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| **Comments on Cap-and-Trade Program Public Workshop on Emissions Leakage Studies**  Prepared for:  California Manufacturers & Technology Association  Final Report  June 10, 2016 |

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# INTRODUCTION AND KEY FINDINGS

In 2006, the California Legislature passed the Global Warming Solutions Act or AB 32. It calls for California to return its greenhouse gas (GHG) emissions to 1990 levels by 2020, which is expected to result in an emissions reduction of 30% below business as usual (no greenhouse gas policy) levels.[[1]](#footnote-1) Legislators gave the California Air Resources Board (ARB) the primary authority to implement AB 32. The ARB developed a Scoping Plan, which outlines California’s strategy for meeting the AB 32 emission targets. The Scoping Plan includes a cap-and-trade program as well as command-and-control measures (or complementary measures).

The cap-and-trade program directly increases the cost of fossil energy by placing a price on GHG emissions, and the complementary measures increase costs by forcing specific sectors to make direct reductions. Therefore, imposing AB 32 on California entities increases their costs of production relative to entities outside of California.

In response to increases in production costs, companies may move some or all of their operations outside of California and then export to California, or shut down altogether requiring California to import goods previously produced in-state. In all these scenarios, there is a market transfer from the regulated region, California, to another region outside California. This market transfer results in emissions leakage. Leakage occurs when production (and emissions) shifts from a regulated to a non-regulated region, which in general, harms the environmental integrity of an emissions reduction program. Specific to AB 32 and maintaining the policy’s environmental integrity, ARB is required to minimize emissions leakage.[[2]](#footnote-2)

As part of Resolutions 11-32 and 12-33, ARB directed staff to re-evaluate the original leakage risk assessment. Staff contracted three research groups – University of California, Berkeley; Resources for the Future; and California Polytechnic University, San Luis Obispo – to assess the leakage potential for industries covered by the state’s cap-and-trade program. The ARB is relying on the following studies from these groups as it looks to change its methodological framework for emissions leakage designation for the third compliance period (2018-2020) and beyond:

1. Meredith Fowlie, Mar Reguant, and Stephen P. Rayan, University of California, Berkeley, *Measuring Leakage Risk*, (International emissions leakage potential) – UCB Paper
2. Wayne Gray, Clark University Joshua Linn and Dick Morgenstern, Resources for the Future, *Employment and Output Leakage under California’s Cap-and-Trade Program*, (Domestic emissions leakage potential) – RFF Paper
3. Stephen Hamilton, California Polytechnic University, San Luis Obispo*, Production and Emissions Leakage from California’s Cap-and‐Trade Program in Food Processing Industries: Case Study of Tomato, Sugar, Wet Corn and Cheese Markets*, (Food processors emissions leakage potential) – CalPoly Paper

California Manufacturers & Technology Association (CMTA) contracted NERA Economic Consulting (NERA) to review and comment on two of the studies (the UCB paper and the RFF paper) which broadly cover most manufacturing. Our comments focus on the adequacy of the data, robustness of the results, and applicability of the approach to determine leakage risk for policy application based on the information provided in the study papers.

Based on our review of the studies, we believe that the data used for the studies are outdated and do not correspond to the study objectives. In addition, we agree with the authors’ lack of confident in their results and cautious about using the results of these studies to predict future leakage risk for trade-exposed manufacturing and other sectors of the economy. ARB’s approach and plan to use the outcomes from each of the studies conducted is also flawed since it is not possible to separate energy intensity and trade effects, and both international and interstate competition must be addressed simultaneously. Our review of the data, approach, and the results of the two studies suggest that it is premature to apply the results for policy work in the absence of detailed peer review and exploring other appropriate approaches.

Below we summarize our main comments:

* *The studies draw upon historical data that do not reflect California’s future.*

These studies are good econometric research into the relationships between changes in past energy prices and changes in industry activity. However, following the authors’ caveats about their analysis, one should exercise extreme caution in using the results of their research to predict future leakage impacts. The data used to construct the regressions in the UCB and RFF studies neither include any time in which a price on GHGs existed in California nor include the impact that California’s complementary measures are having today and forecasted to have in the future. Furthermore given Senate Bill 350 (SB 350) and the decisions to reduce GHG emissions to 40% below 1990 levels by 2030, the regulatory environment in California will surely differ greatly from the period in which the data were collected and the change in energy prices will be far outside the range of the data (and in the opposite direction of the energy price changes of the UCB study). Therefore, the regression relationships are built on historical data that do not reflect the future.

* *Allowance prices do not fully reflect AB 32’s impact on the California’s energy prices leading to misleading results.*

Applying the regression analysis to compute leakage effects involves making an assumption that the AB 32 allowance prices fully reflect the full change in California energy prices and changes in production costs for California industries, relative to unregulated jurisdictions. This is an incorrect assumption because as of today, California’s complementary measures have at least as much impact on production costs as the AB 32 allowance price. Therefore only using the allowance price to estimate changes in production costs would be misguided as it would miss a substantial contribution of California’s climate change program to the change in California energy prices and industry production costs.

* *We recommend a rigorous peer review of the studies and a well-suited alternative approach to estimate leakage risk.*

The authors from both studies state how some of their data and hence their results are highly uncertain. Because the researchers raise caution on their results, regulators should not develop thresholds from these. If regulators want to use the regression analysis to help inform their decision on how to address leakage, they should wait for researchers to develop results for which they have greater confidence. As a result, we recommend that California regulators conduct a rigorous peer review of the studies. In addition to, or instead of, the regression analysis, we recommend that regulators perform an analysis of leakage using a Computable General Equilibrium (CGE) modeling framework. This analysis overcomes many of the flaws and shortcomings of the regression analysis. In addition, this analysis could estimate leakage for sectors such as mining and upstream oil and gas that the regression analyses omit. Representing these sectors explicitly in a CGE model would be far superior to estimating leakage of these sectors based on estimates derived from other sectors. The CGE analysis should include a number of scenarios in which the assumption about the substitutability of goods produced inside and outside of California and the stringency of California’s GHG policy are varied.

The remainder of the report is organized as follows: Section II provides an overview the leakage risk methodology; Section III briefly describes the two studies; Section IV provides comments that are common to both studies; detailed comments that are specific to the two studies are discussed in Section V; Section VI concludes with thoughts about the applicability of these studies for updating the assistance factor and reasons why an alternate approach should be considered.

# OVERVIEW OF THE LEAKAGE RISK METHODOLOGY

## Current Method to Prevent Leakage

To mitigate emissions leakage, ARB provides direct assistance to industries that are deemed to be at risk for leakage. Direct assistance comes in the form of an allocation of free allowances. The number of allowances is determined by the following output-based formula:

Allocation = A x B x C x O

Where:

* A = Assistance factor, which is based on leakage risk classification (see below)
* B = GHG emissions efficiency benchmark in emissions per unit of output
* C = Cap adjustment factor, which tracks overall economy-wide allowance budget
* O = Product output in physical units (e.g., barrels of crude produced)

The ARB uses two metrics to classify an industry’s risk of leakage:

* Emissions intensity – measured as the ratio of emissions of GHGs to the industry’s value added; and
* Trade exposure – measured as the ratio of a sector’s imports plus exports divided by the sum of its shipments and imports.

Industries are then categorized as having very low, low, medium, or high emissions intensity based on this ratio and deemed to have low, medium, or high trade intensity based on this ratio. An industry’s leakage risk depends on the combination of its emissions intensity and trade exposure categorization (see Figure 1).

Figure : Mapping of Emissions Intensity and Trade Exposure to Leakage Risk



For example, industries with an emissions intensity of High and any level of trade exposure are said to have a High leakage risk. The industry assistance factor (A) is determined from its leakage risk classification. This factor also depends on the compliance period as well (see Figure 2). Direct allocations were provided to minimize emissions leakage and to provide transition assistance in the early years of the program. Industries in all three leakage risk categories received a 100% assistance factor in the first (2013-2014) and second compliance (2015-2017) periods. This factor is slated to decline in the third compliance period (2018-2020) for industries in the medium and low leakage risk categories.

