

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

May 9, 2016

Authors:

Dr. Stephen F. Hamilton, Professor
Orfalea College of Business
Cal Poly San Luis Obispo

Dr. Ethan Ligon, Associate Professor
Department of Agricultural and Resource Economics
University of California Berkeley

Dr. Aric Shafran, Associate Professor
Orfalea College of Business
Cal Poly San Luis Obispo

Dr. Sofia Villas-Boas, Professor
Department of Agricultural and Resource Economics
University of California Berkeley

The statements and conclusions in this report are those of the Contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with the material reported herein is not to be construed as actual or implied endorsement of such products.

The authors thank Lauren Beauchamp, Naomi Brown, Kyle Hafey, Mackenzie Smith, Qu Tang and Mathew Thomson for invaluable research assistance.

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

Table of Contents

Executive Summary	<i>iii</i>
1. Introduction	1
2. Background	2
2.1 California’s Climate Change Regulations	2
2.1.1 Cap-and-Trade Program	3
2.1.2 Regulations on California Food Processors	4
2.2 The Food Processing Industry	5
2.3 Competitive Advantage in California Food Processing Industries	8
2.4 Industry Detail	9
2.4.1 Processing Tomatoes	10
2.4.2 Cheese	14
2.4.3 Wet Corn	14
2.4.4 Sugar	15
3. Methodology	17
3.1 Overview	17
3.2 Analytic Framework	21
3.3 Supply Model	22
3.3.1 Processing Tomatoes	23
3.3.2 Wet Corn.....	26
4. Data and Econometric Methods	27
4.1 Processing Tomatoes	29
4.2 Cheese	29
4.3 Wet Corn	30
4.4 Sugar	31
5. Results	31
5.1 Market Estimation	31
5.1.1 Processing Tomatoes	32
5.1.2 Wet Corn	33
5.2 Residual Demand	34
6. Market Transfer and Emissions Leakage	35
6.1 Processing Tomatoes	37
6.2 Cheese	38
6.3 Wet Corn	39
6.4 Sugar	40
6.5 Production Leakage	41
6.6 Emissions Leakage	43
7. References	44

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

Executive Summary

This report models the potential extent of market transfer and emissions leakage resulting from California's Cap-and-Trade Program on California tomato, sugar, wet corn and cheese processing industries. GHG regulations that raise energy input prices at food processing plants in California have the effect of selectively raising the marginal cost of food processing for California plants, resulting in a cost advantage for unregulated plants in other production regions.

Our analysis indicates that selective GHG regulation in California's Cap-and-Trade Program results in substantial market transfer of production from California food processing industries to food processors that produce in unregulated regions. Market transfer effects hinder well-functioning greenhouse gas (GHG) regulations for at least two reasons. First, selective regulations on California plants reduce regional manufacturing activity in the state, decreasing both tax revenue and employment. Second, the associated transfer of production from California to other region results in leakage of GHG emissions across state (and national) lines, dampening the effect of selective GHG regulation on global climate outcomes.

The predicted market transfer effect in each food processing industry depends on supply and demand conditions facing California producers. Some combination of three things must occur in response to an increase in compliance costs: *(i)* the cost increase can be passed forward to consumers in the form of higher prices for manufactured food; *(ii)* the cost increase can be passed backward to farmers in the form of lower farm prices; or *(iii)* the cost increase can result in narrower margins for food processors. In this report, we subsume the latter two effects into our calculation of backward shifting, as our data are not sufficiently rich to distinguish how cost increases predicted to be absorbed in each industry are likely to be shared between California farmers and food processors. Backward shifting of compliance costs from the Cap-and-Trade Program results in lower value for farm products procured by California food processors, which would be shared in some fashion between food processors and agricultural producers through lower prices for farm products, and our results are expressed in terms of this lower combined value in the California supply chain.

Market transfer from California food processors to food processors in other, unregulated production regions is mediated through forward shifting effects of the regulation into consumer prices. Cost increases passed forward into consumer prices provide food processors in other regions with the economic incentive to increase production. As a result, the forward shifting effect of an increase in marginal cost among California producers leads to both decreased demand for the processed food product as well as a loss in market share for California plants. We model the market transfer effect in each of four food processing industries -- tomato, sugar, wet corn and cheese processing-- as the share of the decrease in processed food output by California producers that is acquired by out-of-state producers.

The largest sector of the food industry by emissions and facilities covered in the Cap-and-Trade Program is the tomato processing sector. The tomato processing industry in California maintains

a large market share of global production and we consider market transfer of processed tomato production to be mediated through global market demand. For the sugar, wet corn and cheese processing industries, California producers face significant competition from producers in other states, and farm programs exist that insulate U.S. producers from foreign competition.¹ Accordingly, we consider market transfer to be mediated through U.S. market demand for producers in these industries.

Table ES.1 shows the predicted share of a marginal cost increase that is shifted forward into consumer prices and the resulting market transfer effect the Cap-and-Trade Program. In response to a rise in energy prices under the Cap-and-Trade Program, food processing industries in California are predicted to lose market share to competing food processors out-of-state, and the market transfer effect represents the share of output decline in California that is offset by increased output from out-of-state competitors. The market transfer effect ranges from 57% of the decrease in California processed cheese output shifted to out-of-state producers to 76% of the decrease in California wet corn milling shifted to out-of-state producers.

We calculate the change in California production and market transfer effect of the Cap-and-Trade Program for the case in which no allowances are provided to food processors. Thus, the effect of compliance costs of \$20 per metric ton (MT) of carbon dioxide equivalent (CO₂e) with no allowances provided to firms can be interpreted as the predicted outcome under a 50% allocation of allowances at a \$40 allowance price.

Table ES.2 details the effect of \$20/ MT CO₂e compliance cost on price on market outcomes in each food processing industry. At \$20/ MT CO₂e compliance cost, the predicted increase in marginal cost at California food processing plants ranges from a 0.75% increase for refined sugar production to 1.2% for wet corn milling. The projected decrease in California processed food supply is 7.2% for processing tomatoes, 1.0% for cheese, 2.2% for wet corn, and 1.2% for sugar. The market transfer effect in each industry is given by the share of the reduced California production transferred to out-of-state producers in Table ES.1.

The market transfer effects calculated in Table ES.2 result in “production leakage” of California processed food production to food processors operating across state lines. Production leakage can be related directly to emissions leakage by adjusting the market transfer effect for the relative emissions-intensity of the plants acquiring and losing market share. If production leakage occurs to plants outside of California that have similar technology and use identical fuel inputs (i.e., natural gas) as the California plants that reduce production, then the market transfer effect of the Cap-and-Trade Program would result in a one-for-one transfer of CO₂e emissions. However, if market transfer occurs from California food processing plants that rely on natural gas for energy to out-of-state producers that rely on coal for energy, then each unit of production that transfers out of California would result in higher CO₂e emissions.

A difficulty in measuring the extent of emissions leakage from the Cap-and-Trade Program is that it is hard to predict the regions in which production and emissions increases will occur. For the case of California food processors, the typical plant operates on natural gas; however, global food processing plants including those in other U.S. states rely on other sources such as coal and

¹ Industry-specific conditions are described in Section 2.4 of this report.

fuel oil. In 2002, 52% of total energy supply utilized in the U.S. food manufacturing industry was natural gas, 21% net electricity, 17% coal, 3% fuel oil, and 8% other (e.g., waste materials).² In aggregate, the market transfer of California production to producers in other U.S. locations therefore is likely to occur to plants relying on a mix of fuels that produce higher levels of emissions per unit of energy. In the case of processing tomatoes, the market transfer is likely to occur predominantly to international producers in the E.U. and China. If the global market transfer of processing tomatoes occurs between food processing facilities in California and food processing facilities in China, for example, the transferred quantity of production is likely to be produced at coal-fired plants, potentially resulting in a rise in global CO₂e emissions.

Table ES.1. Predicted Cost-Shifting and Market Transfer Effects of California's Cap-and-Trade Program

Industry	Share of Cost Increase		Market Transfer
	Shifted Backward	Shifted Forward	
Processing Tomatoes	76%	24%	68%
Cheese	87%	13%	57%
Wet Corn	99%	1%	76%
Sugar	91%	9%	71%

Table ES.2. Predicted Effects of \$20/MT CO₂e Compliance Cost on Selected Food Processing Industries

Impact of Cap-and-Trade Program	Food Processing Industry			
	Tomatoes	Cheese	Wet Corn	Sugar
Initial Market Quantity (1,000 MT)	37,904	5,140	28,840	7,480
Initial California Quantity (1,000 MT)	12,093	1,086	504	866
Initial Value (\$/MT)	\$891	\$3,679	\$441	\$700
Percent Increase in MC of Processing	0.97%	0.93%	1.18%	0.75%
Processed Food Price Increase (\$/MT)	\$2.09	\$4.57	\$0.07	\$0.45
Cost Absorbed by Producers (\$/MT)	\$6.52	\$29.64	\$5.13	\$4.80
Reduction in California Supply (1,000 MT)	868	10.50	11.11	10.10
Percent Decrease in California Supply	7.17%	0.97%	2.21%	1.17%
Production Leakage (1,000 MT)	592	6.04	8.41	7.22
Leakage as Percent of California Supply	4.90%	0.56%	1.67%	0.83%

² U.S. Environmental Protection Agency, *Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, March 2007, p. 3-32.

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

1. Introduction

Environmental regulations that raise energy input prices at food processing plants have important impacts on agricultural producers and consumers of processed goods. In particular, a rise in California energy prices, which increases the variable cost of food processing operations for California plants, can result in market transfer of processed food production from California food processors to food processors operating in unregulated regions. Market transfer effects hinder the performance of regional GHG regulations for at least two reasons. First, a one-to-one transfer of GHG emissions across state (and national) borders does not improve global climate outcomes, while at the same time hampering regional economic activity and reducing associated tax revenue and employment in California. Second, the market transfer of production from one region to another may raise emissions per unit of output if the plants that increase production are less efficient than the plants that reduce production. Indeed, if GHG regulation in California shifts production from relatively less emissions-intensive producers in California to more emissions-intensive producers out-of-state, the market transfer of production across state lines can lead to reduced global production and higher consumer prices, while at the same time increasing global GHG emissions. The potential for global consumer markets to mediate a market transfer in regional production levels that results in a net increase in environmental harm has been recently documented by Rausser, Hamilton and Kovach (2009) in the case of endangered species protection.³

In this report, we consider the market transfer of processed food production from California to outside regions in response to the Cap-and-Trade Program authorized by Assembly Bill 32 (AB 32). The magnitude of the market transfer effect that occurs in a particular food processing industry is industry-specific and depends on the economic characteristics of the market, for instance the ability of foreign (out-of-state and international) firms to increase production and the sensitivity of consumers to price increases that are passed through from food processors to consumers in downstream processed goods markets.

We consider four (4) food processing industries in California: (i) processing tomatoes (paste and canned); (ii) wet corn milling; (iii) sugar refining; and (iv) cheese. For each industry, we rely on confidential producer data to estimate the impact of various carbon permit prices on production costs, and the sensitivity of industry market share to higher costs that are passed through to higher consumer prices in processed foods markets.⁴

³ Rausser, Gordon, Stephen F. Hamilton, Marty Kovach, and Ryan Stifter. 2009. "Unintended Consequences: The Spillover Effects of Common Property Regulations." *Marine Policy* 33(1):24-39.

⁴ To facilitate our analysis, we assume a competitive, global food processing market for each good. In a competitive market, increases in marginal cost are passed through one-to-one into prices. Under imperfect competition, costs can be passed through into prices at either more or less than a one-for-one rate, depending on the curvature of demand. For example, Kim and Cotterill (2008) estimate pass-through rates between 73% and 103% under Nash-Bertrand competition in the U.S. cheese market. Kim, Donghun and Ronald W. Cotterill. 2008. "Cost Pass-Through in Differentiated Product Markets: The Case of U.S. Processed Cheese." *The Journal of Industrial Economics* 56(1): 32-48.

2. Background

For global environmental problems such as global warming, the effectiveness of the policy in reducing global GHG emissions depends on a combination of three factors: (i) reduced consumer purchases of goods produced with emissions as a by-product; (ii) input substitution among producers to less emissions-intensive techniques; and (iii) “end-of-pipe” remediation effort, such as carbon capture and storage. A potentially efficient policy can provide economic incentives to engage in the minimum cost combination of all three activities, but can also be disrupted by the lack of global harmonization of policies. Specifically, higher costs in one region can allow firms to expand production in unregulated regions and acquire market share without raising global prices consumers pay for emissions-intensive goods. In such cases, market transfer can occur from producers in a regulated zone to producers in an unregulated zone, resulting in emissions leakage.

Emissions leakage arises when regional regulators attempt to address environmental problems that extend across regional boundaries. The reason is that environmental problems are created both through production and consumption activities. For example, when a “small” region adopts an environmental policy that raises production costs in the region, the policy may have only a negligible effect on the prices consumer pay for globally-produced goods. Absent significant price effects in consumer markets that reduce aggregate consumption of the good, the decrease in production of regulated firms in response to the policy can be offset nearly one-to-one by an increase in production for unregulated firms. To the extent that producers in the unregulated region have higher levels of emissions per unit of output, global emissions can rise in response to the market transfer, hindering the ability of a region to unilaterally improve global environmental outcomes.

2.1 California’s Climate Change Regulations

The need for comprehensive, global climate policy has been increasingly apparent over the last few decades. Various greenhouse gases that are emitted into the atmosphere by anthropogenic sources contribute to climate change, and atmospheric concentrations of greenhouse gases have dramatically increased over the last 150 years. The accumulation of greenhouse gases is likely to impose substantial costs on the global economy through higher worldwide temperatures, global sea level rise, more frequent and severe extreme weather events, and greater fluctuations of temperature and precipitation.

On September 27, 2006, the California Legislature passed AB 32, the Global Warming Solutions Act. AB 32 requires producers in the State of California to reduce their Greenhouse Gas Emissions to 1990 levels by 2020, which is expected to result in an emissions reduction of approximately 30% below the “business as usual” scenario.⁵ As the leading agency implementing AB 32, the California Air Resources Board (ARB or Board) developed a comprehensive Scoping Plan, which is updated every 5 years to outline California’s strategy for meeting program goals.

⁵ Assembly Bill 32 Overview, California Air Resources Board (<http://www.arb.ca.gov/cc/ab32/ab32.htm>)

The ARB is the lead agency responsible for implementing compliance with AB 32. The major GHGs that are regulated under AB 32 include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF₆) and nitrogen trifluoride (NF₃).

The framework for reducing GHG emissions in California is defined by ARB's Scoping Plan. The initial Scoping Plan, approved in December 2008, proposed a comprehensive set of actions designed to direct efforts towards clean, energy efficient production by shifting California producers towards the use of carbon-reducing technology. These actions include the development of new technologies that reduce dependence on fossil fuels and ensure long-term economic and employment benefits.⁶

2.1.1 Cap-and-Trade Program

The Cap-and-Trade Program is a critical element of California's plan for meeting the AB 32 target. The Cap-and-Trade Program imposes a limit on the emissions from sources responsible for over 85% of California's GHG emissions. These restrictions are expected to cut GHG emissions by about 18 million metric tons in 2020, an estimated 20% of the total reduction in GHG emissions needed meet 2020 goals.⁷

The Cap-and-Trade Program not only limits the amount of GHGs emitted into the atmosphere, but it is also designed to help reduce the risk of emissions leakage by reducing compliance costs in industries most sensitive to the market transfer of production. Emissions leakage, which occurs when a reduction in emissions of greenhouse gases in one state is offset by an increase in emissions of GHGs in other states or countries, arises whenever producers in the regulated region lose business to unregulated competitors. The market transfer of production from California to other regions is a relevant concern both for the viability of California's economy as well as for the success of AB 32.

