Production and Emissions Leakage from the Cap-and-Trade Program in California's Food Processing Industries

Stephen F. Hamilton (Cal Poly)
Ethan Ligon (UC Berkeley)
Aric Shafran (Cal Poly)
Sofia Villas-Boas (UC Berkeley)

CAL POLY
ORFALEA COLLEGE OF BUSINESS
SAN LUIS OBISPO

CAL POLY
SAN LUIS OBISPO

1. Introduction

- The Cap-and-Trade Program has the potential to transfer output from California producers to out-of-state producers
  - Market transfer effects arise when a cost shock (compliance costs) applies unilaterally to one region (California), creating cost-advantage in other regions
    - Production leakage refers to the increase in output in other regions in response to cost-advantage
  - **Emissions leakage** depends on production leakage and the relative emissions efficiency (CO_2e/MT) of plants reducing output and those increasing output

1.1 Market Transfer and Leakage

- Unilateral environmental regulations raise cost for CA firms, reducing output ($\Delta Q_{CA} < 0$)
- When market prices rise in response, output rises in unregulated regions ($\Delta Q_{UR} > 0$)
  - ΔQ_{UR} is the amount of "production leakage"
- Market transfer (M) relates the two effects
  - In absolute value terms: $\Delta Q_{UR} = M^*(\Delta Q_{CA})$
    - If M = 1, production is offset 1-to-1 by outside producers
    - Generally, 0 < M < 1 (less than 100% leakage of production)

1.2 Market Transfer Mechanism

- Market transfer effects occur following a regional cost increase through "forward-shifting" of cost
  - 1 of 3 things occur from a regional cost increase:
    - Cost is shifted backwards to the regional supply chain in the form of lower farm prices for raw material
    - Cost is absorbed by food processors in decreased margins
    - Cost is shifted forward into higher consumer prices
  - Forward shifting of cost into consumer prices causes:
    - Decreased total production (regulated + un-regulated areas)
    - Increased output in un-regulated areas (production leakage)

1.3 Emissions Leakage

- Emissions leakage depends on production leakage and relative emissions efficiency
  - For equally-efficient plants, emissions leakage occurs one-for-one with production leakage
    - If market transfer is 50% of California production, then every 1 unit of emissions decrease in California is associated with ½ unit of emissions increase elsewhere
      - Global CO_2e emissions decline by half as much as in California
  - If market transfer occurs from natural gas-fired plants in California to coal-fired plants elsewhere, then emissions leakage will exceed production leakage

1.4 Note on Production Leakage

- Production leakage and emissions leakage only occur when regional policies are not harmonized:
  - If all producers face similar compliance costs, then *all* regions curtail production in response to higher costs
    - Global prices for goods requiring CO_2e inputs rise
    - Costs are passed through to higher consumer prices without stimulating production by unregulated polluters
    - A smaller share of cost is shifted backwards to reduce economic activity in regulated regions
- Allowance allocations (and other policies) can reduce production and emissions leakage

1.5 Scope of Study

- We examine production leakage from California food processors to out-of-state food processors in response to the Cap-and-Trade Program absent any allowance allocation:
  - Processing tomatoes (global market transfer)
  - Cheese (market transfer within the U.S.)
  - Wet Corn (market transfer within the U.S.)
  - Sugar (market transfer within the U.S.)

2. The Model

- Market transfer depends on the extent to which cost increases are passed into consumer prices, stimulating increased out-of-state production
- Forward passing of cost into consumer markets raises consumer prices, resulting in:
  - (1) Decreased California production
  - (2) Decreased U.S. (or global) production
- Production leakage (increased out-of-state production) is the difference: (1) – (2).