Figure : Industry Assistance Factor as a Function of Leakage Risk and Compliance Period



## ARB’s Proposed New Methodological Framework

For its proposed updated assistance factors and leakage risk methodology, ARB proposes replacing its existing metrics of trade exposure and emissions intensity with two new metrics – international market transfer and domestic value-added loss – respectively. The international market transfer measures the fraction of each dollar drop in U.S. production offset by a dollar increase in international production. The UCB and CalPoly papers estimate this metric for manufacturing industries by using regression approach. The domestic value-added loss metric measures the drop in California output that is picked up by increased out-of-state (non-international) industrial facilities. The RFF study estimates this metric.

The new metrics are designed to account for domestic and international trade exposure; whereas the old metrics were designed to account for emissions intensity and international trade exposure of each industry. In estimating the new metrics, the regressions account for energy intensity in terms of an industry’s cost share for natural gas and electricity.

These studies focus on only the manufacturing sectors. The ARB plans to match non-studied sectors (e.g., mining) to the studied sectors that are most similar based on U.S. Census energy cost intensity and trade exposure.

Figure 3 illustrates ARB’s conceptual proposal for how it would use the new metrics to assign leakage risk and hence each industry’s assistance factor. Industries that are found to have the low values for the international market transfer and domestic value-added loss (i.e., closest to the origin) would receive the lowest level of or no assistance; whereas, industries with a high level of these two metrics (i.e., the northeast corner of the figure) would receive the most assistance.

Figure : ARB’s Conceptual Proposal for Using New Metrics to Assign Leakage Risk



Source: California Air Resources Board

Prior to the release of the initial regulatory change proposal, the ARB has not specified how they would map specific values for each of these metrics into an assistance factor. The ARB could follow its previous methodology where it set thresholds for each metric, then determined an industry’s leakage risk on the levels of the two metrics (see Figure 1), and finally base an industry’s assistance factor on its leakage risk (see Figure 2). Alternatively, the ARB could use a more continuous relationship where a threshold above which an industry would receive full assistance and low threshold below which an industry would receive no assistance. Then a continuum could be applied for all industries that fall between the two thresholds. In whatever approach ARB takes, it needs to define a relationship between the values of the metrics to the assistance factor. Application of these two metrics as orthogonal measures is inappropriate since what matters to the competitiveness of California industries is overall leakage regardless of location. That is, if a California industry only competes mainly in the U.S. market, then having no international market transfer and a high level of domestic value-added loss should put this industry in the “most assistance” category rather than in the “more assistance” category. Therefore, it is impossible to separate energy intensity and trade effects, and both international and interstate competition must be addressed simultaneously.

# DESCRIPTION OF THE LEAKAGE STUDIES

## Overview of the UCB Study

*Measuring Leakage Risk, by Meredith L. Fowlie, Mar Reguant, and Stephen P. Ryan May 2016*

According to the authors of the UCB study, “our work assesses the potential for international market transfers and emissions leakage to jurisdictions outside the United States.” To do so, the authors assemble data on 96 industries identified as “Energy Intensive, Trade Exposed” under California rules and proposed national greenhouse gas legislation, and use the recent experience of declining U.S. natural gas prices relative to international gas prices to estimate how changes in energy costs cause changes in industry output, imports and exports. They analyze these changes on a national basis, and assume that the national results are representative for California as well. From these estimates of output and trade impacts, they construct measures at the industry level of how much output of foreign industries might grow in response to the shrinkage in California production.

There is little or no data to directly measure California energy prices, imports or exports at the level of industry resolution needed for this study, nor are there data on foreign production or the emissions intensity of foreign production. The study uses a number of proxies for California data: based on detailed census data and EIA MECS data they calculate average energy prices at the national level by industry, value of production and energy cost shares for these industries nationwide, production, and from commerce department data they calculate the value of goods landed at California ports and goods shipped out of California ports. Their study period is 1993 –to 2012. Some data are available for every year and some in five-year increments.

Output, imports and exports for each industry are represented as a function of domestic energy prices, foreign energy prices, industry characteristics other than energy intensity, wages by industry, “3-digit NAICS fixed effects”, and “year by sector fixed effects.” The two latter variables are intended to control for all the other factors that have also changed between 1993 and 2012, the influence of which would be improperly attributed to energy prices if all other potential causes of changes in industry output and trade were not included. They use a large number of different functional forms to represent the relations among these variables.

The authors use their estimates of the percentage change in output attributable to a one percent change in energy prices (the output elasticity) to calculate the impacts of a $10 per metric ton of carbon dioxide price. They find that the effect of this carbon price varies across industries because of different energy intensities and market characteristics. On average, the study finds that this arbitrary choice of a carbon tax would reduce exports on the order of 6 percent or smaller for a majority of industries currently eligible for compensation in California. For cement, lime, industrial gas, wet corn milling, nitrogen fertilizer, iron and steel industries, they estimate negative impacts on export volumes of 20 percent or greater.

Lacking data on production by foreign industries, the authors assume that the change in foreign production for each industry matches the change in California net exports for that industry, and based on this assumption calculate a market transfer rate equal to the ratio of the change in foreign production to the change in California production. To convert these rates into leakage estimates, it would be necessary to have data on the marginal emissions intensity of foreign production, which the authors admit are not available. In order to produce some leakage numbers, the authors assume that foreign and California emissions intensities are the same.

As to leakage, the authors do state that “we use our elasticity estimates to calibrate upper bounds on market transfer rates and associated leakage potential. The imprecision of our estimates makes it difficult to estimate leakage potential for any particular industry with any degree of precision.”

## Overview of the RFF Study

*Employment and Output Leakage under California’s Cap-and-Trade Program, by Wayne Gray, Joshua Linn, and Richard Morgenstern May 2016*

Leakage occurs when production (and emissions) shifts from a regulated to a non-regulated region. This is a consequence of a unilateral environmental regulation such as California’s cap-and-trade program, California’s Global Warming Solutions Act of 2006 (AB 32). The state regulator, the California Air Resources Board (CARB) has developed an approach to protect sectors at risk from leakage and is directed to take efforts to minimize leakage to the extent feasible. In the Resources For the Future’s discussion paper, “Employment and Output Leakage under California’s Cap-and-Trade Program,” hereafter referred as the “RFF paper,” the authors Wayne Gray, Joshua Linn, and Richard Morgenstern provide analysis to help support CARB with their objective.

The RFF paper uses a statistical model to examine the effects of energy prices on the competitiveness of California plants compared with domestic competitors and emissions leakage based on detailed plant-level data. The study sample is based on multiple sources. Output is based on the NBER-CES Manufacturing Industry Database, value added is based on the Annual Survey of Manufacturers (ASM) and Census of Manufacturers (CMF). Electricity and natural gas prices are derived from US EIA and SEDS datasets. The authors rely on ASM, CMF, and MECS to estimate energy and natural gas shares. Data for the control variables are also derived from official statistics, e.g. U.S. Bureau of Economic Analysis (BEA) Input-Output tables, Commodity Flow Survey (CFS), and others.

The study posits that the California’s cap-and-trade programs will raise energy prices in the state’s manufacturing plants. The study assumes a compliance cost of $10/metric ton of carbon dioxide equivalent (CO2) in California with no output-based updating and a no compliance cost elsewhere. The plants will then respond to higher prices with consequences on production, employment, and value-added. The authors develop a statistical model based on a generalization of a Cobb-Douglas production function in which cost shares interact with the energy prices. The model formulation expresses output, employment and value-added as a function of the energy prices of manufacturing plants in California, energy prices of its out-of-state competitors, and controls variables to address other factors. This model is defined as the short-run model. The authors also devise a long-run model to estimate the long-run impact of energy prices by reformulating the short-run in which the outcome variables are represented as *changes* in five-year periods adjusted for the fixed effect and control variables. The short-run and the long-run models are estimated by ordinary least squares (OLS) for a compliance cost of $10/metric ton of carbon dioxide equivalent (CO2) to estimate “counterfactual” predicted values for output, value added, and employment for each plant. These predicted values, plant by plant, are compared with the “actual” predicted values obtained when using the original 2009 prices. The study computes the aggregate change for each outcome for all California plants by industry, and similarly for all non-California plants by industry to estimate the leakage.

