Impact of CO2 Emission Policies on Food Supply Chain:

Application to the U.S. Apple Sector

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Impact of CO2 Emission Policies on Food Supply Chain: Application to the U.S. Apple Sector*

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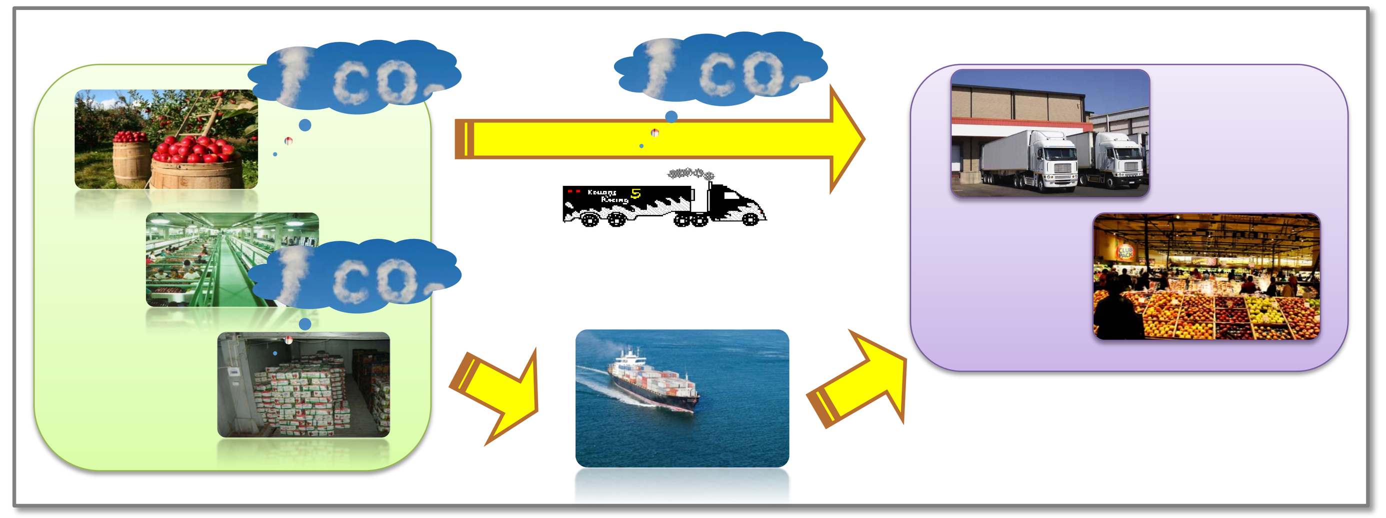
Introduction

Food supply chains (FSCs) are an important source of CO2 emissions in their production, processing, distribution and consumption activities. Such policy instruments as a carbon tax and a cap-and-trade program have been considered to reduce CO2 emissions in FSCs. At the same time, some argue that production agriculture may be an important source of CO2 offsets. However, little is known about the potential impacts of these policies (i.e. carbon tax, cap-and-trade, and offset credits) on the structure of FSCs as well as on the welfare implications for supply chain participants.