2.1 Residual Demand

- Residual demand facing California food processors: $D^R(P) = D^T(P) - S^U(P)$
  - $D^T(P)$ = Total Market demand
  - $S^U(P)$ = Supply from unregulated regions
- Residual demand is more elastic than market demand:

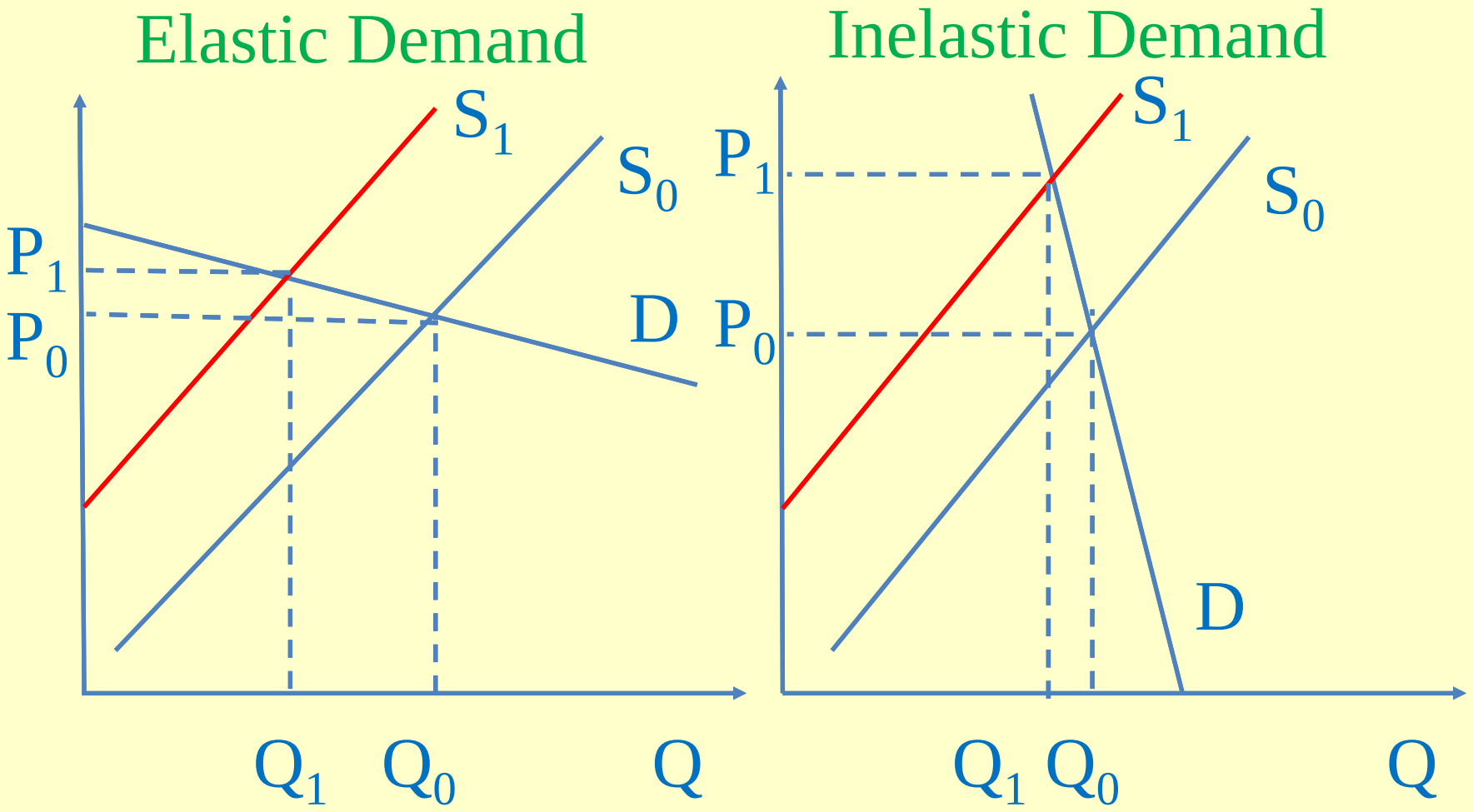
$$\varepsilon_R = \frac{\varepsilon_T}{s} + \left(1 - \frac{1}{s}\right)\varepsilon_U$$

  - ε_R = residual demand elasticity
  - ε_U = supply elasticity of out-of-state producers
  - s = market share of California producers