The RFF study approach differs from other studies, in particular from the Aldy and Pizer study, in several ways as per the authors. First, the analysis is conducted at the plant level, and the model results are evaluated at the six-digit North American Industry Classification System (NAICS) industry. Second, the study considers three different key metrics (output, employment, and value added) for the analysis. The authors claim that “using multiple outcomes provides a more complete picture of the implications of compliance costs in California.” Finally, the study captures the effects of the Cap-and-Trade Program on energy prices inside California.

As per the study findings, the key two conclusions are: (i) an increase in California energy prices relative to prices in nearby regions will raise production costs in energy-intensive industries located in California and likely result in short-term (one year) losses in output, employment, and value added for those industries; and (ii) the effects are smaller for the long run than the short run, although the authors offer caution when interpreting these long-run results.

# COMMON ISSUES WITH THE LEAKAGE STUDIES

## Overview of Methodology

At a high level, these studies apply a common methodology. Each study develops a regression that uses past economic data to relate changes in electricity and gas prices to changes in economic activity. The studies compute elasticities that capture the responsiveness of domestic production and trade flows to changes in relative energy prices. At the end of each study, the authors use their elasticity estimates to compute the impacts on California industries of carbon tax of $10/MT of CO2e. [[3]](#footnote-3) They choose a carbon tax of $10/MT of CO2e because they believe that carbon tax values in this range represent the range of changes in relative energy prices for their data.

We find these studies share some common flaws in how they propose to make use of their elasticity estimates and in the estimation of their elasticity values. The remainder of this section discusses these common flaws.

## Problems with the Proposed Application of the Elasticity Values

### Carbon Price Range

The carbon prices that compare to the energy price changes of these studies corresponds to a price on CO2 ranging from about $10/MT CO2 to $20/MT CO2. The upper end of this range is likely to be quite low compared with likely California allowance prices if California is to reduce its GHG emissions to 40% below 1990 levels by 2030.[[4]](#footnote-4) In our own analysis, we find prices on CO2e several times these levels by 2030. The authors’ carbon price is even well below the Federal Government’s estimates for the social cost of carbon. Therefore, the likely future price of California’s allowances prices will likely greatly exceed relative energy prices upon which these analyses are based. Furthermore, California’s allowance price is likely to increase over time implying an exponentially growing forecast error as the emissions cap continues to tighten.

### True Cost of California’s Climate Change Program (Complementary Measures)

California’s climate change policy includes both a cap-and-trade program and many complementary measures. Therefore, the changes in California’s energy prices are a function not only of the cap-and-trade program allowance price but also the complementary measures. For example, electricity prices are affected by the allowance price as well as the state’s Renewable Portfolio Standard (RPS). Costs to industries are also affected by building efficiency standards, which are also not captured in the regression analyses.

Because the complementary measures are not market based programs, their effect on energy prices or cost of production in industry can only be determined by representing the programs themselves in an appropriate industry or economy-wide model. Thus, one cannot use the energy price elasticities from the regression analyses alone to estimate the full impacts of California’s climate change policy on each sector.

### Expectations (Energy Price Volatility vs. California Policy)

The regression analyses are built upon changes in relative energy prices. For UCB the change in relative energy prices is driven by changes in U.S. natural gas prices over the period from 1993 to 2012. These prices were highly volatile in the entire period, and even in the later part of the period when natural gas prices were falling, there was little confidence that they would not rise again. Even in 2012, the U.S. Energy Information Administration was projecting that natural gas prices would nearly double from the low levels they had reached at that point in time.[[5]](#footnote-5)

For the RFF study, the changes are based on the differences in California and rest of U.S. energy prices. But California gas and electricity markets are well integrated with those in the West.[[6]](#footnote-6) Thus, difference in energy prices between California and the rest of the U.S. are likely to be transitory. On the other hand, the allowance prices and California’s GHG policies in general will have a clear persistent effect on energy prices and production costs. Therefore, firms are likely to have a much different reaction to these random fluctuations in energy prices than a persistent change in costs. Thus, the historical results upon which the elasticity estimates are based are unlikely to resemble how firms will behave to California’s GHG regulations.

### Accounting for Long-Run Costs and Costs of Capital/Investment

The authors themselves caution against what their analysis says for long-run results. The UCB authors mention that “An important caveat is that estimates are noisy and capture relatively short-run impacts, “and the RFF authors are even more explicit in urging that their counterintuitive long run results should not be used for policymaking purposes.

The reasons for the lack of significant long run results should be clear – the energy price data came from a period of high volatility when determining whether a short run change would continue or be reversed was very difficult. This means that the standard practice of comparing production levels in a given year to price changes in a prior year provides no information about long run responses, since prices are likely to have moved up and down in the interim and could well have reversed whatever change had been observed in the initial year.

### Inability to Account for Potential Future Changes

The regression model is based on past market structure so it cannot account well for future changes in market structure or changes in the marketplace. As one example, the regression analysis cannot capture the effects of changes in the marketplace that could cause an industry that is currently not trade exposed to become trade exposed. Specifically, the regression model cannot anticipate the future implications of California’s shrinking demand for transportation fuels and the pressure this would place on California refineries to sell product to markets outside the state when the refining sector is put into the cap and trade system.

As another example, under a cap-and-trade program, there are potential impacts in other inputs beyond energy prices. In particular, under a deep decarbonization regime, the energy system could change dramatically resulting in a higher rental price of capital. These potential changes are ignored by assuming a modest carbon price on direct emissions in the analysis. Furthermore, the regression analysis ignores what such a change would do to emissions intensities and cost factors for energy.

## Advantages of Using a General Equilibrium Approach

At a minimum, CGE model should be used to analyze leakage as a complementary approach. Using a computable general equilibrium (CGE) model to estimate leakage risk for industries would overcome a number of the shortcomings involved with a regression analysis in general and with the regression analyses from the UCB and RFF studies in particular. The CGE model structure can capture the effect of the following: command-and-control regulations, carbon prices directly as opposed to indirectly through energy price changes, interactions among all sectors, effects on capital markets, and effect of price changes well outside historical ranges. Unlike the fixed relationships in a regression analysis, the general equilibrium approach can represent the change in economic relationships over time. For example, the CGE model can account for changing production and cost structures as markets evolve.

Furthermore, because of this lack of rigidity, the model results for the general equilibrium approach are much more robust and therefore valid over a much larger range of results. Specifically, the leakage results from a CGE model would be valid for a much wider range of permit prices. Because the general equilibrium model can represent the entire economy and major policies, it can account for the cap-and-trade program as well as the most important complementary measures. Thus, the CGE model can capture most of the impacts on energy prices and production costs brought about California’s greenhouse gas policy. This ability contrasts with the regression analyses that can only capture at best the effect of the cap-and-trade program.

The CGE approach is also able to account for future expectations about California’s GHG policies. Therefore, one could use the CGE approach to measure the effect of different proposed Scoping Plans on leakage risk by industry. Such forward looking behavior cannot be captured in a regression analysis as the relationships are based on historical relationships.

The UCB paper states that a shortcoming of the CGE approach is its inability to represent many sectors. However, using various techniques and focusing the CGE analysis on a particular dimension, one can analyze many sectors at once. There are many analyses that have developed a CGE model to analyze at disaggregate sectoral level including at 6-digit product or commodity level.[[7]](#footnote-7) Others have developed CGE models to analyze impacts on over 10,000 types of households. In NERA’s own analysis, we have assessed the economic impacts of various policies on 25 sectors simultaneously.[[8]](#footnote-8)

Even the RFF authors recognize the importance of using CGE models to estimate leakage and how they could at a minimum serve as a complementary approach:

*“These CGE models have been useful in quantifying aggregate leakage rates as well as important interaction effects across markets that only a general equilibrium model can capture. A limitation of these models is their focus on aggregate effects that obscures effects on individual industries. While informative, this approach provides little to no differentiation among industries with different energy intensities and elasticities with respect to energy prices. Indeed, it is typical to make a common set of assumptions that yield a common response across the entire manufacturing industry to a carbon-pricing policy. As our analysis shows, this approach can underestimate the impacts on the more energy intensive manufacturing industries. In this way, our work is a natural complement to this literature.”[[9]](#footnote-9)*

## Common Data Issues

### Emission Sources Omitted

Both studies ignore non-CO2 process emissions, emissions from transportation, and emissions associated with fuel gas. Therefore, the impacts on sectors such as fertilizer, lime, industrial gases, and non-ferrous smelting are significantly understated because of their high share of non-CO2 process emissions. The emissions associated with any imports that displace California produced goods for consumption in California are ignored. Thus, the effect of leakage is understated to the extent that imported goods would incur additional emissions associated with transportation.