ARB places a limit on GHG emissions by issuing a limited number of tradable permits (allowances) each year, equal to the cap. These allowances are either freely allocated or auctioned off and bid on in quarterly auctions, and firms can both buy and sell allowances in the market. In order to reach the intended emissions reduction, the total number of allowances in circulation declines each year. Each source is required to submit one allowance for every metric ton (MT) of carbon dioxide equivalent (CO₂e) emission that it produces.

To help mitigate the risk of emissions leakage, ARB allocates free allowances to regulated industries, mostly through output-based updating, to energy-intensive, trade-exposed industries in which emissions leakage is most likely to occur.⁸

Beginning in 2013, the cap is applied to emissions from electricity and large, stationary sources. Starting in 2015, the cap also applies to transportation fuels and residential and commercial use of

⁶ AB 32 Scoping Plan, California Air Resources Board (<http://www.arb.ca.gov/cc/scopingplan/scopingplan.htm>)

⁷ AB 32 Cap-and-Trade Program, California Air Resource Board. (<http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm>)

⁸ Assembly Bill 32 Overview, California Air Resources Board (<http://www.arb.ca.gov/cc/ab32/ab32.htm>)

natural gas and propane. Out of the total emission allowances distributed, a portion is allocated to free covered entities, a portion is placed in a cost containment reserve, and the remainder is auctioned off.

2.1.2 Regulations on California Food Processors

Our focus is directed towards the impacts of the Cap-and-Trade Program on food processors in California. In particular, we focus on the effects of the Cap-and-Trade Program on tomato processors (cans and paste), wet corn, sugar, and cheese. While the Cap-and-Trade Program does not encompass agriculture production, agriculture food processors have not been excluded from compliance and face potential increases in food processing costs that could cause both farmers and processors to co-locate to unregulated regions. To mitigate the risk of emissions leakage, ARB established a benchmarking procedure to segment industries into categories with allowance assistance provisions. These provisions include large portions of allowances that are allotted free of charge, disbursed according to category of risk (high, medium, and low). Category of risk is based off of two measures: emissions intensity (1) and trade share (2).⁹

Emissions intensity is calculated as,

$$Emissions\ Intensity = \frac{metric\ tons\ CO_2e}{value\ added}$$

where value added (in million \$s) is derived from the Annual Survey of Manufacturers and U.S. Economic Census.

Table 2.1 shows the ARB risk levels associated with emissions intensity.

Risk Level	Emissions Intensity
Very Low	< 100 mtCO ₂ e/\$M value added
Low	100 – 999 mtCO ₂ e/\$M value added
Medium	1000 – 4999 mtCO ₂ e/\$M value added
High	> 5000 mtCO ₂ e/\$M value added

Trade share is calculated as

$$Trade\ Share = \frac{(imports + exports)}{(shipments + imports)}$$

To calculate trade share, imports, exports, and shipments data from the U.S. Census Bureau and the International Trade Commission.

Table 2.2 shows the risk levels determined by ARB from the trade share calculation.

⁹ Analysis of the Economic Impact of AB 32 for California Food Processing Industry (<http://globalag.net/wordpress/wp-content/uploads/2013/02/Portland-Seminar-AB32-Presentation-Final1.pdf>)

Table 2.2. Trade Share Categorized by Risk Level

Risk Level	Trade Share
Low	< 10%
Medium	10% - 19%
High	> 19%

ARB uses a combination of these two measures to categorize the leakage risk of industries. In order to mitigate the risk of leakage, ARB allocates free allowances, or Assistance Factors (AF), to industries based on their risk level.

Table 2.3 shows the classification of leakage risk associated with ARB calculation of emissions intensity and trade share are utilized.

Table 2.3. Leakage Risk Assessment

Leakage Risk	Emissions Intensity	Trade Share
High	High	High
		Medium
		Low
Medium	Medium	High
		Medium
	Low	Low
		High
Low	Low	Medium
		Low
	Very Low	High
		Medium
		Low

ARB categorizes food processors as medium risk for leakage. This leakage classification implies that for the first and second compliance periods, food processors receive an assistance factor of 100 percent of their product-specific benchmark allowances per unit of output multiplied by a cap decline factor. In the third compliance period they are scheduled to receive an assistance factor equal to 75 percent of their benchmark allowances per unit of output multiplied by the cap decline factor.^{10,11} The benchmarks are usually 90 percent of each industry’s production-weighted carbon emissions per unit output. In the case that no facility hits this efficiency target, the benchmark is set at the most carbon-efficient facility’s carbon emissions per unit output.¹²

¹⁰ http://www.arb.ca.gov/cc/capandtrade/capandtrade/unofficial_ct_030116.pdf

¹¹ In the case of wet corn milling, allowances are allocated based on energy use, rather than units of product output.

¹² <http://www.arb.ca.gov/regact/2010/capandtrade10/candtappb.pdf>

The cap decline factor is a fraction less than one decreasing over time at the same rate as the overall decline in the annual covered emissions limit under the Cap-and-Trade Program.

2.2. The Food Processing Industry

The U.S. food processing sector is classified by industry and by state and county of production according to the North American Industry Classification System (NAICS) under two categories within the manufacturing sector: (1) food manufacturing (code 311), and (2) beverage and tobacco product manufacturing (code 312). The U.S. Census data are further classified by industry at the 5-digit and 6-digit levels of categorization.

Food processing establishments engage in the mechanical, physical, or chemical transformation of raw agricultural products into a variety of food and beverage products. The processed food and beverage products may be finished products ready for utilization or consumption or may be semi-finished products utilized by other food processing establishments as an input for further manufacturing. For example, initial processing by manufacturing establishments in California's processing tomato industry primarily manufacture tomato paste, a raw ingredient that is distributed and sold to manufacturing plants further downstream for use in retail and foodservice packs of soups, sauces, catsup, and paste.

According to information from the 2012 U.S. Census, the U.S. food manufacturing sector (code 311) employs 1,406,336 workers and produces a total value of \$747.6 billion in sales, representing 4.6 percent of U.S. Gross Domestic Product (GDP).

California has the largest concentration of food processing facilities in the nation. Table 2.4 shows the number of plants, number of employees and total value of shipments for California in selected food processing industries. In 2012, the California food manufacturing sector was comprised of 3,392 food manufacturing establishments, which employed 153,927 workers and produced a value of \$73.6 billion in shipments. The value of food shipments in California represented 10 percent of the total value of processed food shipments in the U.S. and amounted to 3.5 percent of California Gross State Product (GSP).¹³

Within California's food processing sector, the dairy product manufacturing industry is the largest industry group in terms of the value of shipments, with sales representing 21.2 percent of the total value of all processed goods, followed by fruit and vegetable processing with 16.4 percent, grain and oilseed milling with 7.2 percent, other sugar and confectionery product manufacturing with 3.8 percent.

¹³ U.S. Census Bureau (2012): <http://www.census.gov/econ/manufacturing.html>

Table 2.4. Value of Shipments in Selected California Food Processing Industries in California (2012)

NAICS Code	Industry	Number of Plants	Number of Employees	Value of Shipments (\$1000s)
311	Food manufacturing	3,392	153,927	\$73,580,066
3112	Grain and oilseed milling	81	3,911	\$5,264,071
31122	Starch and vegetable fats and oils manufacturing	40	1,335	\$2,179,837
311221	Wet corn milling ¹	4	111	\$223,235
3113	Sugar and confectionery product manufacturing	195	7,771	\$2,794,436
31131	Sugar manufacturing	4	903	NA
3114	Fruit and vegetable preserving and specialty food manufacturing	302	31864	\$12,030,532
31142	Fruit and vegetable canning, pickling, and drying	194	20,116	\$8,739,124
311421	Fruit and vegetable canning	117	14,079	\$5,811,123
3115	Dairy product manufacturing	204	16,879	\$15,583,569
31151	Dairy product (except frozen) manufacturing	127	14,203	\$14,699,542
311513	Cheese manufacturing ¹	49	6,178	\$5,451,754

¹Value of shipments inferred from total cost of materials and value-added
Source: U.S. Census (2012)

An important concern with environmental regulations in California is the potential flight of manufacturing jobs from California to other regions in the U.S. (or internationally) with lower production costs. The location of food processing establishments over time is primarily determined by: (i) raw material costs (in particular, the delivered prices of raw agricultural products), (ii) labor costs, (iii) environmental compliance costs, and (iv) proximity to consumer markets. Food processing plants are typically located in close proximity to areas with significant agricultural activity, which reduces the length of time between harvest and processing to ensure freshness. The co-location of agricultural producers and food processing facilities and the discrete nature of processing plant location decisions causes processing plant location decisions to have important implications for regional production patterns and prices.¹⁴ For example, processing tomatoes harvested in California's Central Valley are typically transported to food processing plants and transformed into tomato paste and other processed products within 6 hours after harvest.¹⁵ For this reason, adjustments in the location of food processing industries are closely linked with adjustments in the regional pattern of farm production, leading to co-location of food processing plants and supporting agricultural production in rural areas of California.

Given the co-location decision of farming operation and food processing establishments, policies that affect the vitality of food processing plants also affect the vitality of farmers who serve these markets. When processing plants enter or exit a region of production, farm products migrate to these regions as well, so that overall changes in market activity as a result of environmental regulations that are reflected in consumer prices can potentially mask large changes in the regional distribution of production between regulated and unregulated regions of production.

¹⁴ Apland, J., Anderson, H. 1996. "Optimal Location of Processing Plants: Sector Modeling Considerations and an Example" *Review of Agricultural Economics*, Vol. 18, No. 3. (Sep., 1996):491-504.

¹⁵ Brunke, H., Sumner, D. A. 2002. "Assessing the Role of NAFTA in California Agriculture: A Review of Trends and Economic Relationships," UC Davis AgIssues Center Report, November 2002.

In general, there has been ongoing concern over the flight of manufacturing jobs from California to other regions in the U.S. (or internationally) with lower production costs. Table 2.5 shows changes in the number of operating plants in selected food processing industries in California over the period 2002-2012. Overall, the period is marked by consolidation in the number of plants, with an associated declined employment in California food manufacturing industries. With the exception of the starch and vegetable fats and oils manufacturing industry, California's food processing industries consolidated over the period 2002-2012.

Table 2.5. Change in the Number of Operating Plants in Selected California Food Processing Industries in California (2002-2012)

NAICS Code	Industry	Number of Plants		
		2002	2012	% change
311	Food manufacturing	3,814	3,392	-11.1%
3112	Grain and oilseed milling	98	81	-17.3%
31122	Starch and vegetable fats and oils manufacturing	36	40	11.1%
311221	Wet corn milling	3	4	33.3%
3113	Sugar and confectionery product manufacturing	220	195	-11.4%
31131	Sugar manufacturing	8	4	-50.0%
3114	Fruit and vegetable preserving and specialty food manufacturing	336	302	-10.1%
31142	Fruit and vegetable canning, pickling, and drying	230	194	-15.7%
311421	Fruit and vegetable canning	145	117	-19.3%
3115	Dairy product manufacturing	211	204	-3.3%
31151	Dairy product (except frozen) manufacturing	136	127	-6.6%
311513	Cheese manufacturing	50	49	-2.0%

Source: U.S. Census (2002 and 2012)

2.3 Competitive Advantage in California Food Processing Industries

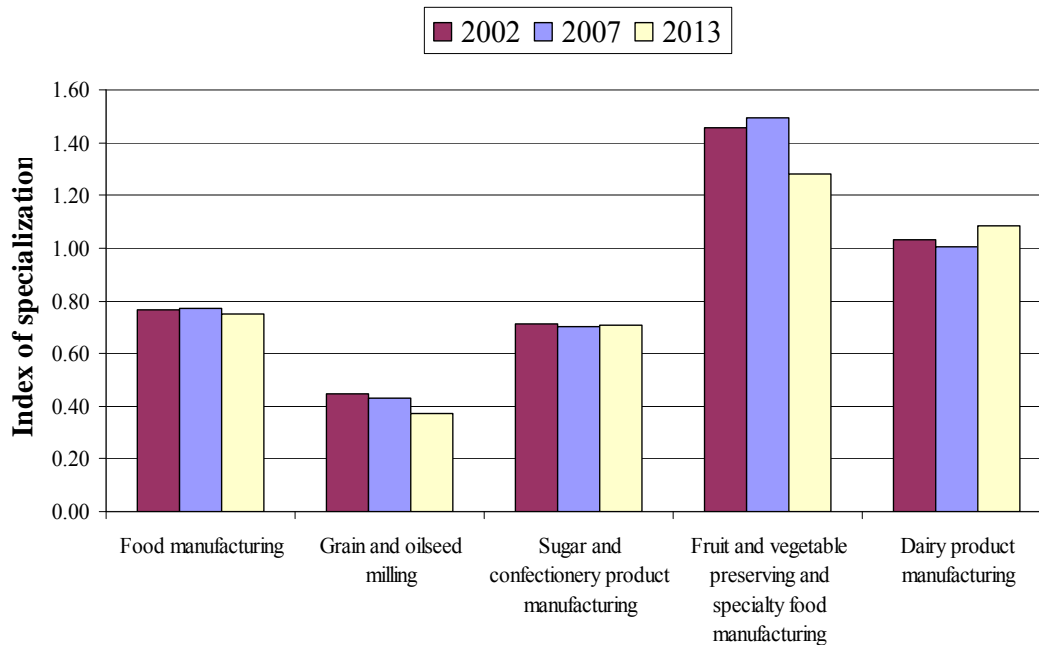
It is possible to measure the competitive advantage of the various food processing industries in California relative to other regions in the United States by calculating specialization indices for each industry. A specialization index, or location quotient, measures the concentration of California's production activities in a particular food processing industry relative to the concentration of the same industry in other regions of the U.S.

For each processed food category, a specialization index is calculated as the ratio of the value of shipments as a share of GSP in California to the value of shipments as a share of GDP in the U.S. If the share of value in a certain processed food industry in California is greater than the share of value in the same processed food industry in the U.S., then the California economy devotes more resources to the production of this good than the share of resources devoted to this same good in other regions in the U.S. Accordingly, an index number greater than 1 suggests that California has competitive advantage over other states in the production of the manufactured food, whereas

an index number less than 1 suggests that California is at a competitive disadvantage relative to other states in the production of the food product.

Figure 2.1 depicts specialization indices for selected food processing industries in California as well as for all food over the period 2002-2013.

**Figure 2.1. Index of Specialization for California
Food Processing Industries, 2002-2013**



Source: U.S. Bureau of Census, Annual Survey of Manufacturers

Overall, within the food manufacturing sector (NAICS code 311), the competitive advantage of California’s manufacturing sector has been relatively stable over the period 2002-2013, with a slight decline in competitive advantage reflected in a decrease in the specialization index from 0.76 in 2002 to 0.75 in 2013.

California increased its competitive position in dairy product manufacturing with a rise in the specialization index from 1.03 in 2002 to 1.08 in 2013, but decreased its competitive position in all other industries considered. The decrease in California’s competitive advantage in food processing over the period 2002-2013 was marked by a decline in the specialization index from 0.71 to 0.70 in sugar and confectionary product manufacturing, from 0.45 to 0.37 in grain and oilseed milling, and from 1.46 to 1.28 in fruit and vegetable processing.