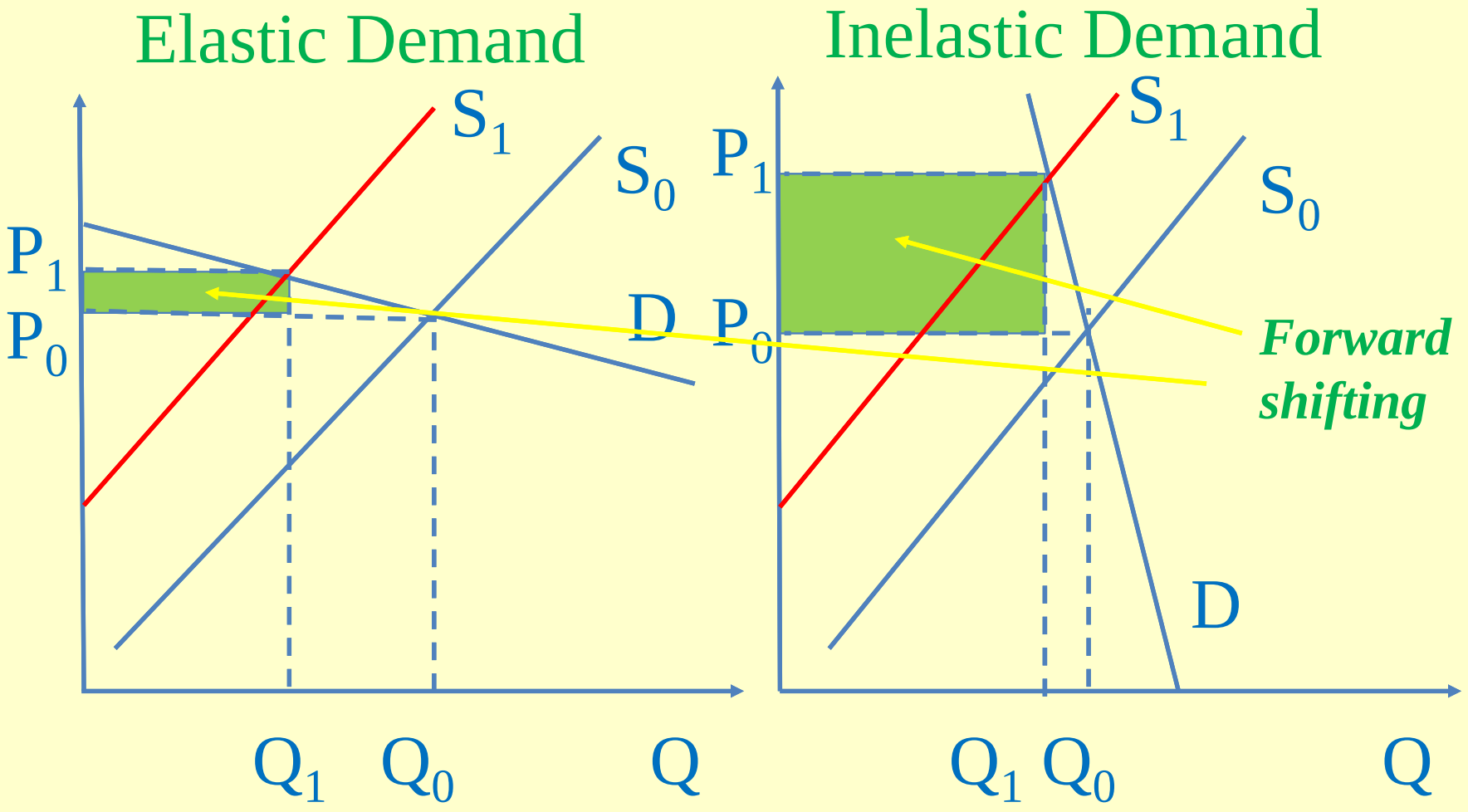
2.2 Market Transfer Effects

- Market transfer effects are calculated in the case of competitive equilibrium
  - Cost changes from the Cap-and-Trade Program are passed backwards (decreased farm prices) or forward (increased consumer prices) according to:
    - Residual demand elasticity facing California producers
    - Supply elasticity in the California market
- When residual demand is more elastic:
  - Smaller share of cost is shifted forward
  - Larger share of cost is shifted backwards, reducing economic value in California's supply chain