The omission of consumption of other fuels (e.g. fuel-gas, petroleum coke, and fuel oil) in the California refineries results in underestimating the energy intensity of the refineries.[[10]](#footnote-10) The sample data from both studies does not consider this as they only account for electricity and natural gas usage. The California refineries are much more energy intensive than what is reflected in the studies. The lack of proper energy accounting leads to understating the leakage that would occur if output from California refineries were displaced by output from refineries outside the state. This renders the current analyses in both studies to be inappropriate. [[11]](#footnote-11)

### Sectors Not Modeled

The studies limit their analysis to manufacturing sectors included in NAICS codes 31 to 33. This leaves out the sectors of agriculture,[[12]](#footnote-12) mining, and upstream oil and gas that are affected by AB32 regulations. The regulation of these sectors will have knock-on consequences for California industries that use their products as feedstocks, in particular the California refining industry. Moreover, applying to these sectors a formula or rule for determining trade exposure estimated solely on the basis of data from other industries ignores the entire reason for doing the study, which is to see whether there are systematic relationships between industry characteristics and leakage that can be used to predict the effects of applying a carbon tax.

### Omitted Variables

None of the studies control explicitly for factors other than energy price changes that could affect production, imports, or exports of California industries. They also fail to address relations among industries that could affect the same variables.

By using data on a large number of 6-digit industries with heterogeneous characteristics, the study risks confounding the effects of changes in specific markets on those industries with the effects of changing energy prices. For example, crude oil prices varied widely over the period but their effect on refining is not represented. Thus if crude oil prices were falling during a sub-period when natural gas prices were rising, the regression analysis might conclude that refinery output was relatively insensitive to increases in the prices of natural gas and electricity.[[13]](#footnote-13)

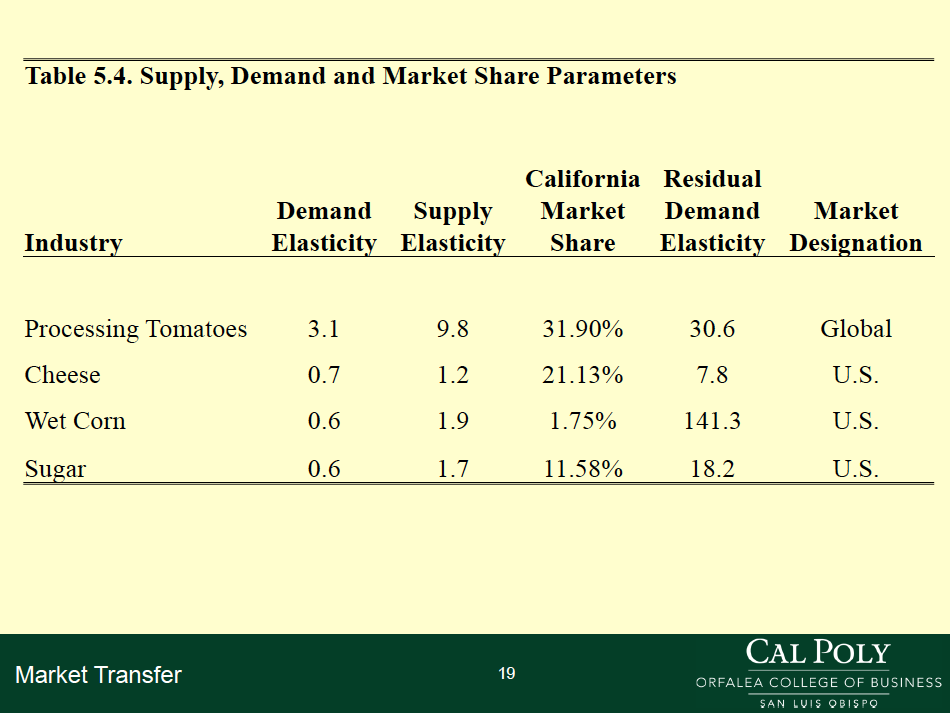
Likewise, ignoring industry interactions means that an increase in output in one industry caused by events that reduce output of an industry producing substitutable goods will confound effects of energy price increases.

### Misspecification of Models

More broadly, using a smooth profit function to represent the response of every industry at best obscures, and in the worst reverses, the insights that more detailed models of the actual processes used in those industries. This is particularly true of the refining industry, in which production and location decisions can be modeled in detail by use of available commercial models, and which cannot be readily summarized by a single estimating equation.

The factors that affect production and trade for a given industry are not hard to describe in principle, and are laid out clearly in the study of four food processing industries done by CalPoly San Luis Obispo. Their model for estimating production impacts depends on just four parameters, as shown in the slide below from their report[[14]](#footnote-14):

Figure : Supply, Demand and Market Share Parameters

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The elasticity of market demand, the supply elasticity for the industry, and the share of California production in the relevant market are sufficient to estimate both the market transfer and the production impact of a cost increase.

The econometric models used in the UCB and RFF studies have to estimate all these elasticities accurately in order to capture the differences among industries in their response to a carbon tax, without any structural representation of the underlying markets.

The slide below shows how large the differences in response to compliance cost among these four food processing industries turn out to be:

Figure : Range of Impacts across Agricultural Industries from the CalPoly Paper



# CRITIQUE OF INDIVIDUAL STUDIES

## Specific Comments Related to the UCB Study

The concept of using the experience of past periods in which energy prices changed significantly to understand how industrial output, value added and employment respond to such changes is sound only if it is possible to quantify and control for all the other factors that might have contributed to past changes in industry performance.

Statistical correlations between past changes in energy prices and past changes in industrial output, value added and employment provide valid estimates of how future changes in energy prices will affect those variables only if:

* It is possible to control for all the other factors that might have contributed to past changes in industrial performance;
* The statistical methodology provides unbiased and statistically significant estimates of the parameters; and
* Future price changes are in all relevant respects comparable to past price changes.

Moreover, any such use of historical experience must also assume that underlying markets, institutions, policies and expectations present in the past remain unchanged in the future.

There are serious problems in each of these categories with the UCB study.

### Past Changes in Average California Energy Prices Used in the Study are Not Comparable to Future Increases in Energy Prices Due to AB32

Historical energy prices declined over time while carbon price if applied would be increasing over time. The authors themselves caution: “… identifying variation in energy prices is not perfectly isomorphic to the policy-induced change we wish to evaluate. One obvious difference is that we observe a decline in domestic energy prices relative to foreign energy prices, while a carbon policy would work in the opposite direction.” [[15]](#footnote-15) Whether the response to price decreases and price increases is symmetric is itself a thorny econometric issue in energy demand studies, yet there is no test of this symmetry in the UCB study.

Carbon prices will affect gas and electric prices differently, and in particular, the effect on electricity prices will depend on how much the carbon content of electricity is reduced in response to AB32 programs. Combining gas and electric energy prices into a single “energy” price makes the historical elasticity of response to “energy” price increases useless for estimating the impact of a greenhouse gas allowance price, which will have different effects on gas and electricity costs as well as demand in the future.

Expectations of how prices would move in the future differ for mean-reverting volatile energy prices and upward trending allowance prices, so that immediate responses to their introduction will be different. If the change in gas prices was anticipated to be relatively brief, as it was through 2012, there would be much less response than to an introductory allowance price that is expected to ramp up as the greenhouse gas cap becomes more and more binding.

”On the empirical side, we use variation in energy prices generated by the shale gas boom in the United States to estimate the relationships between relative energy prices.”[[16]](#footnote-16) Shale gas effects may or may not have similar effects on the energy prices as a carbon price.