2.4 Industry Detail

The following sections provide background details on the food processing industries encompassed in this report.

2.4.1 Processing Tomatoes

The largest sector of the food industry by emissions and facilities covered in the Cap-and-Trade Program is the tomato processing sector.

Tomato is a warm-season crop, either planted by sowing seeds directly into the ground during late January or early February, or grown in greenhouses until they are ready to be planted outside in the spring.¹⁶ The harvest and production period begins in the end of July, and operates at full capacity throughout August and September, with the production season generally winding down in mid-October.¹⁷

California is the leading producer of processing tomatoes, maintaining the largest market share both domestically and worldwide. Within the state, the three biggest processing tomato counties are Fresno, Yolo, and San Joaquin, in order of importance, with significant production also occurring in Kings, Colusa, Merced, Stanislaus, Solano, and Sutter counties. While production is primarily centered in the San Joaquin and Sacramento Valleys, nearly the entire state is involved in the processing tomato market. After California, Indiana, Ohio, and Michigan account for most of the remaining domestic production, while the dominant international producers that compete with California are located in China, Spain, and Italy.¹⁸

Throughout the 1980s and 1990s, the California processing tomato market experienced substantial growth due to higher-yielding hybrid varieties, high prices, new processing plants, and expanded acreage. In 1999 and 2000, the market reached its highest paste prices in a decade while achieving record quantities of production; however, around 2000, industry observers began to acknowledge an over-supply problem, resulting in low farm-gate prices, decreased domestic demand, and a lack of international competitiveness. These circumstances eventually caused the Tri Valley Growers, one of the largest tomato processors at the time, to file for bankruptcy.¹⁹ Since 2000, the market recovered, and California processing capacity has settled at about 11 to 11.5 million tons per season since 2005.

California's market share of U.S. production has risen from 79% in 1980 to 96% today and processed tomato manufacturers in the state currently account for approximately one-third of global processing tomato production. Figure 2.2 shows the recent growth of California tomato processors market share as a share of U.S. and world production.

California tomato processors are net exporters. Exports of U.S. processing tomato products have grown from 1% during the 1980s, to 5% in the 1990s, and reached 8% in 2000.²⁰ During the 2005-06 season both exports and imports rose, with exports of processed tomato products totaling 1.78 billion pounds, roughly 10 percent of the U.S. crop. Top U.S. export markets include Mexico and Canada, accounting for up to two-thirds of U.S. processing tomato export

¹⁶ Naeve, Linda, "Tomatoes," Agricultural Marketing Resource Center.

¹⁷ Trueblood, Alexander J., Yin Yin Wu, and Ahmad R. Ganji, "Potential for Energy, Peak Demand, and Water Savings in California Tomato Processing Facilities," BASE Energy, Inc. and San Francisco State University, May 21-24, 2013.

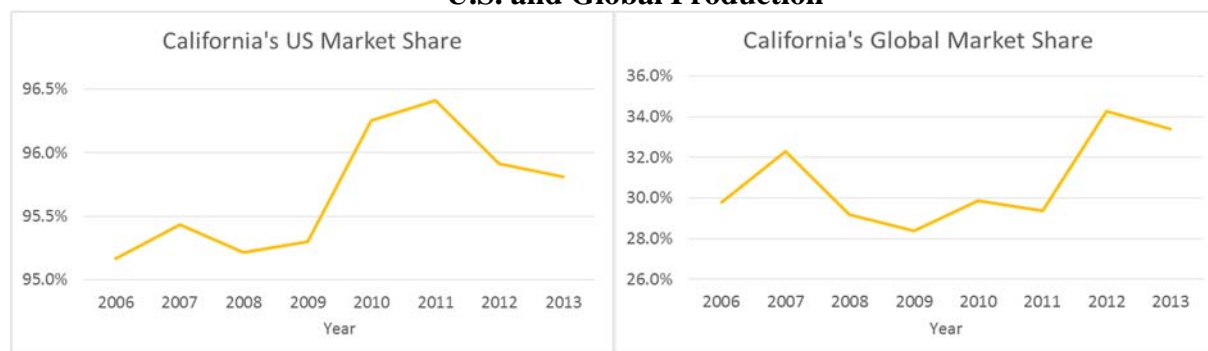
¹⁸ Economic Research Service U.S. Department of Agriculture, "Vegetables & Pulses: Tomatoes," Oct. 9, 2012.

¹⁹ Carter, Colin A., "Economics of the California Processing Tomato Market," Giannini Foundation of Agricultural Research, Dec., 2006.

²⁰ Economic Research Service U.S. Department of Agriculture, "Vegetables & Pulses: Tomatoes," Oct. 9, 2012.

sales, followed by Japan, South Korea, and Italy. However, the stabilization of processed tomato production in California and expanding production in Western Europe and China has resulted in periods of negative growth in California’s worldwide market share.²¹ In 2012, processing tomato imports accounted for approximately 6% of U.S. consumption. While sauces and catsup are usually the top imports among tomato-product, tomato paste has accounted for a significant share of imported volume in years with crops shortages. Major sources of U.S. imported processing tomato products are Canada (accounting for more than 40%), Italy, Mexico, China and Israel.

Figure 2.2. Market Share of California Tomato Production as Share of U.S. and Global Production



Source: USDA, Economic Research Service (2010).²²

While many firms manufacture pulp-based products like stewed and diced tomatoes, most initial processing is done by firms that manufacture raw paste. Almost all processing tomato production in California is forward-contracted between the grower and processing firm, rather than sold on the open market, normally with prices settled well before the season starts. Processing tomatoes are unique in that a single bargaining association, known as the California Processing Tomato Growers Association, represents the majority of the growers and negotiates prices with each of the nine processors. As a result, processors pay all California farmers approximately the same price in a given season. The relatively high level of inventories carried from one season to the next in the California market, averaging almost 40 percent of domestic production, help to absorb shocks to the market and mute the impacts of supply fluctuations on wholesale paste prices.

Costs for processing tomatoes are highly driven by natural gas prices. In recent years, the cost of natural gas for a California tomato processing firm ranged from \$0.03 to \$0.04 for every pound produced. Over the period 2010-2013, energy costs accounted for 4.2% of total variable costs of production for California tomato processors in our sample.

2.4.2 Cheese

U.S. households are among the largest cheese consumers in the world, consuming roughly 36 lbs. of cheese per capita in 2014.²³ Per capita cheese consumption has continued to grow in

²¹ Carter, Colin A., “Economics of the California Processing Tomato Market,” Giannini Foundation of Agricultural Research, Dec., 2006.

²² Economic Research Service U.S. Department of Agriculture, “US Tomato Statistics (2010),” June 2010.

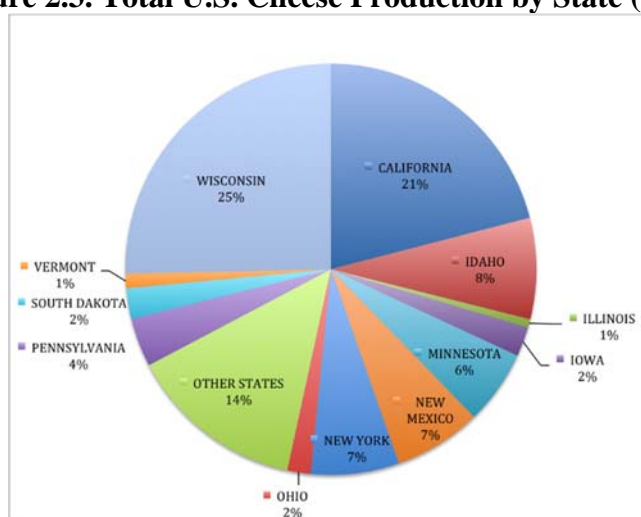
²³ USDA, ERS Dairy Data (<http://www.ers.usda.gov/data-products/dairy-data.aspx>)

recent years largely because of the increased availability of cheese varieties, increased consumption of food away-from-home, and greater popularity of ethnic cuisines that employ cheese as a major ingredient.

The U.S. is one of the largest producers of cheese in the world, operating a total of 529 plants throughout the country. Wisconsin operates 126 plants, the most out of all states, with California ranking second with 64 plants.²⁴

Figure 2.3 shows the market share of California cheese production in total U.S. production in value terms. Wisconsin and California combined to account for almost 50% of total U.S. natural cheese production in 2014. California is the second largest producer of cheese behind Wisconsin.²⁵

Figure 2.3. Total U.S. Cheese Production by State (2014)



Source: USDA, National Agricultural Statistics Service (NASS)²⁶

Within the dairy products sector, California food processing plants tend to specialize in production of hard manufactured products such as butter, non-fat dry milk and cheese.²⁷ In 2001, approximately 19 percent of milk produced in California was used for fluid consumption, 72 percent was used for hard products, and the remaining 9 percent was used for intermediate products such as yogurt, sour cream and ice cream.²⁸

Both the U.S. cheese industry and California industry operate under price support programs. The 2008 Farm Act extended the U.S. milk support purchase program to provide price support for the purchase of manufactured products. It specified support purchase prices, which for cheese was

²⁴ Dairy Products Annual Summary, NASS (<http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1054>)

²⁵ Dairy Products Annual Summary, NASS (<http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1054>)

²⁶ USDA, NASS, (http://www.nass.usda.gov/Statistics_by_Subject/index.php?sector=CROPS)

²⁷ Brunke and Sumner, 2002

²⁸ CDFA, 2005

no less than \$1.13 per pound of cheese in blocks.²⁹ The Dairy Export Incentive Program also pays cash bonuses that allow dairy product exporters to buy at U.S. prices and sell abroad at prevailing (lower) international prices.³⁰

Industry-specific import barriers and export subsidies in the U.S. are present that are unique to the dairy industry. Trade barriers are the most significant feature of U.S. dairy policy. Under the 1996 Fair Act, imports of dairy products in the United States have been limited to about 2 to 3 percent of U.S. consumption each year, which insulates U.S. dairy product markets from world market forces and leads to domestic prices significantly higher than world prices.³¹ For the purpose of this study, the U.S. market is considered to be insulated from foreign import trade.

The operation of an independent marketing system in California for fluid milk used in cheese (class 4b) confounds the market outlook for cheese production. To the extent that California adjusts support prices and transportation allowances within the milk marketing system to compensate for higher processing costs due to environmental regulations, this can mitigate the effect of the Cap-and-Trade Program on cheese production in California. This study considers emissions regulations in isolation, apart from potentially offsetting (or exacerbating) changes that may occur independently in California's dairy marketing program.

Supply factors are the key determinants of the regional distribution of milk production used to manufacture cheese. Because an active interregional trade exists in the U.S. for hard manufactured products, including cheese, it is possible to meet regional changes in population that affect supply and demand of dairy products through transshipment between U.S. states. These factors in combination, suggest that supply variables are the major aspects that influence the regional distribution of U.S. dairy product manufacturing.³²

Relative to other manufactured dairy products, cheese is expensive to produce. The total cost to firms producing cheese ranges from \$50-\$70 million a year, or 10-13 cents per pounds of production. The production process burns around 2 million British Thermal Units (MMBtu) of natural gas per 1000 lbs. of cheese produced, which equates to roughly 1-2 cents per lbs. of cheese. The energy requirement for producing cheese is approximately 5.4 MMBtu per metric ton. Based on an average energy share of 3.9% of raw milk costs, energy costs for the California firms in our sample accounted for 4.4% of total variable costs of producing cheese over the period 2010-2013.³³

2.4.3 *Wet Corn*

The wet corn wet milling industry converts corn into two major end products: cornstarch and corn syrup.³⁴ Except for a small fraction of industry output, cornstarch and corn syrup are commodity products, sold primarily to the food, textile, paper, and adhesives industries. Starch is

²⁹ USDA, Farm Service Agency (http://www.fsa.usda.gov/Internet/FSA_File/dppsp_en_fact_sheet.pdf)

³⁰ USDA, Foreign Agricultural Service (<http://apps.fas.usda.gov/excredits/deip/deip-new.asp>)

³¹ Brunke and Sumner, 2002

³² Yavuz et al., 1996

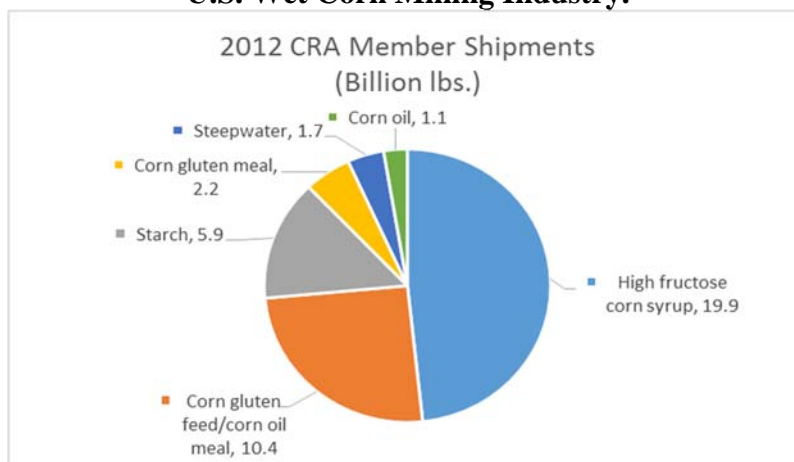
³³ USDA, ERS: <http://www.ers.usda.gov/data-products/milk-cost-of-production-estimates.aspx>

³⁴ Edna C. Ramirez, David B. Johnston, Andrew J. McAloon, Winnie Yee, Vijay Singh, "Engineering process and cost model for a conventional corn wet milling facility," *Industrial Crops and Products* 27, (Jan. 2008):91-97.

used primarily as a stiffening and texturizing agent, while corn syrup is used as a texturizer, thickener, and sweetener. Corn is ground into starch slurry through an operation termed “basic grind”, which is then either further processed into finished starch or converted into corn syrup.

The process of corn wet milling is designed to refine corn into a wide assortment of consumer goods, ranging from food and beverages, to laundry products, ceramics, and textiles.³⁵ The United States is a major player in the world corn trade market, with approximately 80 million acres of land across the country planted to corn, centered primarily in the Heartland region.³⁶ Currently, the end products of the wet milling process are starch slurry, germ, corn gluten feed, and corn gluten meal, which can then be further processed to make byproducts including wet corn gluten feed, corn gluten feed, corn germ meal, corn gluten meal. Starch is the primary byproduct of wet corn milling, and is converted into a number of products, including corn sweeteners and ethanol. According to 2008 data, corn sweeteners produce the most revenue among wet corn milling byproducts, accounting for nearly 50 percent of the U.S. nutritive sweetener market.

Figure 2.4. Share Allocated to Various End-Products in the U.S. Wet Corn Milling Industry.



Source: Corn Refining Association (2012)

Figure 2.4 shows the market share of California wet corn processors. In 2012 California accounted for 1.8% of U.S. wet corn milling production (as measured by value of shipments). U.S. had a total value of shipments of \$12.8 billion, a 6.2% increase from the prior census in 2007.³⁷ In 2012, the U.S. domestic corn refining industry made a total of 92.2 billion shipments of corn refining byproducts around the world, enabling them to remain the world’s largest producer and exporter of corn.³⁸

Over the four year period from January 2010 to January 2014, the price of wet corn product averaged \$0.23 per pound, with corresponding costs \$0.19 per pound.

