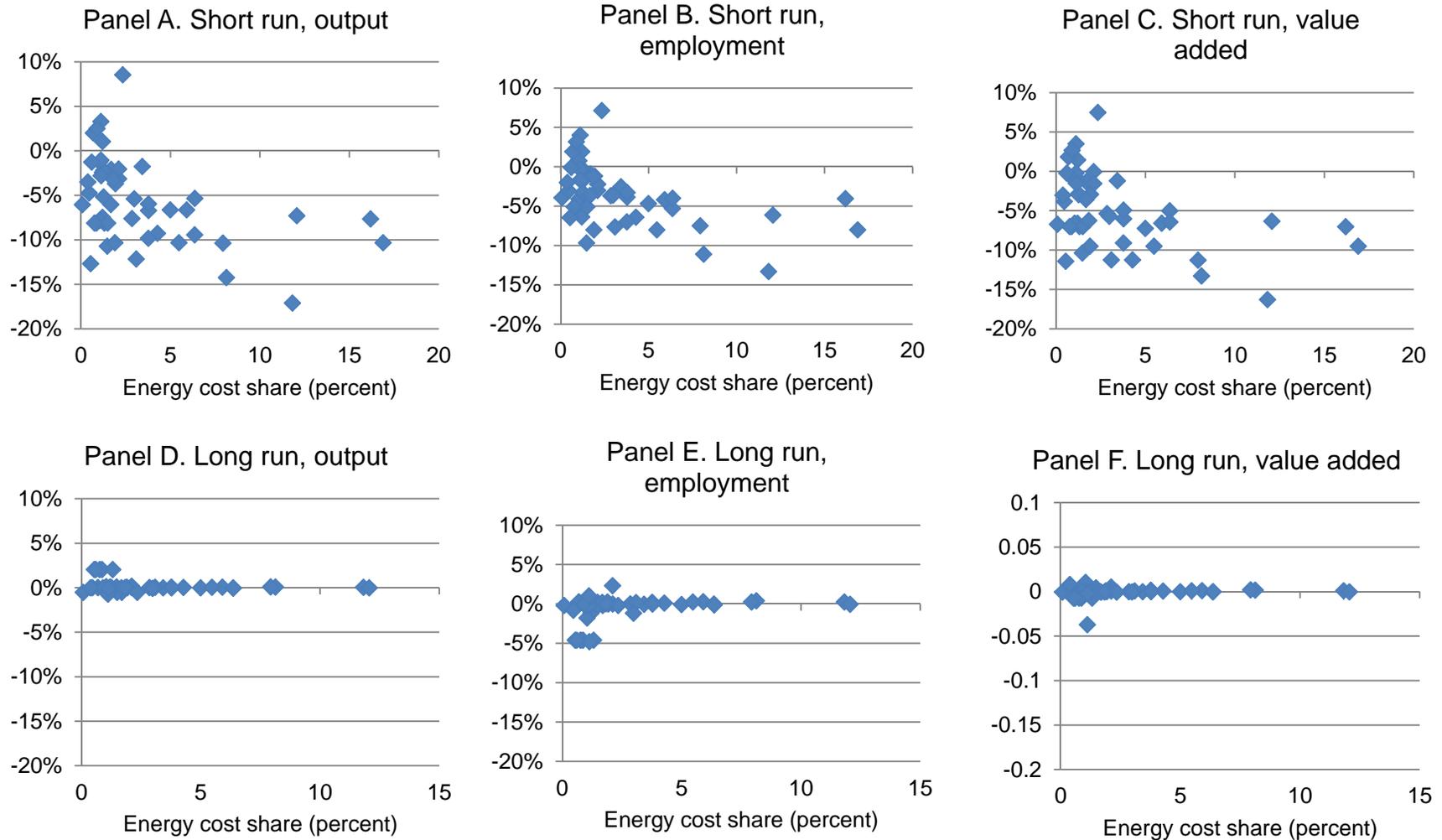


Figure 11: Simulated Short- and Long-Run Percent Changes vs. Energy Cost Shares



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

Exit Analysis

- Estimate linear probability model using long-run data set
 - Average exit of 0.5 plants per industry with \$10/metric ton CO₂
 - 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

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 CO₂ 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 CO₂ 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 CO₂ emissions, such as fertilizer, lime, industrial gases, non-ferrous smelting

Thank You