### Missing Data are Replaced with Irrelevant Proxies

Although a major purpose of the study is to estimate impacts of past energy price changes on California imports and exports, the study has no data on California foreign imports or exports. Lacking that data, all goods entering California ports are assumed to be purchased in California and all goods leaving from California ports are assumed to have been produced in California. The volumes moving through California ports clearly include goods destined for or coming from inland states connected by rail or truck. Only if California’s imports and exports have exactly the same composition as those from other states would this assumption number be valid; and given California’s unique industrial makeup, that is not the case. Use of total California exports and imports would inflate the numerator of the market transfer computation. The authors should have made an effort to refine the data by using bilateral trade data between States to estimate California imports and exports as the difference between foreign flows into California and flows of the same goods out of California to other states, and the difference between flows out of California to other countries and flows of the same good into California to other states.

Foreign average energy prices (between electricity and natural gas) are computed using California’s average exports and imports volume. It would be much more accurate to use the respective foreign countries’ energy use.

The market transfer computation is based on using a proxy for the change in international production. Changes in the value of California’s imports and exports are used as a proxy for international production changes. This is a critical assumption in the analysis and is a bold assumption. Emission factors for foreign competitors are a weighted average of all countries, but different goods have different bilateral trade flow patterns, and the average emission factors for each good depend on the composition of trade partners.

An integral component to analyze leakage is the change in production in foreign markets. The proxy for this metric is at best used to cover up data deficiencies and is not validated.

### Industries Producing Heterogeneous Goods are Treated as if They Produce Homogeneous Goods

The model assumes goods that a particular industry sells in California are identical to those California exports.[[17]](#footnote-17) This is true for some industries, mainly raw material industries producing bulk commodities, but even at the 6-digit level, firms in many downstream industries produce heterogeneous products that cannot be treated as perfect substitutes. Assuming these goods are perfect substitutes is a deviation from the reality, since even at the 6 digit level a heterogeneous mixture of goods are produced by most industries downstream from raw materials production. Further validation of this assumption of homogeneity is needed before applying the study’s results in a policy setting.

Further to this point, a trade model with homogenous goods has the property that trade is unidirectional, which by examination of the data it is not for all sectors considered. Therefore, the homogeneous goods assumption is clearly false and introduces additional sources of error in their regressions.

The regression model is predicated on a constant emission factor – that is on the assumption that emissions per unit of output do not change when energy costs change. Using a varying emissions factor would cause the output subsidy that neutralizes the carbon tax effect on output to be endogenous. This limits the relevance of the market model proposed by the authors, because if firms in an industry can substitute lower carbon for higher carbon energy sources or invest in improving energy efficiency, the industry emission factors can change. Thus, no output subsidy or allocation can be determined in advance from base case emission factors. Nor can we even estimate the change in California emissions without modeling the entire response of each industry to energy prices.

The authors state: “The result summarized by Table 6 account for firms’ ability to re-optimize production (i.e., fuel mix and allocation of production across regions) in response to relative changes in energy prices.”[[18]](#footnote-18) But if they did this, emission factors would have to be recomputed in order to apply a $10 carbon tax to the industry, since the change in energy cost attributable to a carbon tax depends on the fuel mix and amount of energy used per unit of output. Thus, the calculations of even the output impacts of a $10 carbon tax are fatally flawed.

### Analysis Does Not Control Adequately for Changes in Other Factors That Could Have Caused Observed Changes in Industry Output

Although foreign energy prices are included in the analysis, no account appears to be taken of changes in exchange rates or even in the landed prices of imported goods or FOB prices of exports. The sudden slowdown in Asian economic growth and demand also occurred in this time frame. These changes could move imports and exports up or down and confound the effects of energy price changes on imports and exports.

Likewise, the US economy went through drastic changes from 1993 to 2013, including a financial crisis, large changes in interest rates, wide variation in oil prices, and changes in financial and labor market regulations, that could well have heterogeneous effects on production at the 6-digit industry level.

Since each of the 6-digit industries could be affected differently by these changes over time, it is difficult to place any confidence in claims that the time-varying two-digit fixed effect variables would “sweep out” their influence.

### Simultaneous Equations Bias is Likely to be Present, Since Energy Prices Used to Explain Output Changes are Themselves Affected by Random Shocks to Industry Output

The authors state, “Prices and quantities are simultaneously determined.” [[19]](#footnote-19) This simple fact greatly complicates empirical tests for a causal effect of a regional emissions policy on trade flows. In our case, we are interested in estimating how changes in relative energy prices (a proxy for market-based climate change policy) affects trade patterns. Note that causal relationships can run in both directions. For example, suppose economic growth abroad increases demand for our exports. This increased demand could increase domestic manufacturing output, increase industrial energy demand, and increase domestic energy prices.”

Aside from mentioning their fixed effects parameters, which address confounding variables rather than endogeneity, UCB makes no effort to assess or correct for simultaneous equations bias (e.g. by using instrumental variables, maximum likelihood estimators, 3 stage least squares, etc.).

### Use of Value of Output Rather than Real Output as the Dependent Variable Makes it Impossible to Calculate a Proper Elasticity of Output with Respect to Price, Since Their Variable is Price Times Real Output

Leakage is defined as the emission increase abroad divided by the emission decrease in the regulated jurisdiction. UCB assumes that the emission factors are constant, so that they can compute the emission increase by multiplying the domestic emission factor by the change in California output and the overseas emission factor by the change in overseas output.

Since emissions are a function of physical output not value of output, the changes in prices that are a component of the value of output confound any attempt to estimate what the change in emissions in California might be.

This problem cannot be fixed by measuring in constant 2010 dollars unless each observation is deflated by an industry-specific deflator (as done by RFF). UCB’s approach creates major statistical problems and makes all the estimates useless for predicting leakage, which depends on emission factors that are only constant as ratios of emissions to real output, not as a ratio of emissions to value of output.

### Leakage Cannot be Calculated from the UCB Study

As the authors state, the lack of information on foreign emissions intensity makes it impossible to reach any conclusions about leakage from their estimates of market transfer rates. Thus, there is no basis for using these results to achieve the AB32 mandated goal of allocating subsidies to minimize leakage. As the authors state, “If the marginal emissions intensity associated with foreign production is higher (lower) than the domestic emissions intensity, our measure will under (over) estimate the rate of emissions leakage.” [[20]](#footnote-20) In other words, they have no way to rank industries in order of likely leakage.

Even if foreign emission factors could be estimated, other deficiencies would make estimates of leakage based on market transfer rates unreliable.

As per the authors, “we estimate the increase in foreign imports plus the reduction in domestic exports (measured in dollar terms) associated with a dollar reduction in domestic production. Recall that we cannot measure foreign production directly, so the sum of the change in imports plus exports can be interpreted as an upper bound on the change in foreign production.” [[21]](#footnote-21) The authors make change in overseas output is equal to change in California net shipments create another source of unknown error in calculating market transfer and leakage.

Leakage has to be calculated based on the future AB32 emission factor for each industry, after its emissions per unit of output are reduced by cap-and-trade and complementary measures. No basis for this calculation can be found in UCB study. Will differ for each industry and probably firm. For all these reasons, the authors conclude that their industry level market transfer estimates cannot be relied on:

* “The imprecision of our estimates makes it difficult to estimate leakage potential for any particular industry with any degree of precision.” [[22]](#footnote-22)
* “Given the noisiness of these estimates, we cannot estimate the transfer rate for any given industry with any degree of confidence.” [[23]](#footnote-23)

If the industry level market transfer estimates are unreliable, so are the leakage estimates by industry that are based on those estimates. There is no way to infer from output or trade impacts alone whether there is a large or small amount of leakage from an industry, since in addition to output and import/export changes for the California industry it is necessary to know the emission factor and change in output for foreign industries to calculate leakage.

Changes in output from foreign firms classified in the same industry are not the only source of leakage for a carbon policy applied to a specific U.S. industry. For example, if a California industry has a significant share of the global market and therefore AB32 causes an increase in the world price for that industry, global demand for that good will fall but due to substitution of global demand for other goods may rise. For example, if California tomatoes are a large share of global supply, as mentioned by UCB, there will be a reduction in world tomato demand when AB32 drives up California prices, but part of that reduction will be due to substitution of other vegetables in global food purchases. Thus, the total production change overseas that must be used in calculating leakage will equal the change in production of tomatoes worldwide plus the change in production of substitutes for tomatoes.