³⁵ “About the Corn Refiners Association,” Corn Refiners Association.

³⁶ “Corn: Background,” USDA ERS.

³⁷ “Economic Census: Industry Snapshots- Wet Corn Milling,” United States Census Bureau, 2012.

³⁸ Corn Refining Association, 2012.

Among the food and kindred products group, corn wet milling is the most energy intensive industry, accounting for 15% of energy use in the entire food industry. Energy is the largest component of the operating cost for corn wet millers in the U.S. apart from corn purchases. The energy cost of a typical wet corn milling plant in the United States is approximately \$20 to \$30 million per year.³⁹ While total costs have remained relatively constant over the past four years, the cost of natural gas has varied substantially over time. Over the past four years, natural gas costs have grown from 1% to 3% of overall costs in 2010, to 5% to 9% in 2013.

The energy requirement for wet corn milling is approximately 4.4 MMBtu per metric ton. In 2013, energy costs for the California firm in our sample accounted for approximately 6.9% of total variable costs of production.

2.4.4 Sugar

Unlike most other producing countries, the U.S. has both large and well-developed sugarcane and sugar beet industries. Since the mid 1990's, sugar cane has accounted for roughly 45% of the total sugar produced domestically, and sugar beets for about 55% of production.⁴⁰ Total U.S. sugar production has increased over time, largely due to substantial investment in new processing equipment, the adoption of new technologies, the use of improved crop varieties, and acreage expansion.

Sugar beets can only be stored for a short time after harvest before being refined into sugar. This means the number and location of sugar-processing plants are critical to sugar production. Without sugar beet refineries, sugar beets have little or no economic value. The number of sugar refineries has declined significantly over time,⁴¹ due in large part to the sugar program, which substituted high fructose corn syrup (HFCS) for sugar as a sweetener. Sugar is processed not only into refined sugar but also into a range of products containing sugar, including bakery products, beverages (canned, frozen, and bottled), confections, and dairy products.

The U.S. Government supports domestic sugar prices through loans to sugar processors and a marketing allotment program. The U.S. sugar program uses price supports, domestic marketing allotments, and tariff-rate quotas to influence the amount of sugar available to the U.S. market.

The domestic price support program makes loans to processors and not directly to producers. These loans guarantee a minimum price regardless of the true market conditions. At the end of the loan term (generally 9 months), sugar producers and processors make one of two choices. Either turn over to the government the sugar they produced as payment for the loan or sell their sugar on the market if the going price is higher than the USDA loan amount. Marketing allotment programs also allocate a share of the anticipated U.S. sugar market to sugar producers annually. This allotment determines the amount of sugar an individual company is allowed to

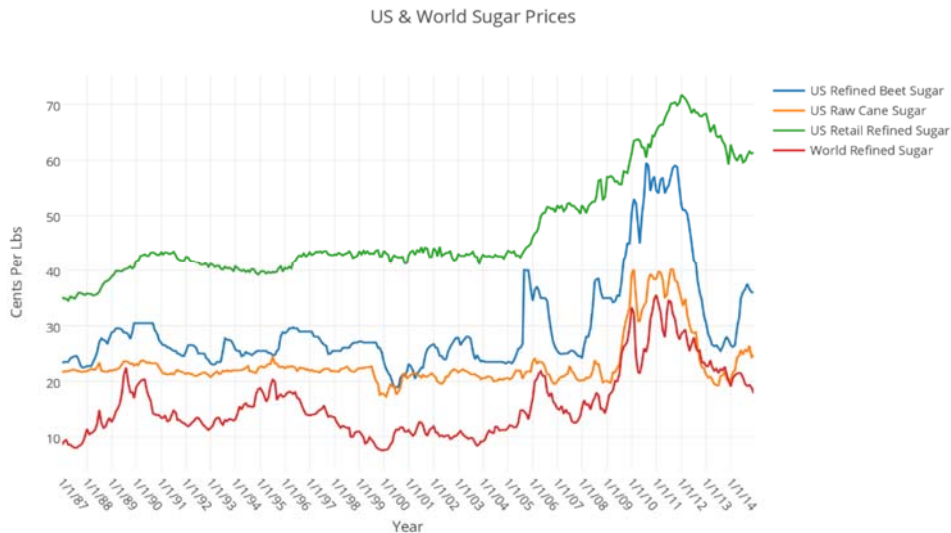
³⁹ Christina Galitsky, Ernst Worrell and Michael Ruth, "Energy Efficient Improvement and Cost Saving Opportunities for the Corn Wet Milling Industry- An ENERGY STAR Guide for Energy and Plant Managers," Ernst Orlando Lawrence, Berkeley National Laboratory, Environmental Energy Technologies Division, Sponsored by the U.S. Environmental Protection Agency, Jul., 2003.

⁴⁰ USDA, Economic Research Service (<http://www.ers.usda.gov/topics/crops/sugar-sweeteners/background.aspx>)

⁴¹ 2007 U.S. Agricultural Census, (http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/st99_1_033_033.pdf)

sell for that year. On top of this, the government also use import and re-export programs to further regulate markets. These price support systems are the reason why U.S. sugar prices have, historically, been well above world prices as shown in Figure 2.5.

Figure 2.5. U.S. and World Sugar Prices, 1987-2014.



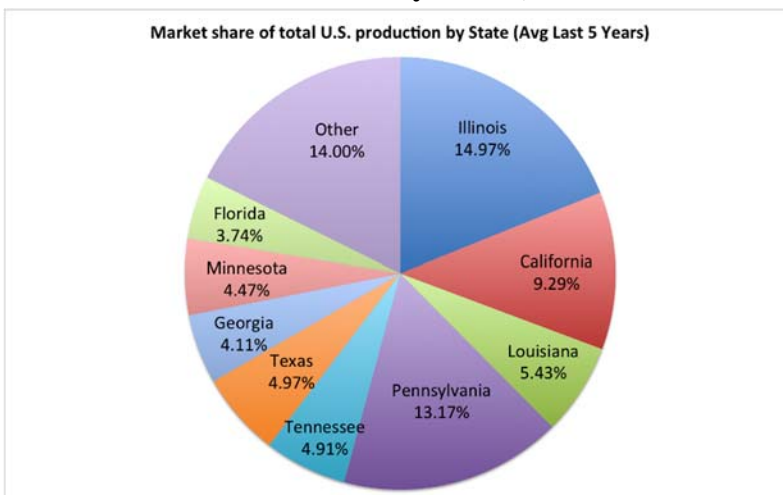
Source: USDA, Economic Research Service – Sugar & Sweeteners Yearbook Tables⁴²

Due to the U.S. sugar price supports, the relevant market for calculating emissions leakage for sugar is the U.S. market. Figure 2.6 shows the average market shares of U.S. production by state, as an average of the value of shipments of sugar and confectionary products (NAICS 3113) over the last 5 years.

Although sugarcane and sugar beets are agronomically different plants, they are both used to produce an identical end product, refined (or “white”) sugar. Sugar beets are refined through processing at a single location, a beet processing plant or factory. A price range for wholesale Midwest refined beet sugar is quoted each week in Milling and Baking News. During the 2000’s this, wholesale beet price has ranged from a low of 19 cents a pound in 2000 to a high of 60 cents a pound in 2010.

⁴² <http://www.ers.usda.gov/data-products/sugar-and-sweeteners-yearbook-tables.aspx>

Figure 2.6. Market Shares of U.S Production by State (measured in value of shipments).



Source: U.S. Census, Annual Survey of Manufactures⁴³

Typically, for firms producing sugar, fixed costs are made up of facility and capital expenses, maintenance expenses and operating costs and also insurance and tax costs. Together these make up around 5-10% of total costs. Variable costs such as the cost of transportation and fuel, energy, labor and also the cost of the raw materials make up the remainder of total costs. In the past 5 years, energy and raw material costs have made up the largest portions of firms total costs. In sugar beet production in particular, the cost of the beets is the most expensive thing and often accounts for up to 50% of a firm's costs.

Energy costs typically account for between 5-10% of the total costs of sugar production. The energy requirement for producing sugar is approximately 4.12 MBtu per metric ton. Over the period 2006-2009, energy costs for the California firms in our sample accounted for 5.3% of total variable costs of production.

3. Methodology

3.1 Overview

This section presents the methodological framework for modeling emissions leakage in California's food processing industries as a result of the Cap-and-Trade Program. In general, emissions leakage occurs when increased compliance costs in a regulated region result in a market transfer of production from producers in the regulated region to producers in non-regulated regions and a commensurate loss of market share for regulated firms. Our focus in this report is on estimating the market transfer of production as a result of the Cap-and-Trade Program from California food processors in 4 industries (tomatoes, cheese, wet corn, and sugar) to food processors serving these industries from other regions.

From a policy standpoint, "emissions leakage" as a result of the Cap-and-Trade Program is linked to the market transfer of production across California state lines. Nevertheless, although

⁴³ U.S. Census Bureau, Annual Survey of Manufacturers.

emissions leakage is a direct result of market transfer effects, there are several critical differences. First, the decrease in California production as a result of a regulation can differ from the increase in out-of-state production. That is, production in a regulated region is generally not transferred one-to-one to non-regulated regions as a result of higher emissions compliance costs. The market transfer of production from a regulated region to an unregulated region, what we might refer to as “production leakage”, refers only to the change in production absorbed by unregulated firms. Because production leakage arises through changes in market prices, total global output will tend to decline in response to a positive cost shock in the regulated region. For this reason, the market transfer of production from the regulated region to other global production regions is generally smaller than the decrease in production in the regulated region.

Second, emissions leakage differs from production leakage if the emissions-intensity of regulated firms differs from the emissions intensity of non-regulated firms. For example, if regulated firms in California produce 10 tons of a processed food from each ton of carbon emissions and non-regulated firms produce 5 tons of processed food from every ton of carbon emissions, then production leakage of each ton of processed food results in a doubling of global emissions.

In this report, we consider production leakage from California food processors to out-of-state (domestic and international) food processors. We characterize production leakage in terms of the projected decrease in output of California firms in response to the regulation and the projected increase in out-of-state production attributed to the regulation. Market transfer from one region to the other depends on the ability of firms to pass through cost changes.

For the case of California food processors, the degree to which increased food processing costs are passed forward to consumer markets through higher prices for processed goods depends on the ability of consumers to find reliable substitute goods to replace the relatively high-cost processed good of a regulated firm. For processed foods that can be transported long distances without suffering significant declines in product quality, transshipment of processed goods from other regions can provide adequate substitutes in consumer demand functions, which in turn limits the ability of food processors in California to pass an increase in production cost forward to consumers in the form of higher consumer prices.

The degree to which increased food processing costs are passed backwards to agricultural producers in the form of lower prices for raw agricultural products depends on the alternative land uses available to farmers. In the short-run, a decline in the price of an agricultural product that occurs after the acreage has been allocated to the crop may have little effect on the quantity produced, resulting only in changes in the fresh and processed allocation, and this facilitates backwards shifting of cost into agricultural production markets. In the long-run, the ability of farmers to allocate their land to the production of alternative crops (or to other alternative uses such as urban development) limits the degree that an increase in food processing costs can be shifted backwards into agricultural production markets in the form of lower prices for agricultural products. Given that much of California’s food processing industry operates on relatively long-term contracts with farmers for farm products, the emphasis of this study is on the long-run implications of the Cap-and-Trade Program using long-run estimates of farm product supply.⁴⁴

⁴⁴ Long-run implications refer to the length of time it takes for farmer’s to switch production to alternative crops.

The relative degree to which an increase in food processing costs following GHG regulations is passed forward to consumer markets and passed backwards to agricultural producer markets depends on the price elasticity of demand and the spatial flexibility of supply. The spatial flexibility of supply is a measure of the degree to which agricultural producers switch to alternative crops (or exit agricultural production entirely) when the price of the product decreases. The exit of agricultural producers from a cropping region tends to occur spatially from the most distant shipment points, because the effective price of the delivered agricultural product to a processing facility (gross of the transportation cost) rises over distance from a food processing plant. Farmers located at greater distances from processing facilities are more likely to switch into alternative crops, land quality held constant, than those located at shorter shipping distances. For the agricultural production region as a whole, the spatial price flexibility is the reciprocal of the elasticity of farm supply (Durham and Sexton, 1992).⁴⁵ In general, when demand is more elastic than supply, a greater portion of the cost shifts backward into the agricultural product market and the remaining portion shifts forward to the consumer market, and when supply is more elastic than demand, a greater portion of the cost shifts forward into the consumer market than shifts backward into the agricultural product market.

In this study, we view the decision of farmers and processors to produce in a given region to be a co-location decision. Increased production costs from environmental regulations are either shifted forward to consumers in the form of higher prices for processed foods or are absorbed by regulated firms in the form of narrower margins that depress regional economic activity in the long-run. Food processing plants and the farmers that support them tend to exit the market together when the margin between the consumer price and farm price for a good narrows in relation to the margin that can be enjoyed elsewhere.

The price elasticities of supply and demand are key determinants that mediate the market transfer or leakage effect of GHG regulations. In terms of the market transfer effect of food processing activity from the regulated region to regions with lower production costs, the location of food processors is influenced both by proximity to consumer markets and proximity to the supply of raw agricultural products. Moreover, because farming and processing operations are co-located, production leakage in the processing industry may tend to occur in conjunction with production leakage of farm output as well, for instance agricultural land removed from production when a food processor exits the market. In a given industry, the transfer of processed food production out of a particular region is closely tied to the land allocation decision of farmers in the region (i.e, the long-run price elasticity of farm supply), and to the ability to transship processed goods into the consumer market from other regions to meet consumer demand.

Figure 3.1 depicts the market transfer effect of GHG emissions regulations in a food industry. For expositional convenience, the figure shows the case of fixed proportions technology where units of output (Q) have been re-scaled so that 1 unit of farm product results in one unit of the processed good. Prior to environmental regulation, the quantity produced (in both panels) is labeled Q_0 and the consumer price and farm price are P_0^c and P_0^f , respectively. The shaded region represents the value-added component in the food processing industry.

⁴⁵ Durham, Catherine A., and Richard J. Sexton. 1992. "Oligopsony Potential in Agriculture: Residual Supply Estimation in California's Processing Tomato Market." *American Journal of Agricultural Economics* 74(4):962-72.

In both panels of the figure, the increase in the variable cost of food processing brought about by higher energy prices is shifted backward into agricultural product markets (represented by the decline in the farm price from P_0^f to P_1^f) and forward into consumer markets (represented by the rise in the consumer price from P_0^c to P_1^c). Panel (a) of Figure 3.1 depicts the case of elastic supply and demand conditions. In the case where both supply and demand facing the food processor are relatively elastic, the production leakage (the decrease in regional processed food production from Q_0 to Q_1) is relatively large. The reason is that, under elastic supply and demand conditions, agricultural producers have reasonably attractive alternative uses for their land and, at the same time, consumers have reasonably good substitution possibilities in consumer markets for processed goods. Under these conditions, a relatively large amount of food processing activity transfers out of the region to other regions in response to an increase in food processing costs.