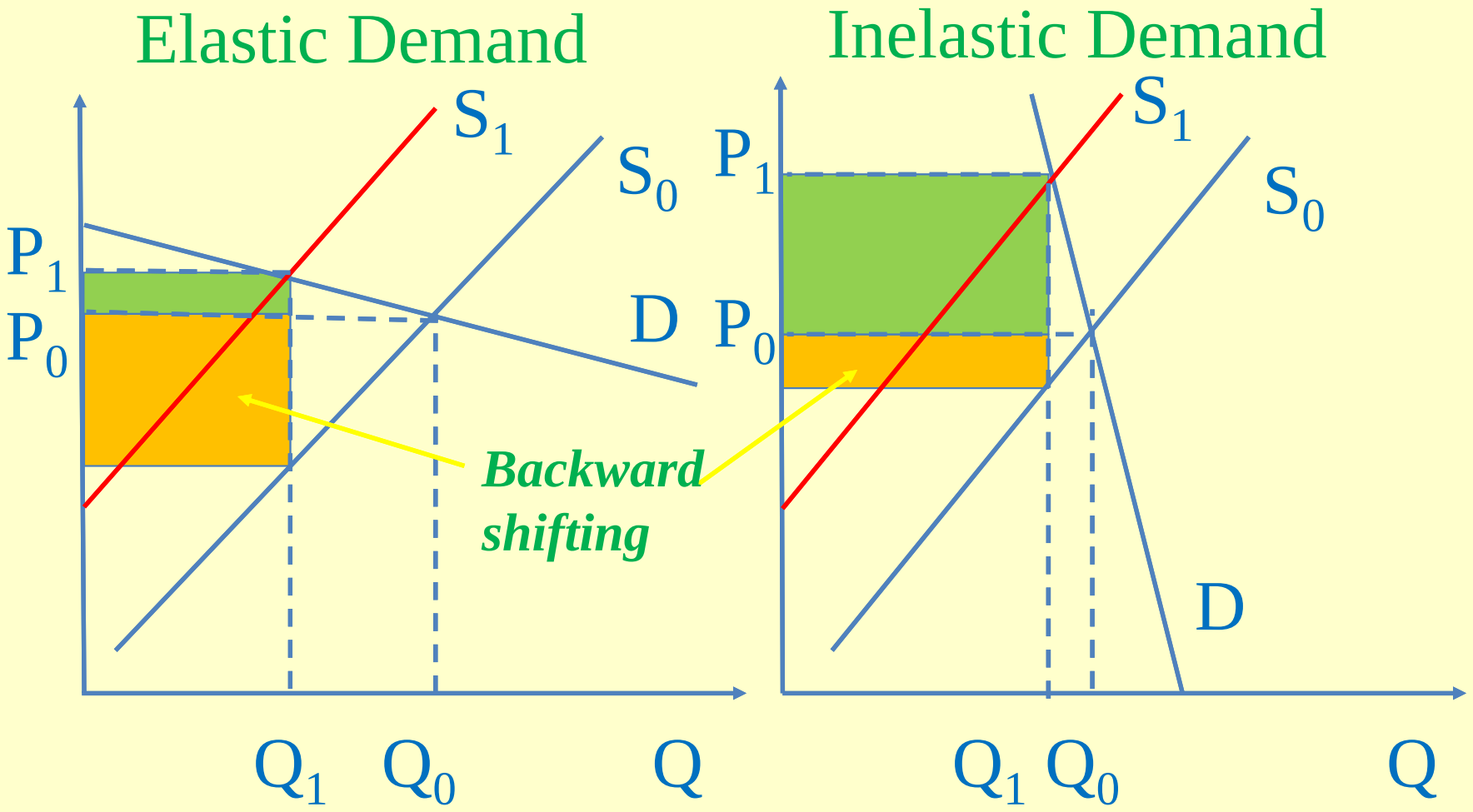
2.3 Forward Pass Through



2.3 Forward Pass Through



2.3 Forward Pass Through



3. Data and Methods

- Industries considered: 17 of 38 regulated food processing facilities in California
  - Energy share of variable cost based on industry data

Table 4.1. Energy Intensity of Production in Selected Industries

Industry	Time Period	Natural Gas ($/MMBtu)	Energy Share of Variable Cost (%)	Energy per Unit of Output (MMBtu/MT)
Processing Tomatoes	2010-2012	$4.68	4.24%	5.36
Cheese	2010-2013	$5.04	4.40%	5.43
Wet Corn	2013	$6.25	6.90%	4.39
Sugar	2006-2009	$7.57	5.33%	8.85