Moreover, adding up the results from a single equation regression will not give an accurate estimate of impacts on California output, imports or exports. That is because the overall trade balance constraint is missing from any simulation that relies on a single equation for each industry. For markets to be in balance, either capital flows or imports/exports from other California industries must change when there is a change in any one industry’s imports or exports. That is, a reduction in exports or increase in imports in one industry leads to an increased deficit in the overall current account balance. This must be made up by an increase in exports or decrease in imports in other industries or an increase in borrowing from outside the state. And, since the UCB study uses only national data, there is no way to calculate what these compensating changes would be.

The only way to deal with these multiple industry effects is by modeling the interactions among all industries simultaneously and observing trade balance and capital flow constraints – that is by using a multi-industry trade model that in its most comprehensive form will be a CGE model.

### California Impacts Cannot be Calculated Accurately using US Total Output and Average Prices

The UCB study estimates elasticities from energy price and industrial output data for the entire U.S., and uses these nationwide elasticities to estimate the change in California industrial output, value added and employment. It derives calculations of market transfer from these estimates of output change. This procedure cannot yield accurate estimates of either industrial impacts or leakage, as the authors admit, and the errors will vary from one industry to another.

For this procedure to yield accurate estimates, California industries individually and as a whole would have to be identical to the national industry. A simple examination of the data shows this is not the case:

* Output of California industries in the study range from 0.6% to 15.5% of the total national output of the industry, according to IMPLAN data, implying also that the shares of each industry in total California output differ from their shares of national output.
* The authors also state: “The California subsample is less energy-intensive on average than the full sample, despite California having higher domestic energy prices.”

Since the errors vary from industry to industry, the results will provide inaccurate rankings of industries and are therefore likely to identify some relatively unaffected industries as being more in need of assistance than more vulnerable industries.

The authors assume that “On the empirical side, we use variation in energy prices generated by the shale gas boom in the United States to estimate the relationships between relative energy prices.” However, shale gas effects may or may not have similar effects on the energy prices as a carbon price. [[24]](#footnote-24)

Use of nationwide prices also introduces errors in the measurement of prices affecting California industries for periods in which California prices moved differently from national prices. Since price changes are used as explanatory variables, this leads to a problem of “errors in variables” that the UCB study does not take into account in by giving corrected estimates of statistical significance.

### It is Impossible to Capture the Likely Response of Some Sectors with a Regression Model Based on a Smooth and Continuous Profit Function

Only process models that capture the details of their specific production processes should be used for some industries. In particular, for petroleum refining, the combination of low value-added, sunk investments, process plus fuel use emissions and low cost national and international transportation of products make it impossible to capture in a simple econometric model or production function an accurate picture of the regional shifts in refinery activity likely to be caused by California-only carbon policies. Furthermore, the process models can be used alone for an approximation of leakage if they contain all competing refineries in the US and overseas, as do several widely used commercial models, or they can be linked to CGE models to capture more fully the interindustry and indirect effects of changes in fuel prices and refined product production.

## Specific Comments Related to the RFF Study

### The Study Premise that California Energy Prices Would Reduce Total National Economic Activity is Not Necessarily an Accurate Assumption

The study at the outset makes a claim that “To the extent that an increase in California energy prices would reduce total national economic activity for a specific industry, e.g., by decreasing consumption or increasing imports, our simulation results *understate* the absolute decreases in California activity, but *overstate* emission leakage.” The analytical framework also assumes that for a plant located outside California, the energy prices it faces do not change and the competition behavior is completely driven by changes in the California prices. This is an oversimplification, inaccurate, and misleading since it is a quantitative question. Based on the national and California’s Input Output table for 2008, California’s energy-intensive industries have a relatively small share of the total national manufacturing output value.[[25]](#footnote-25) For example, California’s chemical manufacturing industry is about only 1.3% of the total national chemical manufacturing output value. Any changes in California’s energy prices could shift production from California to the rest of the U.S. The amount of shift depends upon the trade elasticity of the good or whether the traded good is homogenous or an imperfect substitute for the good in other regions.

### The Analysis is Rooted in Data That Are Incomplete, inconsistent, and Not Reflective of Current or Future Outlook When the Policy Will Apply

It is not uncommon for a regression analysis based study to pool data from various sources that may or may not have been generated consistently or may use data from different benchmark years. The data sample required for the RFF study is constructed with a focus to use all available data rather than to construct a dataset that is inherently consistent.

The study used Census of Manufactures (CMF) data from 1992-2007 from the U.S. Census Bureau which does not include the most recent data that have been published by the Census Bureau (date of access: 06-02-2016 <https://www.census.gov/ces/dataproducts/economicdata.html>). In addition, the Census Bureau has also published data that are more recent for the Annual Survey of Manufactures (ASM) that was not taken into account for generating the data sample. It is unclear from the RFF study if the results would have changed if any if the sample included more recent data (date of access: 06-02-2016 <http://www.census.gov/programs-surveys/asm/data/tables.html>). The RFF study uses 1991 Manufacturing Energy Cost Survey (MECS) data to compute natural gas cost share for each industry in the sample (page 9). These data are almost 20 years old. Moreover, the U.S. Energy Information Administration (US EIA) has released MECS data for 2010. The RFF study constructed electricity cost and natural gas cost shares for their regression analysis following the approach outlined in Aldy and Pizer. However, Aldy and Pizer also computed contemporaneous shares for their analysis that the RFF study omits.

A key driver for the elasticity computation is the electricity price. The RFF study computes the plant-level electricity price as the ratio of expenditure to quantity *purchased*. The quantity of purchased electricity will be less than the actual use for plants the self-generate some of their electricity. If the RFF study only accounted for the *purchased quantity* and *not the total quantity* in constructing their data, then the expenditure ratio is overestimated or the implied energy intensity would be underestimated which will affect the leakage rate computation.

The RFF study models use distance between plants rather than the underlying cost structure of the plants to determine which plants can compete with each other. The potential for competition among plants is based on an arbitrary rule that includes plants only within a 250-mile or 500-mile radius of each another. The randomness in defining competition, an important determinant of leakage, arbitrarily excludes potential competitors. This assumption about which plants can compete with each other may be valid for goods with low value to weight, but for high value to weight or low cost bulk transportation (e.g. rail or water), one should assume a national or global market. Using a distance formula to limit competition could narrow the set of competing firms too much. The arbitrariness of the distance formulation assumption is reflected in the fact that the study “results appear to be particularly insensitive to the distance used to define competing plants” (page 19).

It is also unclear from the RFF study if the increase in energy prices assumed by a carbon price of $10 per MT of CO2 is within the variation of energy price implied by the sample data.

Given the inconsistency, incompleteness, and arbitrary nature of some key assumptions the results should be viewed with caution until the study include robustness of the assumed sample data.

### The Model Used for the Study is Not Based on an Optimizing Behavior of Competing Plants Between Regulated and Unregulated Regions

The model specification for the RFF study is based on the general assumption of the authors that a generalization of a Cobb-Douglas production function for all plants in all industries is a starting point. The assumed production function does not provide any information about competition between plants but only provides information about how inputs are combined to produce an output or output metric in the case of this study. The Cobb-Douglas formulation contains only interacted price and share variables that are not based on a profit maximizing model of a firm. The study does not provide any discussion or indication of the goodness-of-fit for the specification nor does it provide estimates of other region’s energy price elasticity estimates to validate the Cobb-Douglas assumption in general.

From the RFF study, it is unclear if the authors’ choice of the number of electricity and natural gas groups are based on statistical inferences or an arbitrary selection criterion as the “five-groups appear to sufficiently capture the cross-industry heterogeneity.”[[26]](#footnote-26)

### The Control Variables in the Model Specification are Ad Hoc

The leakage rate invariably depends upon the relative price movement between California, the international, and rest of the U.S. markets. The RFF study assumes industry-by-year interactions to control for unobserved demand and supply shocks that proportionately affect all plants in the same industry and year. However, the plant industry-by-year fixed effect could also pick up domestic effects. The study is unclear how this fixed factor could simultaneously control for domestic as well as international effects. In addition, the study is unclear if the fixed effects by year remove all economic events (e.g., recession, California tax increases, and other environmental regulations, etc.) that would affect output other than energy prices.