Figure 3.1. Long-Run Market Transfer Effect of an Increase in Food Processing Cost

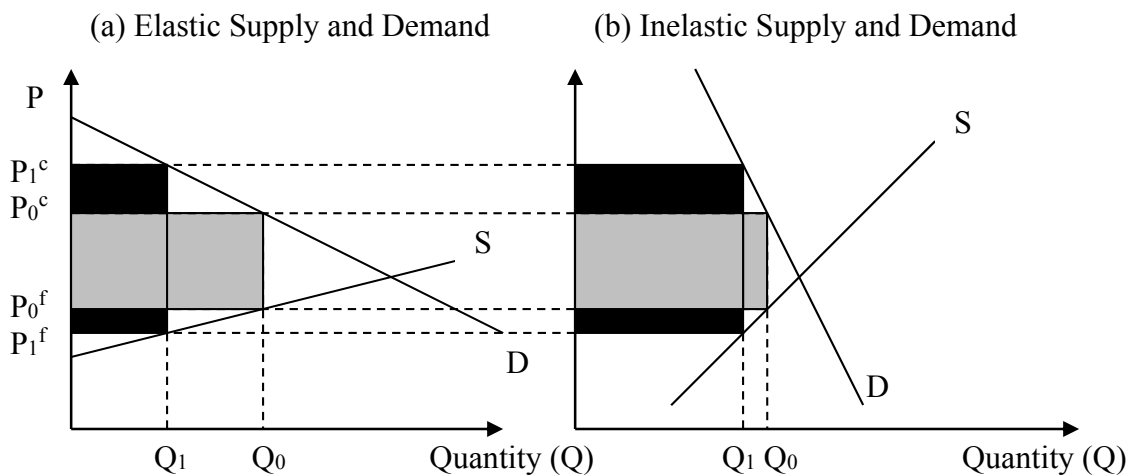


Figure 3.1(b) depicts the case of inelastic supply and demand conditions. In the case of inelastic demand, consumers face few reliable substitutes for the regionally-produced food product, so that the consumer price rises in response to an increase in food processing costs without an appreciable decline in the quantity produced. Similarly, in the case of inelastic supply, farmers have few alternative uses for land, so that farm prices decline in response to the increase in food processing costs without causing a large decrease in farm production. As a result, the market transfer effect (the decrease in regional processed food production from Q_0 to Q_1) is relatively small.

The incidence of an increase in food processing costs can be calculated using estimates of the elasticity of consumer demand and the long-run supply elasticity for the farm product. To identify the extent of production leakage of processing and farming operations in response to the Cap-and-Trade Program, it is important to consider long-run supply elasticities calibrated to a time-horizon in which entry and exit can occur. In the long-run, a rise in the unit cost of

processed food production reduces processor profits and induces the relocation of a portion of the region's food processing operations to other production regions. In a competitive food industry, for example, the increase in food processor cost following an environmental regulation is entirely passed through to consumers and growers in the long-run (Gardner, 1975).⁴⁶

3.2 Analytic Framework

This section develops an analytical framework to identify the salient features of production leakage and the attendant implications for farm production and consumer food prices. For the case of regional environmental regulations in California's Cap-and-Trade Program, the GHG emissions regulations affect only the subset of food processors located within California's borders. An increase in cost among food processors in California creates an economic opportunity for a market transfer of production to occur that redistributes processed food production from food processors within California to unregulated food processors in other states and countries.

For regulations that encompass only a subset of food processors serving a global consumer food market, a rise in consumer prices that results in a decrease in overall market quantity may mask a substantial decline in regional production activity when consumer price increases mediate the market transfer of production to locations outside the regulated area. Markets for processed food products are national (and in many cases international) in scope, and demand for processed food can be readily met through the transshipment of goods from production regions outside the state that are not subject to higher energy prices.

To estimate the extent of production leakage in a given food processing industry, we estimate residual demand functions for processed food produced in California. Residual demand for a processed good refers to the portion of market demand that is met by producers in a given region. Let Q_T denote total demand for a processed food product in the market and let Q_R and Q_U refer to the production level of firms facing regulatory increase in cost and the production level of unregulated firms, respectively. Under this designation, total demand in the market is met by total production, which defines the residual demand facing regulated firms as

$$Q_R = Q_T - Q_U.$$

Differentiating this equation with respect to the market price and converting the resulting expression into elasticity form allows the elasticity of residual demand to be expressed as

$$\varepsilon_R = \frac{\varepsilon_T}{s} + \left(1 - \frac{1}{s}\right)\varepsilon_U, \quad (1)$$

where s is the market share of producers affected by GHG emissions regulation, ε_R is the price elasticity of residual demand, ε_T is the market demand elasticity, and ε_U is the elasticity of supply

⁴⁶ Gardner, Bruce L. 1975. "The farm-retail price spread in a competitive food industry." *American Journal of Agricultural Economics* 57(3): 399-409.

of firms in the unregulated region. If the regulation uniformly increase production costs for all firms in the market, then the combined market share of the regulated firms is 100 percent of the market ($s = 1$), and $\varepsilon_R = \varepsilon_T$; however, as the market share of firms subject to environmental regulation falls ($s < 1$), an increase in price charged by regulated firms stimulates the production of goods in the unregulated region. Production leakage occurs through increased supply by unregulated firms until the quantity supplied equates with the higher market price.

Notice that the residual demand facing the regulated firms is more elastic due to the replacement of regional production with production by unregulated firms. The market transfer of production to regions outside of California causes a price increase in the regulated region to have a larger effect on the regional quantity produced than the effect on total market quantity, and this makes residual demand facing the regulated firms more elastic. Put differently, a regional cost increase is at least partially passed-through to consumer prices, which provides a market incentive for unregulated firms to expand production.

The magnitude of the market transfer effect to other regions is determined by the elasticity of supply in unregulated production regions. If market supply in unregulated regions is highly price elastic, then a small increase in the market price greatly stimulates production in these regions. Because the long-run supply is relatively price-elastic for the case of many raw agricultural products used to produce manufactured foods, the potential exists for a large amount of processed food production to shift out of California into other regions that are not subject to an increase in food processing cost from local GHG regulations.

We have highly detailed cost information available for California food processors in our sample. However, we do not have comparable cost information for out-of-state firms. In this study, we rely on our detailed cost information for California firms as a proxy for production conditions facing food processors in other, competing regions that serve the U.S. or global market. This implicitly assumes that production leakage predominantly occurs to firms using similar production technology and facing similar input costs as California firms apart from cost changes created by the Cap-and-Trade Program.

3.3 Supply Model

Data supplied by California food processing plants are sufficient to estimate supply relationships for processing tomato and wet corn milling industries. This section details the methodology used to estimate supply relationships in each of these industries. The basis for our analysis of firm supply in both cases is a spatial model of agricultural product procurement in which farms are located in proximity to food processing plants and face increasing transportation costs over distance to deliver farm products to processing plants. Due to differences in the available data as well as to heterogeneous production processes, our empirical approach differs for the processing tomato and wet corn milling industries.

3.3.1 Processing Tomatoes

For many of the firms we study, tomato processing is quite literally a matter of using energy to heat the agricultural input. At the individual plant level, we therefore consider food processing to involve fixed-proportions technology. Processing x unit of the agricultural input is assumed to require $1/\alpha$ units of energy e , so that (given a plant of sufficient capacity) output is given by

$$\min(\alpha e, x).$$

We assume the firm uses capital and labor to operate a plant; the size of the plant then creates a capacity to process the agricultural input. Plant construction involves a standard Cobb-Douglas production function, with capacity equal to

$$BL^\beta K^\gamma$$

where β and γ are the usual curvature parameters in the Cobb-Douglas production function, and where B is a productivity parameter.

Combining the “plant operation” and “cooking” technologies described above yields an overall production function for the firm which depends on four inputs: energy (e), the agricultural input (x), labor (L), and capital (K). The production function is assumed to yield an output y , and takes the form

$$y = F(e, x, L, K) = A \min \{ \min(\alpha e, x), BL^\beta K^\gamma \}$$

where, in addition to the parameters and variables defined above, A is a scale parameter. This production function can be seen to allow for substitution between capital and labor in the operation of the plant, but within the plant uses a Leontief technology, which we believe captures the nature of the actual production processes employed by many food processors.

For simplicity, we assume that energy, capital, labor can all be acquired either without transportation or at a fixed marginal transportation cost. However, sourcing the agricultural input involves using some transportation network to move the agricultural output from the land where it is produced to the plant.

We conceive each plant as being located in an agricultural landscape, where the surrounding agricultural land varies in productivity for processing the raw input. We index land productivity by introducing a productivity parameter μ .

We next need to put some structure on the space within which the firm makes its locational decision. We consider a parsimonious structure that locates agricultural land on a Hotelling-like line in which transportation costs for delivering the raw product to the processing plant are increasing in the distance between the processing plant and the farmers that produce the raw product for delivery to the plant.

Let the cost of transporting the agricultural input a distance of θ be proportional to distance, with transportation cost for a unit of the input located θ units from the plant given by

$$t(\theta) = t\theta .$$

Since the plant can source the input from each of two directions, we can relate the quantity of input x to be sourced to the greatest distance $\bar{\theta}$ from which the firm will transport the input, with $x = 2\bar{\theta}\sqrt{\nu\mu}$. The total cost of transporting x is then

$$\int_0^{x/2\sqrt{\nu\mu}} 2t\theta d\theta = \frac{t}{4\nu\mu} x^2.$$

Adding a fixed farm-gate price q to the cost of acquiring the input, then the total cost of sourcing a quantity of input x is given by

$$q(x) = qx + \frac{t}{4\nu\mu} x^2.$$

Now consider the problem facing a price-taking, profit-maximizing firm operating the production function described above and having to deal with the transportation costs of the agricultural input. Given the Leontief technology described above, cost minimization implies that the firm will choose energy e , the agricultural input x , and labor and capital such that

$$\min(\alpha e, x) = BL^\beta K^\gamma.$$

Because energy is related to the use of the agricultural input via

$$\alpha e = x$$

we have $x = BL^\beta K^\gamma$.

We can then describe the firm's decision about how much labor and capital to employ by computing the most efficient way to process a quantity of agricultural input x , which solves

$$\min_{L,K} wL + rK$$

subject to

$$x = BL^\beta K^\gamma$$

The solution to this problem is to choose

$$K^* = \left(\frac{w\gamma}{r\beta}\right)^{\frac{\beta}{\beta+\gamma}} \left(\frac{x}{B}\right)^{\frac{1}{\beta+\gamma}} \quad \text{and} \quad L^* = \left(\frac{r\beta}{w\gamma}\right)^{\frac{\gamma}{\beta+\gamma}} \left(\frac{x}{B}\right)^{\frac{1}{\beta+\gamma}}.$$

Then, given the need to process a quantity x of the input, the total 'overhead' costs of capital and labor for the cost-minimizing firm can be written

$$E(x; r, w) = \left(w^\beta r^\gamma \frac{x}{B} \right)^{\frac{1}{\beta+\gamma}} \frac{\beta + \gamma}{\beta^{\frac{\beta}{\beta+\gamma}} \gamma^{\frac{\gamma}{\beta+\gamma}}}.$$

This expression gives us the minimum overhead involved in operating a plant capable of processing x units of the agricultural input. We now turn our attention to the question of the cost minimizing way to produce y units of processed output. Let p denote the price of energy. Define the firm's cost function

$$C(y; p, q, r, w) = \min_{e, x, K, L} pe + q(x) + rK + wL$$

subject to

$$y = F(e, x, L, K).$$

Noting that this is necessarily the same as

$$C(y; p, q, r, w) = \min_{e, x, K, L} pe + q(x) + E(x; r, w)$$

subject to

$$y = A \min(\alpha e, x),$$

and since (using the last constraint) $x=y/A$, we have

$$C(y; p, q, r, w) = \frac{py}{\alpha A} + q\left(\frac{y}{A}\right) + E\left(\frac{y}{A}; r, w\right).$$

Turning finally to the profit maximization problem, we obtain

$$\max_y vy - C(y; p, q, r, w)$$

where v is the price of the processed output. This gives the first order condition

$$v = \frac{p}{\alpha A} + \frac{q}{A} + \frac{ty}{2\mu v A^2} + \left(\frac{r^\gamma w^\beta}{AB\beta^\beta \gamma^\gamma} \right)^{\frac{1}{\beta+\gamma}} y^{\frac{1-\beta-\gamma}{\beta+\gamma}}.$$

The right-hand side of this optimality condition is of course just the firm's marginal cost; we can regard this expression as providing a solution to the firm's inverse supply function.

Using the implicit function theorem, we calculate

$$\frac{dy}{dv} = \frac{1}{\frac{t}{2\mu v A^2} + \frac{1-\beta-\gamma}{\beta+\gamma} \left(\frac{r^\gamma w^\beta}{AB\beta^\beta \gamma^\gamma} \right)^{\frac{1}{\beta+\gamma}} y^{\frac{1-2\beta-2\gamma}{\beta+\gamma}}}.$$

The elasticity of supply is thus

$$\varepsilon_s = \frac{dy}{dv} \frac{v}{y} = \frac{v}{\frac{ty}{2\mu v A^2} + \frac{1-\beta-\gamma}{\beta+\gamma} \left(\frac{r^\gamma w^\beta}{AB\beta^\beta \gamma^\gamma} \right)^{\frac{1}{\beta+\gamma}} y^{\frac{1-\beta-\gamma}{\beta+\gamma}}}$$

We use our detailed cost data to calibrate parameter values in this equation and derive the elasticity of supply for processed tomatoes.

3.3.2 Wet Corn

The process of producing corn starch yields four byproducts: gluten meal, germ, wet feed, and steep water. Corn starch can be sold as a final product or further processed into high fructose corn syrup (HFCS), where HFCS typically is sold in two varieties, HFCS 42 and HFCS 55, that differ according to the fructose content of the syrup.

We model the profit maximization decision of a price-taking firm to generate a supply function with parameters that can be estimated with our data. Let p_i denote the prices of the three final output goods for $i = 1, 2, 3$ representing starch, HFCS 42 and HFCS 55, respectively. Let φ denote the revenue from selling byproducts of starch production per unit of starch produced. Then, the firm's profit is:

$$\pi = \sum_{i=1}^3 p_i q_i + \varphi Q - c_1(Q) - c_2(q_2 + q_3) - c_3(q_3)$$

where $Q = q_1 + \theta(q_2 + q_3)$ denotes total pounds of starch produced (including starch sold as a final product and starch further processed into corn syrup) and where $\theta = \frac{31.5}{33.33}$ is the ratio that translates pounds of corn syrup to pounds of starch.⁴⁷

We further assume that firms face a constant unit cost for corn and energy inputs but that there are diminishing returns to labor, leading to a labor cost that is quadratic in quantity produced. Note that there are other possible explanations for why cost might be quadratic in the quantity produced such as the transportation costs of sourcing inputs.

$$c_1(Q) = \frac{\alpha_1}{2} Q^2 + \beta_0 r_0 + \sum_{j=1}^2 \beta_j r_j Q$$

$$c_2(q_2 + q_3) = \frac{\alpha_2}{2} Q(q_2 + q_3)^2 + \sum_{j=1}^2 \gamma_j r_j (q_2 + q_3)$$

⁴⁷ USDA ERS Sugar and Sweeteners Yearbook Tables, Table 31a. Available at: <http://www.ers.usda.gov/data-products/sugar-and-sweeteners-yearbook-tables.aspx>

$$c_3(q_3) = \frac{\alpha_3}{2} q_3^2 + \sum_{j=1}^2 \delta_j r_j q_3.$$

The cost of making starch is $c_1(Q)$ and is made up of three parts: the cost of labor, the cost of corn, and the cost of energy (natural gas and electricity). The term r_j denotes the price of inputs, where $j=0,1,2$ corresponds to corn, natural gas, and electricity, β_j is a productivity parameter that translates units of input to units of output, and α_1 is a productivity parameter for labor.