3.1 Cap and Trade and Energy Cost

- Increased energy cost under the Cap-and-Trade Program mediated through natural gas prices:
  - U.S. Energy Information Administration (2007) CO_2e emissions factors per MBtu of natural gas
    - Allows changes in compliance costs to be mapped to changes in effective cost per MBtu of natural gas.
  - In periods with "low" natural gas prices, compliance costs are a larger percentage of variable cost
    - Food processors outside California are assumed to have similar technology as California plants

3.2 Data and Methods

- Methods differ by food processing industry according to quality of available data:
  - Processing Tomatoes (paste and diced):
    - Estimate both supply and demand elasticities
  - Wet Corn: Estimate supply, demand elasticities taken from the economics literature
  - Cheese: Supply and demand elasticities taken from estimates in the economics literature
  - Sugar: Supply and demand elasticities taken from estimates in the economics literature

3.3 Long Run Supply Estimates

- **Processing Tomatoes: Supply elasticity = 9.8**
  - Spatial simulation model based on transport costs
- **Wet Corn: Supply elasticity = 1.9**
  - Two-Stage Least Squares (TSLS) estimate
    - Instumented with Midwest starch prices
- **Cheese: Supply elasticity = 1.2**
  - Chavas and Klemme (1986): 6-year supply response
- **Sugar beets: Supply elasticity = 1.7**
  - Lopez (1989) = 1.2; Sudaryanto (1987) = 2.3

3.4 Demand Elasticities

- **Processing Tomatoes: Demand elasticity = 3.1**
  - TSLS with cost instruments
- **Wet Corn (sweeteners): Demand elast. = 0.6**
  - Sudaryanto (1987)= 0.6; Lopez (1988) = 0.6
- **Cheese: Demand elasticity = 0.7**
  - Bergtold (2004) = 0.7; range in literature = 0.4 - 1.5
- **Sugar (sweeteners): Demand elasticity = 0.6**

Table 5.4. Supply, Demand and Market Share Parameters

Industry	Demand Elasticity	Supply Elasticity	California Market Share	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.

Table 5.4. Supply, Demand and Market Share Parameters

Industry	Demand Elasticity	Supply Elasticity	California Market Share	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.

Residual demand facing California food processors is an order of magnitude more elastic than market demand ➔ Greater backward shifting of cost (less forward shifting)

4. Leakage Results

- Market Transfer: Share of California output decrease that is offset by increased out-of-state production

Table 6.1. Predicted Cost-Shifting and Market Transfer Effects

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

4.1 Processing Tomatoes

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

	Compliance Costs ($/MT CO_2e)				
Impact	**$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	$894.29
Percent increase MC of processing		0.62%	0.81%	1.13%	1.63%
Increase in global price ($/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%

4.2 Cheese

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

	Compliance Costs ($/MT CO_2e)				
Impact	**$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%

4.3 Wet Corn

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

		Compliance Costs ($/MT CO_2e)			
Impact	**$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%

4.4 Sugar

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

		Compliance Costs ($/MT CO_2e)			
Impact	**$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%

5. Conclusion

- Estimated market transfer effects are substantial:
  - 57% to 76% of the production decrease in California is offset by production increases elsewhere (U.S. or international)
- Decrease in California production varies substantially across industries. In the case of $20/MT compliance cost:
  - Tomatoes: 7.17% decrease with 68% market transfer
  - Cheese: 0.97% decrease with 57% market transfer
  - Wet Corn: 2.21% decrease with 76% market transfer
  - Sugar: 1.17% decrease with 71% market transfer

Supply is more elastic in the case of processing tomatoes and wet corn

5.1 Conclusion

- Majority of cost increase is shifted backwards in supply:
  - Absent allowance allocations, the California supply chain absorbs 76% - 99% of the cost increase
    - Lower farm prices and reduced processing margins (continuous effects)
    - Potential exit of food processing plants (discrete effects)
- **Emissions leakage** differs from **production leakage**
  - Emissions leakage depends on relative efficiency of California plants reducing output and out-of-state plants increasing output
    - Emissions efficiency (MT CO_2e / MMBtu) for natural gas = 0.053
    - Emissions efficiency (MT CO_2e / MMBtu) for bituminous coal = 0.093