To relax the exogeneity assumption between the shocks to the factor markets and energy prices, the authors include two control variables: (i) a labor costs index faced by nearby plants in the same industry; and (ii) an index for the growth in demand for the plant’s products. If the nearby plants were real competitors within a specific industry then the growth in one plant would have impact on the other plant’s resource inputs including labor demand. Under such a condition, these two control variables could be potentially confounding variables, which would bias the estimates. The study does not provide adequate information to infer if the variables are confounding or not.

### Industry Rankings Diverge from Historical Experience

As a result of the biases and errors in specification and data described above, the rankings of specific industries appear almost random. One industry, nitrogenous fertilizer, has had a long history of expanding when natural gas price fall and shrinking almost to oblivion when they rise. This is because bulk fertilizer is a homogenous commodity, globally traded and cheap to ship, and almost its entire cost is based on natural gas prices. Yet the study lists this industry as barely trade exposed.

The auto industry is also listed as highly vulnerable, yet its energy intensity is almost exactly at the national average and demand for autos produced in the United States has never shown any sensitivity to the cost of energy for vehicle manufacturing. It has instead been driven by macroeconomic factors and oil prices that clearly are not controlled for adequately.

### The Results are Not Robust and Do Not Support the Model Specification to Compute Leakage Rate

Based on the model specification, the results for the short-run and long-run show distinct differences and for some sectors are even counter intuitive. The authors estimate positive elasticities for some of the industries (e.g., paperboard box manufacturing, biologic product manufacturing, and all other motor vehicle parts manufacturing) and do not provide reasons in the study if these oddities are caused by poor data, incorrect model specification for these industries, or other unforeseen reasons. The authors’ short-run results also suggest that large variation exists in the outcomes for industries with very small energy cost shares when energy prices change. In general, one would expect that for industries with a small energy cost share, the effect on output would not be influenced by a small change in the input energy cost; however, this is not the case in the RFF study. The authors claim that the large elasticities for industries that have a large energy cost share “is consistent with expectations and supports the validity of the modeling approach,” however they overlook the inconsistency in their results for industries that have a small energy cost share.

For the long-run, the authors estimate much smaller elasticities than in the short-run. In most cases, the output, employment, and value-added impacts are near zero or even positive. The results further show that there is great uncertainty in the value-added impacts and in particular for a single industry group (1-group) the value-added impact has a very large range. The authors cite that “We also find some positive long-run responses, most notably for the bundle of five low energy cost industries (L1), which contradicts our theory-based expectations. That bundle of industries also shows a negative impact on employment and value added, which contrasts with their positive impact on output” (page 18). The authors argue that the reason might be due to little variation in energy prices and difficulty in modeling long-run responses. These reasons raise important questions about the ability of the sample data to capture the proposed carbon price changes or even the appropriateness of the method to look at long-run responses. The lack of consistency in results, in particular at the industry level, leads the authors to suggest that caution should be applied in “using the long-run results for individual industries.”

Discrepancies between the short-run and long-run results are also reflected in the correlation between the short-run and long-run results. The authors believe that there should be high positive correlation; however, the study results indicated negative correlations between the short-run and long-run effects. If the industry-specific results are unreliable then the leakage rates based on these results are also equally unreliable for use. The inconsistent and unintuitive results suggest that either the data are unreliable or the base model specification does not have the power to estimate the elasticities and hence the leakage effects.

### Given the lack of Robustness and Anomalies in the Results, the Estimates are Not Ready for Policy Application

The anomalies in the modeling results suggest that they are not robust in several dimensions for which the RFF authors have not provided detailed response or insight in their study. The authors acknowledge that the simplicity of their model construct may not have captured nuances across industries. The conclusions and the results from the study can only be used as an indicative measure of impacts on output, employment, and value-added and hence should not be used for policy application.

# CONCLUSIONS AND USE OF THE LEAKAGE STUDIES

These studies are good econometric research into the relationships between changes in past energy prices and changes in industry activity. However, following the authors’ caveats about their analysis, one should exercise extreme caution in using the results of their research to predict future leakage impacts. The data used to construct the regressions in the UCB and RFF studies neither include any time in which a price on GHGs existed in California nor include times that represent the impact that complementary measures are having today and forecasted to have in the future. Furthermore given SB 350 and the decisions to reduce GHG emissions by 40 percent by 2030, the regulatory environment in California will surely differ greatly from the period in which the data were collected and the change in energy prices will be far outside the range of the data (and in the opposite direction of the energy price changes of the UCB study). Therefore, the regression relationships are built on historical data that do not reflect the future.

An additional problem with applying the regression analysis to compute leakage effects involves the fact that the AB 32 allowance price poorly reflects the full change in California energy prices and changes in production costs for California industries relative to unregulated jurisdictions. Today, California’s complementary measures have at least as much impact on production costs as today’s allowance price. Therefore only using the allowance price to estimate changes in production would be misguided as it would miss a substantial contribution of California’s climate change program to the change in California energy prices and industry production costs.

ARB’s plan for how to use the two studies separately is also flawed. The CalPoly study lays out the components of output elasticity clearly. It depends on the cost share of energy, supply elasticity for the domestic firm and for the entire industry, market demand elasticity, and market share (which determine the implicit elasticity for the domestic industry). Different goods will have different markets, ranging from global to national to regional. Market demand elasticity (see CalPoly study) may be orders of magnitude smaller than the elasticity faced by an individual firm, depending on its market share and the homogeneity of the goods involved. Thus it is not possible to separate energy intensity and trade effects, and both international and interstate competition must be addressed simultaneously.

Lastly, the UCB paper authors’ own caveats about their data and results should give one pause in using their results:

*The imprecision of our estimates makes it difficult to estimate leakage potential for any particular industry with any degree of precision. That said, looking across industries, clear patterns emerge. Consistent with CARB’s policy, this study’s leakage estimates are highest for those industries classified as “high” risk of leakage (see Table 8-1 of the Cap-and-Trade Regulation)[[27]](#footnote-27).*

*Overall, these results provide valuable insights into how a policy-induced increase in domestic operating costs can result in emissions leakage via international trade flows. Given available data, we are ineluctably limited in our ability to isolate the effect of a California-specific policy on California-specific imports and exports. Thus, our results are most accurately interpreted as capturing the effect of a regulation that increases domestic energy costs on import and export flows, respectively. These estimates are directly relevant to the assessment of a California Cap-and-Trade Program for those industries in which California producers comprise a majority of exports (or California manufacturers demand the majority of imports of a manufacturing input) [[28]](#footnote-28)*

*The natural next step, from the perspective of a policy maker looking to assess leakage risk and target leakage mitigation measures, is to translate these responsiveness measures to corresponding measures of market transfer and associated emissions leakage. However, pushing on to this next step amounts to pushing up against the limits of available data. One complication is that calibrating the measures of leakage risk implied by the theory requires dividing one noisy estimate by another. Other caveats include the fact that we cannot directly observe foreign production and instead employ an imperfect proxy. In what follows, we describe a conceptually consistent, albeit noisy and caveated, derivation of leakage risk measures.[[29]](#footnote-29)*

*Note that these industry-specific transfer rates are constructed as a ratio of our imprecise elasticity estimates. A ratio of noisy numbers can be very noisy; our industry-specific estimates of market transfer rates are sensitive to changes in how the underlying estimating equations are specified. …Given the noisiness of these estimates, we cannot estimate the transfer rate for any given industry with any degree of confidence.[[30]](#footnote-30)*

Industry-level results in the RFF study are too erratic to be used to determine energy intensity, and they would exclude industries with high energy costs relative to margins and value added, while including industries clearly no different from average. A number of industries are found to have increases in output when energy prices increase, suggesting strongly that there are omitted variables, simultaneous equation effects (due to induced changes in relative prices of substitute goods not incorporated in the single-equation regressions), or just too little variation in independent variables to produce significant results.