The additional cost of making HFCS 42 ($c_2(q_2 + q_3)$) from starch includes labor cost and energy costs, and γ_j denotes productivity parameters for gas and electricity in the production of HFCS 42.

The additional cost of making HFCS 55 from HFCS 42 ($c_3(q_3)$) includes labor cost and energy costs, and δ_j denotes productivity parameters for gas and electricity in the production of HFCS 55. Finally, α_i is a productivity parameter for labor in the production of starch ($i=1$), HFCS 42 ($i=2$), and HFCS 55 ($i=3$).

The solution to the firm's profit maximization problem is:

$$q_3^* = \frac{p_3 - p_2 - \sum_{j=1}^2 \delta_j r_j}{\alpha_3}$$

$$q_2^* = \frac{p_2 - \theta p_1 - \sum_{j=1}^2 \gamma_j r_j}{\alpha_2} - q_3^*$$

$$q_1^* = \frac{p_1 + \varphi - \beta_0 r_0 - \sum_{j=1}^2 \beta_j r_j}{\alpha_1} - \theta(q_2^* + q_3^*)$$

Therefore, the profit-maximizing amount of starch to produce is:

$$Q^* = q_1^* + \theta(q_2^* + q_3^*) = \frac{p_1 + \varphi - \beta_0 r_0 - \sum_{j=1}^2 \beta_j r_j}{\alpha_1}.$$

The parameters of this linear supply curve can be estimated directly to provide an estimate of the elasticity of supply.

4. Data and Econometric Methods

The primary industries we examine are: (i) tomato processing (paste and diced canning); (ii) cheese manufacturing; (iii) wet corn processing; and (iv) sugar refining. Producers in these industries encompass 17 out of 38 processing facilities with GHG emissions above the 25,000 metric ton CO₂e threshold. Among these plants, we have detailed cost- and sales-level data from

processing facilities in each industry. We combine these data with primary data available from ERS, National Agricultural Statistics Service (USDA-NASS), and the U.S. Census.

Table 4.1 shows the energy intensity of production in each of the industries considered in terms of natural gas cost as a share of total variable cost over the time period of the data provided. Given the variability in natural gas prices over the periods in which data were provided, energy intensity is calculated as a share of variable cost at the base price listed for natural gas by aggregating natural gas prices and variable costs over the time period. The natural gas price listed in the table is the average price paid by our sample of producers over the period.

Table 4.1. Energy Intensity of Production in Selected Industries

Industry	Time Period	Natural Gas (\$/MMBtu)	Energy Share of Variable Cost (%)
Processing Tomatoes	2010-2012	\$4.68	4.24%
Cheese	2010-2013	\$5.04	4.40%
Wet Corn ¹	2013	\$6.25	6.90%
Sugar	2006-2009	\$7.57	5.33%

¹Energy share of variable cost is calculated for wet corn only in year 2013 due to a mix of steam and natural gas used for production over remaining years in the sample period 2010-2012.

The Cap-and-Trade Program impacts the effective cost of energy for California’s food processing plants. For each industry, the projected increase in the effective cost of natural gas is calculated using data from the U.S. Energy Information Administration on CO₂e emissions factors per MBtu of natural gas.⁴⁸ For all industries, the predicted effect of the Cap-and-Trade Program on industry-level production costs is mediated entirely through increases in the effective cost of natural gas (\$/MBtu).⁴⁹ Thus, the analysis considers only the direct effect of the Cap-and-Trade Program on pricing emissions released from each industry, and does not consider indirect effects of the regulation on electricity prices.

In general, the time horizon considered for the elasticity of supply differs for cheese, wet corn, sugar, and tomato markets. For processed tomato products, sugar and wet corn, the quantity of raw material provided adjusts on a shorter production horizon than for the dairy sector, because acreage adjustments can occur more rapidly in response to regulations that reduce farm prices paid by food processors for farm products. For cheese manufacturing, longer adjustment periods are required to approximate long-run supply conditions in the cheese industry due to the

⁴⁸ Energy Information Administration, Documentation for Emissions of Greenhouse Gases in the United States 2005, DOE/EIA-0638 (2005), October 2007, Tables 6-1, 6-2, 6-4, and 6-5.

⁴⁹ For the one food processing plant in our sample that relies on a mix of coal and natural gas, the energy share of total variable cost is computed by recalculating energy cost and total variable cost of the operation by converting all energy use to natural gas.

dynamics of dairy herd management in milk production. In dairy operations, the short-run (less than one year) adjustment to a change in the milk price paid by cheese manufacturers occurs entirely through adjustment in the amount of milk production per cow, whereas the long-run adjustment (five years or more) occurs predominantly through changes in the size of the dairy herd (Chavas and Klemme, 1986).⁵⁰

4.1 Processing Tomatoes

For tomato processors, energy costs comprise approximately six percent of a facility's total expenses. Tomato processing plants typically operate at maximum capacity through the harvest season (July through October), but sell processed tomato products throughout the year. The primary fuel source for tomato processors is natural gas, the largest consumption of which occurs in the steam boilers. Significant uses of electrical energy arise from paste/puree recirculation in evaporators and product cooling in cooling towers, and hot breaks. For the tomato processing plants in our sample, natural gas energy accounts for approximately 75-90% of the total energy usage.

Based on the distribution of California processing tomato acreage and the location of processing plants, regulated tomato processing plants in California produce 96 percent of all processed tomato products in the U.S. (12.1 million metric tons (MT) out of 12.6 million MT in 2013) and provide 31.6 percent of world tomato supply (12.1 million MT out of 38.2 million MT in 2013). We received data from five tomato processing firms in California. For tomato processors, our data allow direct estimation of supply and demand conditions facing the plants operated by these California firms. For supply, we calculate the elasticity of processed food supply using the method detailed in Section 3.3.1. Because production of processed tomatoes occurs seasonally, we aggregate our data to annual observations and then calibrate the parameters of our model using these data. We assume that the parameters of the Cobb-Douglas production function are the same across all tomato processing firms.

To estimate the elasticity of demand for processed tomatoes, we use monthly shipment and cost data provided by three tomato processing firms.⁵¹ Because the price of processed tomatoes may be endogenous, we use an instrumental variables approach where various factors that affect the cost of processing tomatoes are used as instruments. The three instruments we use are the price of natural gas, the price of electricity, and the price of raw tomatoes. Each variable should be a suitable instrument, affecting the price of processed tomatoes by shifting supply while not directly affecting demand.

The monthly data for natural gas prices came from the U.S. Energy Information Administration.⁵² Electricity prices by utility and zip code came from the U.S. Energy Information Administration Forms EIA-861 and EIA-826. We matched zip codes for all plants to merge electricity price data with data from reporting food processors. We used raw tomato price data provided by the reporting firms.

⁵⁰ Chavas, J.-P., and R. M. Klemme. "Aggregate Milk Supply Response and Investment Behavior on U.S. Dairy Farms." *Am. J. Agr. Econ.* 68(February 1986):55-66.

⁵¹ The remaining two tomato processors did not provide data on monthly shipments and cost.

⁵² <http://www.eia.gov/dnav/ng/hist/n3050ca3m.htm>

4.2 Cheese

According to 2012 U.S. Census data California cheese manufacturing establishments produce 21.3 percent of U.S. cheese supply by value of shipments. Given the current trade situation in global cheese, and the premium prices received for U.S. cheese products relative to rest-of-world prices, the U.S. cheese market is considered as an isolated entity from the world cheese market.

Producer data from California cheese manufacturing are insufficient to estimate supply and demand conditions. We accordingly rely on demand and supply elasticity estimates from the literature. The elasticity of supply for cheese is sensitive to the duration of time considered, because of lags in herd inventory management in dairy cows used for milk production. To characterize supply conditions, Chavas and Klemme (1986) report an annual supply response to changes in the (U.S. class II) milk price, in which the elasticity of farm supply increases from a value of 0.28 in year 1 to a value of 3.51 in year 10. For the leakage estimation, we rely on the estimated long-run (6-year) elasticity of milk supply of 1.2 reported by Chavas and Klemme (1986).

Numerous studies have examined the demand elasticity for cheese, with estimates in the range of -0.4 to -1.5. For the leakage estimation, we take the demand elasticity in the U.S. cheese market at a value of -0.7, which is the estimate recently provided by Bergtold (2004).⁵³

4.3 Wet Corn

According to 2012 U.S. Census data, California wet corn milling establishments produce 1.75 percent of U.S. starch product supply by value of shipments. As in the case of the cheese market, emissions leakage from California wet corn milling is encompassed by the transfer of production from California suppliers to other wet corn milling operations in the U.S.

We received detailed data from the largest wet corn processor in California, an operation that accounted for 72% of the value of shipments from California wet corn milling in 2012. We estimate the supply elasticity of processed wet corn supply using the method detailed in Section 3.3.2. We assume that the parameters of the Cobb-Douglas production function are the same across all wet corn milling plants.

One concern with estimating the supply function for wet corn milling is that there may be omitted variables that affect supply and the price charged by the firm. To deal with the potential endogeneity of price, we instrument price with the wholesale price of corn starch in the Midwest region of the U.S. reported by the Economic Research Service of the U.S. Department of Agriculture.⁵⁴ This price should be correlated with the price charged by California firms but should not affect the supply of California firms in any way except through its effect on price. Hence, we use a two stage least squares regression where the Midwestern price is the exogenous instrument used in the first stage.

⁵³ Bergtold, Jason, Ebere Akobundu, and Everett B. Peterson. "The FAST method: Estimating unconditional demand elasticities for processed foods in the presence of fixed effects." *Journal of Agricultural and Resource Economics* (2004): 276-295.

⁵⁴ U.S. Department of Agriculture Economic Research Service, *Feed Outlook*, 2011-2014, Table 6.

Given the high degree of substitutability of HFCS and sugar as sweeteners, we consider demand for wet corn products and sugar to be determined by pricing conditions in an aggregated sweetener market. The industrial demand for sweeteners have been estimated by Sudaryanto (1987) and Lopez (1988).⁵⁵ Sudaryanto (1987) estimated an industrial demand elasticity of -0.62 and Lopez (1988) estimated a long-run price elasticity of demand of -0.597 for the sugar market. For the leakage estimation, we take the demand elasticity in the U.S. sweetener market at a value of -0.6 for both processed wet corn and sugar.

4.4 Sugar

The 2012 U.S. Census does not presently report U.S. refined sugar production at the 5-digit level (NAICS 31131). According to 2007 U.S. Census data, California sugar refining establishments produce 11.58 percent of U.S. refined sugar supply by value of shipments. As in the case of the wet corn market, emissions leakage from California sugar manufacturing is mediated through production leakage from California suppliers to other sugar refining operations in the U.S.

Producer data from California sugar refining are insufficient to estimate supply and demand conditions. We accordingly rely on demand and supply elasticity estimates from the literature. For the elasticity of supply, Sudaryanto (1987) estimated long-run elasticity of sugar beet supply to be 2.3, Lopez (1989) estimated the long-run elasticity of sugar beet supply to be 1.2, and Marks (1993) estimated the long-run elasticity of sugar beet supply to be 1.2.⁵⁶ For the leakage estimation, we take the supply elasticity in the U.S. sugar beet market at the intermediate value of 1.7 reported by Marks (1993).

For the leakage estimation, we take the demand elasticity in the U.S. sweetener market at a value of -0.6 for both processed wet corn and sugar. This accords with the estimated demand elasticity of -0.62 reported by Sudaryanto (1987) and -0.597 calculated by Lopez (1989).

5. Results

5.1. Market Estimation

Long-run supply elasticity is most relevant for evaluation of the Cap-and-Trade Program, because input substitution towards less pollution-intensive techniques is important.

Demand is estimated for processing tomatoes and relies on industry studies for the remaining industries, for which data are not sufficient to estimate demand.

⁵⁵ Sudaryanto, Tahlim. *The potential impacts of liberalized trade policies in the United States and the European economic community on international markets for sugar*. 1987; Lopez, Rigoberto A. "Political economy of U.S. sugar policies." *American journal of agricultural economics* 71.1 (1989): 20-31.

⁵⁶ Marks, Stephen V. "A reassessment of empirical evidence on the U.S. sugar program." *The Economics and Politics of World Sugar Policies* (1993): 79-108.

5.1.1 Processing Tomatoes

Table 5.1 shows the calibrated values of β , γ , B , and the ratio $\frac{t}{\nu}$ as well as our value for the supply elasticity, ϵ_S . To calculate the ratio $\frac{t}{\nu}$, we use data provided on total trucking cost and the fact that trucking cost equal $\frac{t}{4\nu}x^2$. So, we calculate $\frac{t}{\nu}$ to be trucking cost divided by $\frac{x^2}{4}$. The estimated value for the supply elasticity of processing tomatoes is 9.8. This value accords with the median value of the regional estimates of the long-run elasticity of supply and demand of California processing tomatoes that are provided in the comprehensive study of the California processing tomato market by Durham and Sexton (1992), which reported a long-run supply elasticity for processing tomatoes in the range of 8.6 to 55.49.

Table 5.1: Parameter Values and the Elasticity of Processed Tomato Supply

Parameter	Value
β	0.38
γ	0.3
B	14,328
t/ν	2.4×10^{-12}
ϵ_S	9.84

To estimate processed tomato demand, we employ an instrumental variables approach using production cost variables as instruments for the processed tomato price. The first-stage regression of pricing instruments on endogenous output prices provides an R^2 value of 59.6% ($F = 10.36$) in the linear model and an R^2 value of 60.1% ($F = 9.98$) in the log model and all three instruments are statistically significant. These results indicate that our instruments are somewhat weak (Staiger and Stock 1997), but effective.

Table 5.2 shows the results of OLS and two stage least squares (TSLS) regressions of global processed tomato demand in levels and in logs.⁵⁷ We also include year and firm fixed effects. Based on Column 4, we estimate the elasticity of demand to be -3.1.

⁵⁷ We lose 12 observations in the TSLS estimation compared to OLS, because we did not receive data on raw tomato prices for one firm in our sample for one year, which we accordingly drop from our first stage estimation.

Table 5.2 Parameter Estimates of Processed Tomato Demand				
	(1) OLS	(2) TSLS	(3) OLS	(4) TSLS
	Quantity Shipped	Quantity Shipped	log(Quant. Ship.)	log(Quant. Ship.)
price	-4.02263e+11*** (7.63639e+10)	-3.90360e+11* (1.71619e+11)		
log(price)			-3.792*** (0.458)	-3.142** (1.034)
N	129	117	129	117
R-sq	0.706		0.805	

Standard errors in parentheses
* p<0.05 ** p<0.01 *** p<0.001

5.1.2 Wet Corn

We estimate supply of corn starch using two stage least squares with the Midwest wholesale starch price reported by ERS as an instrument for the firm's starch price. The first-stage regression of pricing instruments on endogenous starch prices provides an R^2 value of 88.6% ($F = 23.40$) in the linear model and an R^2 value of 87.9% ($F = 24.07$) in the log model, suggesting that our instrument is not weak (Staiger and Stock 1997).

The results of OLS and TSLS estimation of the wet corn supply in levels are shown in columns 1 and 2 of Table 5.3, while the same two estimations in log terms are shown in columns 3 and 4. Based on Column 2, the 95% confidence interval for the elasticity is [0.8, 3.6] with a point estimate of 2.2. Based on Column 4, the 95% confidence interval for the elasticity is [0.6, 3.2] with a point estimate of 1.9.

Table 5.3 Estimated Coefficients for Wet Corn Supply

	(1) OLS Quantity	(2) TSLS Quantity	(3) OLS log(Quantity)	(4) TSLS log(Quantity)
Starch Price	154241559.4 (102153829.9)	711418310.1** (223817425.5)		
Natural Gas Price	-43669470.6* (17176707.0)	-79917945.4** (25228120.8)		
Electricity Price	-32799732.2 (126195157.4)	-522061215.0* (227938545.9)		
Corn Price	-136588035.0+ (76135655.6)	-489006873.3* (150946453.4)		
log(Starch P)			0.290 (0.288)	1.897** (0.631)
log(Natural Gas P)			-0.300* (0.133)	-0.543** (0.191)
log(Electricity P)			0.000602 (0.183)	-0.689* (0.324)
log(Corn P)			-0.228 (0.180)	-1.076** (0.356)
_cons	79287733.2*** (11584277.9)	90042489.1*** (15463631.8)	17.78*** (0.370)	17.02*** (0.542)
N	48	48	48	48
R-sq	0.163		0.124	
Standard errors in parentheses				
+ p<0.10	* p<0.05	** p<0.01	*** p<0.001	

5.2 Residual Demand

The critical elements that determine production leakage, and the associated market transfer, as defined by equation (1) are: (i) the price elasticity of demand; (ii) the price elasticity of supply; and (iii) the market share of regulated firms. We consider California processors to have identical processing technology as processors out-of-state and accordingly take the elasticity of supply in

the unregulated region to be equal to the elasticity of supply in the regulated region. These elements together determine the residual elasticity of demand for food processors in California, which defines the market price response under the Cap-and-Trade Program that selectively increase energy costs for California firms.

Table 5.4 presents our calculation of the residual demand elasticity for the four food processing industries considered in the study as well as the definition of the relevant market for calculating market transfer effects. For each industry, the residual demand elasticity is calculated according to the elasticities of supply and demand and the market share of California processors reported in the sections above.

Industry	Demand Elasticity	Supply Elasticity	Market Share of CA Firms	Residual Demand Elasticity	Market Designation
Processing Tomatoes	3.1	9.8	31.90%	30.6	Global
Cheese	0.7	1.2	21.13%	7.8	U.S.
Wet Corn	0.6	1.9	1.75%	141.3	U.S.
Sugar	0.6	1.7	11.58%	18.2	U.S.

The residual demand elasticity represents the percentage change in demand for California processed food in response to a one percent increase in the price of processed food sold by California firms. The residual demand elasticity is larger for food processing industries that face relatively elastic supply and demand conditions in the global market (processing tomatoes) and for industries in which California food processors represent a relatively small share of the wholesale market (wet corn). For industries with small market share, competition from producers in unregulated regions makes it difficult to pass increased food processing costs forward into wholesale (consumer) markets due to the large volume of goods sold by unregulated firms in the common wholesale market.

6. Market Transfer and Emissions Leakage

This section calculates the incidence of the Cap-and-Trade Program on farmers and food processors in California. For each food processing industry, the calculations are made for the case of regulations that impact all food processors in California.

Market transfer is given by the difference between the decrease in CA production and the overall decrease in market production (US production in all cases except processing tomatoes where it is world production). Removal of California production from the market as a result of increased compliance costs with the Cap-and-Trade Program results in a market price increase that stimulates increased production from competing regions that are not subject to cost-increasing regulation. Both the wet corn and sugar industries in California are small relative to the U.S.

market, which dampens the degree that a cost increase can be shifted forward into consumer prices.

Market transfer in each industry is calculated based on the magnitude of the increase in cost for California food processors, the extent to which costs are passed forward into consumer prices or backwards in the regional supply chain, and the respective supply and demand elasticities in each market. For a given cost increase in the regional California market, costs are shifted backwards to an extent that depends on the ratio of the residual demand elasticity to the sum of the residual demand elasticity and supply elasticity in the market, with the remaining share of cost being shifted forward into consumer prices. The reduction in California supply as a result of unilateral GHG regulations is calculated as the product of the initial California quantity supplied, the percentage increase in cost, the extent to which these costs are shifted backwards, and the elasticity of supply. The reduction in total market (global or U.S.) production as a result of unilateral GHG regulations is calculated as the product of the initial market quantity demanded, the percentage increase in cost, the extent to which these costs are shifted forwards, and the elasticity of market demand. Production leakage in each case, which reflects the increased quantity supplied by producers outside California, is the difference between the decrease in California quantity supplied and the decrease in the market quantity demanded.

Table 6.1 reports the calculated incidence effects of the Cap-and-Trade Program on regional agricultural product prices, on consumer prices for processed food products, and on the market transfer in each of the industries examined.

Table 6.1. Predicted Cost-Shifting and Market Transfer Effects

Industry	Share of Cost Increase		Market Transfer
	Shifted Backward	Shifted Forward	
Processing Tomatoes	76%	24%	68%
Cheese	87%	13%	57%
Wet Corn	99%	1%	76%
Sugar	91%	9%	71%

In all processing markets studied, the degree of backward shifting into agricultural producer markets is large in relation to the degree of forward shifting into consumer markets. The reason is that the availability of alternative sources of supply from production regions outside California mitigates wholesale (consumer) price effects. The predicted share of cost increase passed backwards through the California supply chain ranges from 76% of the predicted increase in marginal cost in the processing tomato industry to 99% in wet corn milling. In all cases, the majority of the cost increase is passed backwards to agricultural producers in the form of lower prices for raw agricultural products.

The relatively high degree of backwards shifting in response to higher energy costs implies that the increase in costs is predominantly absorbed by California producers. Backwards shifting of cost has one of two implications for California agriculture: (i) lower farm product prices paid to

farmers producing processed goods; or (ii) narrower margins for food processing plants. In light of the co-location decision of farming and food processing production, our data are not sufficiently rich to distinguish between these two effects, and the analysis should be interpreted as the effect of the policy on California processed food supply in a vertically-integrated farmer-producer industry, like for instance a cooperative. Given the nature of supplier contracts in California's food processing industries, market pressure for backward shifting of costs into the California supply chain is likely to manifest in the form of lower procurement prices for farm products purchased by food processing plants and long-run decisions by farmers to switch harvested acreage to other crops. Data on crop choices available to farmers currently producing raw material for the processing sector, and the impact of cap and trade regulations on farm prices for these alternative crop shares needed to address the impact of the Cap-and-Trade Program on rural communities that depend on California agriculture.

The fourth column of Table 6.1 shows the market transfer effect. The extent of the market transfer in each industry is determined by the share of cost that is shifted backwards into reduced prices for agricultural producers, the elasticity of market demand, and the long-run elasticity of supply in each raw product market. The market transfer effects range between 58% of the decrease in California processed cheese production to 76% of the decrease in California wet corn. The relatively large market transfer effects in the wet corn and sugar industries are driven by a combination of small U.S. market share of California processors and inelastic demand conditions in the U.S. sugar market, while the market transfer is moderated in the case of cheese by the relatively inelastic supply condition in the market.

6.1 Processing Tomatoes

Table 6.2 presents the predicted effect of the Cap-and-Trade Program on the California tomato processing industry. The initial quantity of processing tomatoes produced in California and globally is 12,093 thousand metric tons and 37,904 thousand metric tons, respectively, and the initial market price prior to allowance purchase requirements is \$891/MT.

Industry effects are calculated for a range of compliance costs provided by ARB from the current 2016 price (\$12.73/MT CO₂e) to a projected price of \$33.82 in year 2030. For each level of compliance cost (\$12.73, \$16.69, \$23.40 and \$33.82), the percentage increase in the marginal cost of food processing for California plants is calculated as the product of the energy share of total variable cost and the increment in energy costs that occurs for each level of cost.⁵⁸

⁵⁸ CO₂e emissions factors for natural gas used to convert compliance costs (\$/MT CO₂e) into units of energy are taken from the Energy Information Administration, *Documentation for Emissions of Greenhouse Gases in the United States 2005*, DOE/EIA-0638 (2005), October 2007, Tables 6-1, 6-2, 6-4, and 6-5.

Table 6.2. Predicted Effects of the Cap-and-Trade Program on the Global Processing Tomato Market

Impact	Compliance Costs (\$/MT CO2e)				
	\$0.00	\$12.73	\$16.69	\$23.40	\$33.82
U.S. Quantity (1,000 MT)	37,904	37,729	37,675	37,582	37,439
California Quantity (1,000 MT)	12,093	11,540	11,369	11,078	10,626
Market Price (\$/MT)	\$890.76	\$892.09	\$892.50	\$893.20	\$894.29
Percent increase MC of processing		0.62%	0.81%	1.13%	1.63%
Increase in U.S. price (\$/MT)		\$1.33	\$1.74	\$2.44	\$3.53
Cost Absorbed in Production (\$/MT)		\$4.15	\$5.44	\$7.63	\$11.03
Decrease in California supply (1,000 MT)		552.23	724.01	1,015.10	1,467.12
Percent Decrease in California Supply		4.57%	5.99%	8.39%	12.13%
Production Leakage (1,000 MT)		377.00	494.37	693.12	1,001.77
Leakage as Percent of California Supply		3.12%	4.09%	5.73%	8.28%

The projected increase in global tomato prices is \$1.33/MT, \$1.74/MT, \$2.44/MT, and \$3.53/MT for the \$12.73, \$16.69, \$23.40, and \$33.82 respective increments in compliance costs (\$/MT CO2e), while the projected decrease in supply prices per metric ton of processed tomatoes is \$4.15/MT, \$5.44/MT, \$7.63/MT, and \$11.03/MT for the respective increments in the allowance price. This reduction in supply price is absorbed in the supply chain in the form of lower food processor margins and decreased farm prices for tomatoes. The predicted change in California processed tomato supply is 552 thousand MTs, 724 thousand MTs, 1015 thousand MTs, and 1467 thousand MTs for the respective increments in compliance costs. Additionally, 377 thousand MTs, 494 thousand MTs, 693 thousand MTs, and 1,002 thousand MTs of which transferred to food processors outside of California for each respective increment.

6.2 Cheese

The incidence of the Cap-and-Trade Program on cheese producers is complicated by the fact that the formula price for class 4b milk for cheese production in California is based on the commodity market price of cheddar cheese less a manufacturing cost allowance.⁵⁹ The share of program cost that is passed backwards to milk producers is limited by the support price, which may or may not be adjusted through the manufacturing cost allowance to account for the increased cost of emissions for cheese producers. The incidence analysis considered here allows for the full range of market price adjustments to occur in the formula price of class 4b milk.

Table 6.3 presents the predicted effect of the Cap-and-Trade Program on the California cheese industry. The initial quantity of cheese produced in California and in the U.S. is 1,086 thousand metric tons and 5,140 thousand metric tons, respectively, and the initial market price prior to allowance purchase requirements is \$3,679/MT.

⁵⁹ California Department of Food and Agriculture (2005).

Table 6.3. Predicted Effects of the Cap-and-Trade Program on the U.S. Cheese Market

Impact	Compliance Costs (\$/MT CO₂e)				
	\$0.00	\$12.73	\$16.69	\$23.40	\$33.82
U.S. Quantity (1,000 MT)	5,140	5,137	5,136	5,135	5,132
California Quantity (1,000 MT)	1,086	1,079	1,077	1,074	1,068
Market Price (\$/MT)	\$3,679.42	\$3,682.33	\$3,683.23	\$3,684.76	\$3,687.14
Percent increase MC of processing		0.59%	0.78%	1.09%	1.57%
Increase in U.S. price (\$/MT)		\$2.91	\$3.81	\$5.34	\$7.72
Cost Absorbed in Production (\$/MT)		\$18.87	\$24.74	\$34.68	\$50.13
Decrease in California supply (1,000 MT)		6.68	8.76	12.29	17.76
Percent Decrease in California Supply		0.62%	0.81%	1.13%	1.64%
Production Leakage (1,000 MT)		3.84	5.04	7.06	10.21
Leakage as Percent of California Supply		0.35%	0.46%	0.65%	0.94%

For each level of compliance costs (\$12.73, \$16.69, \$23.40 and \$33.82 per MT CO₂e), we calculate the percentage increase in the marginal cost of cheese production in California using the energy share of variable cost provided in Table 4.1. The projected increase in the U.S. block cheese price is \$2.91/MT, \$3.81/MT, \$5.34/MT, \$7.72/MT for the respective \$12.73, \$16.69, \$23.40, and \$33.82 increments in compliance costs, while the projected decrease in supply prices per metric ton of processed cheese is \$18.87, \$24.74, \$34.68, and \$50.13 for each respective increment in compliance cost. This reduction in supply price is absorbed in the supply chain in the form of lower food processor margins and decreased farm prices for class 4b milk for cheese production. The predicted change in California processed cheese supply is 6.7 thousand MTs, 8.8 thousand MTs, 12.3 thousand MTs, and 17.8 thousand MTs for the respective increments in compliance costs. Additionally, 3.8 thousand MTs, 5.0 thousand MTs, 7.1 thousand MTs, and 10.2 thousand MTs of which is transferred to food processors outside of California for each respective increment.

6.3 Wet Corn

Table 6.4 presents the predicted effect of the Cap-and-Trade Program on the California wet corn milling industry. The initial quantity of wet corn processed in California and in the U.S. is 504 thousand metric tons and 28,840 thousand metric tons, respectively, and the initial market price prior to allowance purchase requirements is \$441/MT. For each level of compliance cost (\$12.73, \$16.69, \$23.40 and \$33.82), the percentage increase in the marginal cost of California wet corn processing is calculated using the energy share of variable cost provided in Table 4.1.

Table 6.4. Predicted Effects of the Cap-and-Trade Program on the U.S. Wet Corn Market

Impact	Compliance Costs (\$/MT CO₂e)				
	\$0.00	\$12.73	\$16.69	\$23.40	\$33.82
U.S. Quantity (1,000 MT)	28,840	28,839	28,838	28,837	28,836
California Quantity (1,000 MT)	504	496	494	491	485
Market Price (\$/MT)	\$441.38	\$441.43	\$441.44	\$441.46	\$441.50
Percent increase MC of processing		0.75%	0.98%	1.38%	1.99%
Increase in U.S. price (\$/MT)		\$0.04	\$0.06	\$0.08	\$0.12
Cost Absorbed in Production (\$/MT)		\$3.26	\$4.28	\$6.00	\$8.67
Decrease in California supply (1,000 MT)		7.07	9.27	13.00	18.79
Percent Decrease in California Supply		1.40%	1.84%	2.58%	3.73%
Production Leakage (1,000 MT)		5.35	7.02	9.84	14.22
Leakage as Percent of California Supply		1.06%	1.39%	1.95%	2.82%

The projected increase in the U.S. wet corn product (starch) price is \$0.04/MT, \$0.06/MT, \$0.08/MT, and \$0.12/MT for each respective increment in compliance cost, while the projected decrease in supply prices per metric ton of processed wet corn is \$3.26, \$4.28, \$6.00, and \$8.67 for each respective increment in compliance cost. This reduction in supply price is absorbed in the supply chain in the form of lower food processor margins and decreased farm prices for corn. The predicted change in California processed wet corn supply is 7.1 thousand MTs, 9.3 thousand MTs, 13.0 thousand MTs, and 18.8 thousand MTs for each respective increment in compliance costs. Additionally, 5.4 thousand MTs, 7.0 thousand MTs, 9.8 thousand MTs, and 14.2 thousand MTs of which is transferred to food processors outside of California for each respective increment.