Therefore, it seems if researchers could accurately estimate the relationships that UCB and RFF are trying to estimate, then they would be better measures, but the problem is that estimating these relationships are challenging and the data are unavailable to provide a robust estimate that can then be used to transcribe the impacts of AB 32 to leakage because of the range of the changes in energy prices and the complementary measures.

In summary, the authors from both studies state how some of their data and hence their results are highly uncertain. Because the researchers lack confidence in their results, regulators should not develop thresholds from these. Rather if regulators want to use the regression analysis to help inform their decision on how to address leakage, they should wait for researchers to develop results for which they have greater confidence and recommend a rigorous peer review before developing the thresholds. In addition to, or instead of, the regression analysis, we recommend that regulators perform an analysis of leakage using a CGE modeling framework. This analysis overcomes many of the flaws and shortcomings of the regression analysis. In addition, this analysis could estimate leakage for sectors such as mining and upstream oil and gas that the regression analyses omit. Representing these sectors explicitly in a CGE model would be far superior to estimating leakage of these sectors based on estimates derived from other sectors. The CGE analysis should include a number of scenarios in which the assumption about the substitutability of goods produced inside and outside of California and the stringency of California’s GHG policy are varied.

As a complement to the CGE analysis, specific process models should be used for some industries, because the combination of low value-added, sunk investments, process plus fuel use emissions and low cost national and international transportation of products make it impossible to capture in a simple econometric model or production function an accurate picture of the regional shifts likely to be caused by California-only carbon policies.

In conclusion, given the incompleteness of the data and the drawbacks identified in the approach, we recommend a rigorous peer review of the studies and a well-suited alternative approach, a CGE based analysis, to estimate leakage risk. The CGE analysis should include a number of scenarios in which assumption about substitutability of goods produced inside and outside of California and the stringency of California’s GHG policy are varied.

1. Assembly Bill 32 Overview, California Air Resources Board (http://www.arb.ca.gov/cc/ab32/ab32.htm). [↑](#footnote-ref-1)
2. “California’s Global Warming Solutions Act of 2006 (AB 32) directs state regulators to minimize leakage to the extent feasible,” RFF study, page 1. “AB 32 requires the State to minimize leakage to the extent feasible,” CA Industry Assistance Credit for Industrial Businesses, <https://pages.email.sce.com/ciac/> [↑](#footnote-ref-2)
3. The UCB study considers a $10 per metric ton of carbon price. The RFF study considers as $10 per metric ton of carbon dioxide equivalent and simulates a higher compliance costs (up to $22 per metric ton of CO2) as a sensitivity case. [↑](#footnote-ref-3)
4. On April 29, 2015, Governor Brown issued Executive Order B-30-15, which calls for California to reduce its greenhouse gas emissions to 40% below 1990 levels by 2030. In addition, the California Senate drafted senate bill 32 (SB 32), which would require the state board to approvea statewide greenhouse gas emissions limit that is equivalent to 40% below the 1990 level to be achievedby 2030. [↑](#footnote-ref-4)
5. U.S. Energy Information Administration, Annual Energy Outlook 2012. [↑](#footnote-ref-5)
6. Wholesale electricity and natural gas markets are integrated across the West and so retail industrial electricity and natural gas rates are highly correlated, only differing by timing lags of wholesale prices being reflected in retail rates, different embedded costs of resources, and regulatory-imposed cross-subsidies. Due to long-term multi-collinearity of electricity and natural gas prices across states, it is doubtful the short-term changes in energy prices will produce precise results as to the long-term effects of the carbon price. Transitory energy price spikes are unlikely to significantly affect long-term firm production decisions.” [Sempra comments to ARB in 2012 3-seu\_commts\_on\_leakage-8\_27\_12.pdf] [↑](#footnote-ref-6)
7. Birgit Meade, Jason H. Grant, and Anita Regmi, “Trade and Welfare Impacts of Partial Liberalization of U.S. Sugar TRQs: The Application of a PE/GE Modeling Approach,” May 2010 used 34 HS6 sugar related products.

   Justin Caron, “Estimating Carbon Leakage and the Efficiency of Border Adjustments in General Equilibrium - Does Sectoral Aggregation Matter?” March 2012 modeled 51 industrial sectors represented in the MECS.

   Jason H. Granta, Thomas W. Hertela, Thomas F. Rutherford, “Dairy TRQ Liberalization: Contrasting Bilateral and Most Favored Nation Reform Options,” 2008 used 26 HS6-digit product lines comprising the dairy sector for the analysis. [↑](#footnote-ref-7)
8. Macroeconomic Impacts of Federal Regulation of the Manufacturing Sector, Commissioned by Manufacturers Alliance for Productivity and Innovation, NERA Economic Consulting, August 21, 2012. [↑](#footnote-ref-8)
9. RFF Paper. [↑](#footnote-ref-9)
10. According to the U.S. EIA, electricity and natural gas consumption is about 40% of the total fuel consumed in the California (PADD 5) refineries; while fuel-gas alone accounts accounted for about 48% in 2014, (<http://www.eia.gov/dnav/pet/pet_pnp_capfuel_dcu_r50_a.htm>). [↑](#footnote-ref-10)
11. The majority of refineries in California use a small amount of purchased natural gas and less than 2% electricity because of the heavy reliance on cogeneration. Moreover, natural gas prices are volatile in the dataset and hence the analysis that relies heavily on natural gas impacts are less reliable as well. [↑](#footnote-ref-11)
12. Though agriculture sector emissions do not fall under the cap, this sector is affected by complementary measures that address emissions from transportation fuels. [↑](#footnote-ref-12)
13. It should also be noted that in California’s refinery output could be influenced by inflow and outflow of petroleum products that are not directly correlated to the price of natural gas. [↑](#footnote-ref-13)
14. Production and Emissions Leakage from the Cap-and-Trade Program in California’s Food Processing Industries Stephen F. Hamilton (Cal Poly Ethan Ligon (UC Berkeley) Aric Shafran (Cal Poly) Sofia Villas-Boas (UC Berkeley) [↑](#footnote-ref-14)
15. UCB Study pg. 29. [↑](#footnote-ref-15)
16. UCB Report, pg. 11. [↑](#footnote-ref-16)
17. “This assumes that the firm produces identical goods for the domestic and exports markets, and therefore the cost of production only depends on their sum.” UCB Report, pg. 15. [↑](#footnote-ref-17)
18. UCB Report, pg. 31. [↑](#footnote-ref-18)
19. Page 18. [↑](#footnote-ref-19)
20. UCB Study, Page 30. [↑](#footnote-ref-20)
21. UCB Study, Page 39. [↑](#footnote-ref-21)
22. UCB Study, Page 7. [↑](#footnote-ref-22)
23. UCB Study, Page 39. [↑](#footnote-ref-23)
24. UCB Study, Page 11. [↑](#footnote-ref-24)
25. NERA calculations based on IMPLAN 2010. California’s share of national output of the following energy-intensive industries: Food Manufacturing (1.1%), Beverage and Tobacco Product Manufacturing (0.4%), Textile Mills (0.0%), Textile Product Mills (0.0%), Apparel Manufacturing (0.2%), Leather and Allied Product Manufacturing (0.0%),Wood Product Manufacturing (0.1%), Paper Manufacturing (0.2%),Printing and Related Support Activities (0.2%), Petroleum and Coal Products Manufacturing (1.6%),Chemical Manufacturing (1.3%), Plastics and Rubber Products Manufacturing (0.2%), Nonmetallic Mineral Product Manufacturing (0.2%), Primary Metal Manufacturing (0.2%), Fabricated Metal Product Manufacturing (0.5%), Machinery Manufacturing (0.5%), Computer and Electronic Product Manufacturing (2.8%), Electrical Equipment, Appliance, and Component Manufacturing (0.2%), Transportation Equipment Manufacturing (1.0%), Furniture and Related Product Manufacturing (0.1%), and Miscellaneous Manufacturing (0.4%). [↑](#footnote-ref-25)
26. The RFF Study, Page 12. [↑](#footnote-ref-26)
27. The UCB paper, page 7. [↑](#footnote-ref-27)
28. The UCB paper, page 7. [↑](#footnote-ref-28)
29. The UCB paper, page 38. [↑](#footnote-ref-29)
30. The UCB paper, page 39. [↑](#footnote-ref-30)