6.4 Sugar

Table 6.5 presents the predicted effect of the Cap-and-Trade Program on the California beet sugar refining industry. The initial quantity of sugar processed in California and in the U.S. is 866 thousand metric tons and 7,480 thousand metric tons, respectively, and the initial market price prior to allowance purchase requirements is \$700/MT. For each level of permit prices (\$12.73, \$16.69, \$23.40 and \$33.82), we calculate the percentage increase in the marginal cost of sugar production in California using the energy share of variable cost provided in Table 4.1.

The projected increase in the U.S. refined sugar price is \$0.29/MT, \$0.37/MT, \$0.53/MT, and \$0.76/MT for every respective increment in compliance cost, while the projected decrease in supply prices per metric ton is \$3.06, \$4.01, \$5.62, and \$8.12 for each respective increment in compliance cost. This reduction in supply price is absorbed in the supply chain in the form of lower food processor margins and decreased farm prices for sugar beets. The predicted change in California refined sugar supply is 6.4 thousand MTs, 8.4 thousand MTs, 11.8 thousand MTs, and 17.1 thousand MTs for each respective increment in compliance costs. Additionally, 4.6 thousand MTs, 6.0 thousand MTs, 8.4 thousand MTs, and 12.2 thousand MTs of which is transferred to food processors outside of California for each respective increment.

Table 6.5. Predicted Effects of the Cap-and-Trade Program on the U.S. Sugar Market

Impact	Compliance Costs (\$/MT CO2e)				
	\$0.00	\$12.73	\$16.69	\$23.40	\$33.82
U.S. Quantity (1,000 MT)	7,480	7,478	7,477	7,476	7,475
California Quantity (1,000 MT)	866	859	857	854	849
Market Price (\$/MT)	\$699.91	\$700.19	\$700.28	\$700.43	\$700.67
Percent increase MC of processing		0.48%	0.63%	0.88%	1.27%
Increase in U.S. price (\$/MT)		\$0.29	\$0.37	\$0.53	\$0.76
Cost Absorbed in Production (\$/MT)		\$3.06	\$4.01	\$5.62	\$8.12
Decrease in California supply (1,000 MT)		6.43	8.42	11.81	17.07
Percent Decrease in California Supply		0.74%	0.97%	1.36%	1.97%
Production Leakage (1,000 MT)		4.59	6.02	8.44	12.20
Leakage as Percent of California Supply		0.53%	0.70%	0.97%	1.41%

6.5 Production Leakage

For all food processing industries considered, a rise in compliance costs results in a decrease in California supply and the market transfer of production to food processors operating across state lines. Table 6.6 summarizes the predicted reduction in California production and market transfer effect in metric tons for each \$1 increase in compliance costs. The entries in this table can be used to recover the predicted market transfer effect of an arbitrary allowance price.

Table 6.6. Predicted Effects per \$1 Increase in Compliance Cost on Selected Food Processing Industries (MT/\$)

Impact of Cap-and-Trade Program	Food Processing Industry			
	Tomatoes	Cheese	Wet Corn	Sugar
California Baseline Supply (MT)	12,092,667	1,086,166	503,547	865,848
Reduction in California Supply (MT)	43,380.13	525.07	555.49	504.75
Percent Reduction in California Supply	0.36%	0.05%	0.11%	0.06%
Production Leakage (MT)	29,620.61	301.83	420.38	360.76

Table 6.7 provides a summary of production leakage for a range of compliance costs provided by ARB.

Table 6.7. Predicted Production Leakage (1,000 MT) for a Range of Compliance Costs (\$/MT CO₂e)

Compliance Cost	<u>Food Processing Industry</u>			
	Tomatoes	Cheese	Wet Corn	Sugar
\$18.91	560.19	5.71	7.95	6.82
\$19.35	573.08	5.84	8.13	6.98
\$19.87	588.55	6.00	8.35	7.17
\$20.55	608.56	6.20	8.64	7.41
\$21.20	628.04	6.40	8.91	7.65
\$21.80	645.62	6.58	9.16	7.86
\$22.62	670.15	6.83	9.51	8.16
\$22.53	667.47	6.80	9.47	8.13
\$22.89	678.15	6.91	9.62	8.26
\$23.63	699.85	7.13	9.93	8.52
\$24.12	714.55	7.28	10.14	8.70
\$24.49	725.27	7.39	10.29	8.83
\$24.88	736.87	7.51	10.46	8.97
\$24.88	736.87	7.51	10.46	8.97
\$25.37	751.61	7.66	10.67	9.15
\$25.88	766.64	7.81	10.88	9.34
\$26.40	781.98	7.97	11.10	9.52
\$26.93	797.62	8.13	11.32	9.71
\$27.47	813.57	8.29	11.55	9.91
\$28.02	829.84	8.46	11.78	10.11
\$28.58	846.44	8.63	12.01	10.31
\$29.15	863.36	8.80	12.25	10.52
\$29.73	880.63	8.97	12.50	10.73
\$30.32	898.24	9.15	12.75	10.94
\$30.93	916.21	9.34	13.00	11.16
\$31.55	934.53	9.52	13.26	11.38
\$32.18	953.22	9.71	13.53	11.61
\$32.82	972.29	9.91	13.80	11.84

6.6 Emissions Leakage

The results presented above calculate the market transfer effects, or “production leakage” of California processed food production to producers out-of-state. Production leakage can be related directly to emissions leakage by adjusting the market transfer effect for the relative emissions-intensity of the plants acquiring and losing market share. If production leakage occurs to plants outside of California that have similar technology and use identical fuel inputs (i.e., natural gas) as the California plants that reduce production, then the market transfer effect of the Cap-and-Trade Program would result in a one-for-one transfer of CO₂e emissions. However, if market transfer occurs from California food processing plants that rely on natural gas for energy to out-of-state producers that rely on coal for energy, then each unit of production that transfers out of California would result in an approximate doubling of CO₂e emissions. According to the U.S. Energy Information Administration, the average level of CO₂e emissions produced by natural gas combustion among industrial sources in the U.S. is 0.53 MT/MBtu, while the average emissions produced from industrial combustion of Bituminous coal is 0.93 MT/MBtu.^{60, 61}

One problem with predicting emissions leakage from the Cap-and-Trade Program is that it is difficult to predict where emissions will occur. For the case of California food processors, the typical plant operates on natural gas; however, global food processing plants including those in other U.S. states rely on other sources such as coal and fuel oil. In 2002, 52% of total energy supply utilized in the U.S. food manufacturing industry was natural gas, 21% net electricity, 17% coal, 3% fuel oil, and 8% other (e.g., waste materials).⁶² In aggregate, the market transfer of California production to producers in other U.S. locations in the U.S. therefore is likely to occur to plants relying on a mix of fuels that produce higher levels of emissions per MBtu. In the case of tomato processing, global market transfer that occurs to food processing facilities in China is likely to result in greater emissions per ton of processed tomatoes, as energy used to process tomatoes in China is generally derived from coal-fired plants.⁶³

⁶⁰ Energy Information Administration, Documentation for Emissions of Greenhouse Gases in the United States 2005, DOE/EIA-0638 (2005), October 2007, Tables 6-1, 6-2, 6-4, and 6-5.

⁶¹ U. S. Energy Information Administration, Documentation for Emissions of Greenhouse Gases in the United States 2008, DOE/EIA-0638 (2006), October 2008, Table 6-2, p. 183.

⁶² U.S. Environmental Protection Agency, *Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, March 2007, p. 3-32.

⁶³ Personal communication with Rob Neenan, California League of Food Processors.

7. References

- Adelaja, A, 1991. "Price Changes, Supply Elasticities, Industry Organization and Dairy Output Distribution." *American Journal of Agricultural Economics* 63:89-102.
- Agricultural Issues Center, University of California, various reports.
- Alston, J. M., Balagtas, J. V., Sumner, D. A., Brunke, H. 2007. "Supply and Demand for Commodity Components: Implications of Free Trade versus the AUSFTA for the U.S. Dairy Industry." *Australian Journal of Agricultural and Resource Economics* (forthcoming).
- Apland, J., Anderson, H. 1996. "Optimal Location of Processing Plants: Sector Modeling Considerations and an Example" *Review of Agricultural Economics*, Vol. 18, No. 3. (Sep., 1996):491-504.
- Bergtold, Jason, Ebere Akobundu, and Everett B. Peterson. "The FAST method: Estimating unconditional demand elasticities for processed foods in the presence of fixed effects." *Journal of Agricultural and Resource Economics* (2004): 276-295.
- Blisard, N., Blayney, D., Chandran, R., Allshouse, J. 1999. "Analyses of Generic Dairy Advertising, 1984–1997." Technical Bulletin 1873, USDA, ERS, Washington DC, 1999.
- Brunke, H. and C. Stanford. 2003. *Commodity Profile: Dairy Products*. Agricultural Issues Center (UC Davis) Marketing Profile, November 2003.
- Brunke, H., Sumner, D. A. 2002. "Assessing the Role of NAFTA in California Agriculture: A Review of Trends and Economic Relationships," UC Davis Ag Issues Center Report, November 2002.
- Carter, C. A. *Economics of the California Processing Tomato Market*, Giannini Foundation of Agricultural Economics, University of California.
- CDFA, 2005. Milk Pricing in California, Dairy Marketing Branch, DMB-SP-101, April 1 2005.
- Chavas, J. P., and R. M. Klemme, 1986. *Aggregate Milk Supply Response and Investment Behavior on U.S. Dairy Farms*, *American Journal of Agricultural Economics* 78:55-66.
- Cox, T., Chavas, J-P. 2001. "An Interregional Analysis of Price Discrimination and Domestic Policy Reform in the U.S. Dairy Sector." *American Journal of Agricultural Economics*, 83:86-106.
- Dorfman, J. H., Kling, C. L., Sexton, R. J. "Confidence Intervals for Elasticities and Flexibilities: Reevaluating the Ratios of Normals Case," *American Journal of Agricultural Economics*, Vol. 72, No. 4. (Nov., 1990):1006-1017.
- Durham, C. A., Sexton, R. J. 1992. "Oligopsony Potential in Agriculture: Residual Supply Estimation in California's Processing Tomato Market." *American Journal of Agricultural Economics* v74, No. 4 (November 1992): 962-72.
- Durham, C. A., Sexton, R. J., Song, J. H. 1996. "Spatial Competition, Uniform Pricing, and Transportation Efficiency in the California Processing Tomato Industry" *American Journal of Agricultural Economics*, Vol. 78, No. 1. (Feb., 1996):115-125.
- FAFRI. 1995. "Impacts of Commodity Program Elimination on the U.S. Dairy Sector." Working paper 4-95, Food and Agricultural Policy Research Institute, University of Missouri-Columbia (April 1995).
- Gardner, B. L. 1975. "Farm-Retail Spread in a Competitive Food Industry." *American Journal of Agricultural Economics* 57: 399-409.

- Heien, D., Wessells, C. R. 1990. "Demand Systems Estimation with Microdata: A Censored Regression Approach," *Journal of Business & Economic Statistics*, Vol. 8, No. 3. (Jul., 1990):365-371.
- Helmberger, P., and Y. Chen, 1994. *Economic Effects of U.S. Dairy Programs*, *Journal of Agricultural and Resource Economics*, 19: 225-38.
- Huang, K.S. 1993. "A Complete System of U.S. Demand for Food." Technical Bulletin 1821, USDA, ERS, Washington DC, 1993.
- Huang, K.S. 1996. "Nutrient Elasticities in a Complete Food Demand System." *American Journal of Agricultural Economics* 78:21-29.
- Huang, S., Sexton, R. J.. 1996. "Measuring Returns to an Innovation in an Imperfectly Competitive Market: Application to Mechanical Harvesting of Processing Tomatoes in Taiwan." *American Journal of Agricultural Economics* 78(3): 558-71.
- Ippolito, R.A., Masson, R. T. 1978. "The Social Cost of Government Regulation of Milk." *Journal of Law and Economics* 21: 33-65.
- Johnson, R. S., Wheeler, W. J., Christensen, L. A. 1999. "EPA's Approach to Controlling Pollution from Animal Feeding Operations: An Economic Analysis," *American Journal of Agricultural Economics: Proceedings Issue* 81(5): 1216-1221.
- Lopez, Rigoberto A. "Political economy of U.S. sugar policies." *American journal of agricultural economics* 71.1 (1989): 20-31.
- Marks, Stephen V. "A reassessment of empirical evidence on the U.S. sugar program." *The Economics and Politics of World Sugar Policies* (1993): 79-108.
- Marsh, J. M. 1994. "Estimating Intertemporal Supply Response in the Fed Beef Market." *American Journal of Agricultural Economics* 76:444-453.
- National Agricultural Statistical Service, USDA. QuickStats (Agricultural Statistics Database): <http://www.nass.usda.gov/index.asp>
- National Agricultural Statistical Service. 2005. Vegetables and Melons Outlook/VGS-308/April 21, 2005.
- Porter, Michael E., and A. Michael Spence. "The capacity expansion process in a growing oligopoly: the case of corn wet milling." *The economics of information and uncertainty*. University of Chicago Press, 1982. 259-316.
- Processing Tomato Advisory Board, various reports: <http://www.ptab.org/>
- Ramirez, Edna C., Johnston, David B., McAloon, Andrew J., Yee, Winnie, Singh, Vijay. 2008. "Engineering process and cost model for a conventional corn wet milling facility," *Industrial Crops and Products*, 27: 91-97.
- Schmit, T.M, Kaiser, H.M. 2002. "Measuring the impacts of generic fluid milk and cheese advertising: A time-varying parameter application." R.B. 2002-06. Ithaca, NY: Department of Applied Economics and Management, Cornell University.
- Schmit, T.M., Kaiser, H. M. 2006. "Forecasting Fluid Milk and Cheese Demands for the Next Decade". *Journal of Dairy Science* 89: 4924-4936.
- Sexton, R. 2000. "Industrialization and consolidation in the U.S. food sector: Implications for competition and welfare." *American Journal of Agricultural Economics* 82: 1087-1104.
- Staiger, Douglas, Stock, James H. 1997. "Instrumental Variables Regression With Weak Instruments." *Econometrica* 65: 557-596.
- Sudaryanto, Tahlim. *The potential impacts of liberalized trade policies in the United States and the European economic community on international markets for sugar*. 1987.

- U.S. Department of Commerce. Economics and Statistics Administration. U.S. Census Bureau. *2002 Economic Census of Manufacturing: Industry Series. Fruit and vegetable Canning: 2002.* (December 2004), <http://www.census.gov/prod/ec02/ec0231i311421t.pdf>
- U.S. Department of Commerce. Economics and Statistics Administration. U.S. Census Bureau. *2002 Economic Census of Manufacturing: Geographic Area Series. California: 2002.* (September 2005), <http://www.census.gov/prod/ec02/ec0231aca.pdf> .
- World Processing Tomato Council: www.wptc.to/Releases-wptc.aspx
- Yavuz, F., Zulauf, C., Schnitkey, G., Miranda, M. 1996. "A Spatial Equilibrium Analysis of Regional Structural Change in the U.S. Dairy Industry." *Review of Agricultural Economics*, 18(4): 693-703.