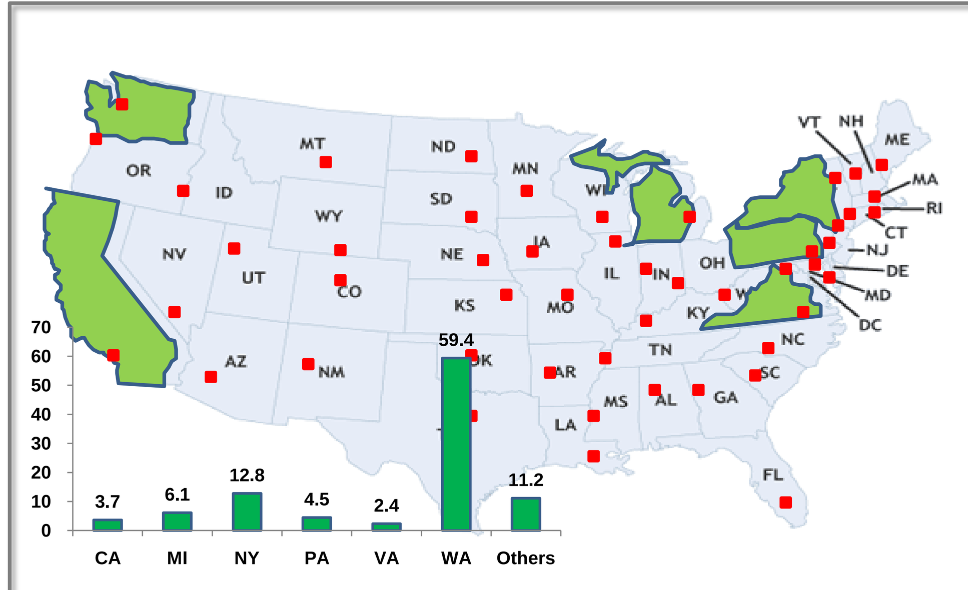
Objectives

Develop an optimization model of the U.S. apple supply chain to measure the impact of alternative CO2 emission policies on supply chain structure as well as on social welfare of supply chain segments.

Apple Supply Chain



Apple Supply Chain Model: Key Features



a) Fresh apples
b) Two time periods (fall and spring)
c) Five varieties (Golden Del., Granny Smith, Red Del., Gala, Others)
d) Truck transportation
e) Regular and CA storage

Model

1. Spatial equilibrium model*

Max

$$\sum_t\sum_k\sum_j \delta^{t-1}\int_0^{qd^t_{k,j}} pd^t_{k,j}(qd^t_{k,j})dqd^t_{k,j} - \sum_k\sum_i \int_0^{qs_{k,i}} ps_{k,i}(qs_{k,i})dqs_{k,i} + \sum_t \delta^{t-1}\int_0^{qim^t} ppim^t(qim^t)dqim^t - \sum_t \delta^{t-1}\int_0^{qex^t} ppex^t(qex^t)dqex^t$$

Social surplus from supply and demand

$$-\sum_k\sum_i pc_{k,i}\cdot qs_{k,i} - \sum_t\sum_s\sum_i \delta^{t-1}\left[sc^t_{s,i}\cdot\left\{\sum_k sa^t_{k,s,i}\right\}\right] - \sum_t\sum_i\sum_j \delta^{t-1}\left[tc^t_{i,j}\cdot\left\{\sum_k\sum_s tfa^t_{k,s,i,j}\right\}\right] - \sum_t\sum_m\sum_j \delta^{t-1}\left[tc^t_{m,j}\cdot\left\{\sum_k tfam^t_{k,m,j}\right\}\right]$$

Costs from supply chain's activities

Constraints

1) Capacity constraints (production and storage)
2) Technical constraints
3) Supply and Demand balances
4) Non-negativity constraints

** See supplementary pages for details*

2. Demand price elasticities

1) LA-AIDS model using Nielsen Homescan data (2005-2006)
2) Heckman's two step procedures to deal with zero consumption problems

Apple Variety	Northeast		Midwest		South		West	
	Spring	*fall*	*spring*	*fall*	*spring*	*fall*	*spring*	*fall*
Golden Del.	-2.00	-1.54	-2.71	-1.17	-1.71	-0.97	-3.22	-0.61
Granny Smith	-2.56	-3.35	-4.68	-1.49	-1.96	-2.00	-2.69	-2.08
Red Delicious	-1.00	-0.98	-1.11	-1.02	-0.99	-0.99	-0.90	-0.93
Gala	-0.71	-1.52	-1.27	-0.69	-0.72	-0.79	-0.96	-1.12
Others	-1.06	-1.05	-1.08	-1.08	-1.10	-1.08	-1.06	-1.09

3. Price elasticities of supply

1) Nerlove's model

California	Michigan	New York	Pennsylvania	Virginia	Washington
0.57	0.36	0.36	0.50	0.55	0.12

4. Costs

1) Production costs
2) Storage costs
3) Transportation costs

Emission Policies*

1. Carbon Tax

1) Carbon tax τ on the ton of CO2 emissions is applied to production and storage activities

2. Cap-and-Trade (without Offsets)

1) Emission allowances (permit) are distributed to each supply region by $A_i = (1-\Phi)E_i = \mu_i * qs_{k,i}$, where Φ is emission reduction plan and μ_i is emission rate.

3. Cap-and-Trade (with Offsets)

1) Allow each supply region to purchase offset credits (CR_i)by δ percents of required emission reductions

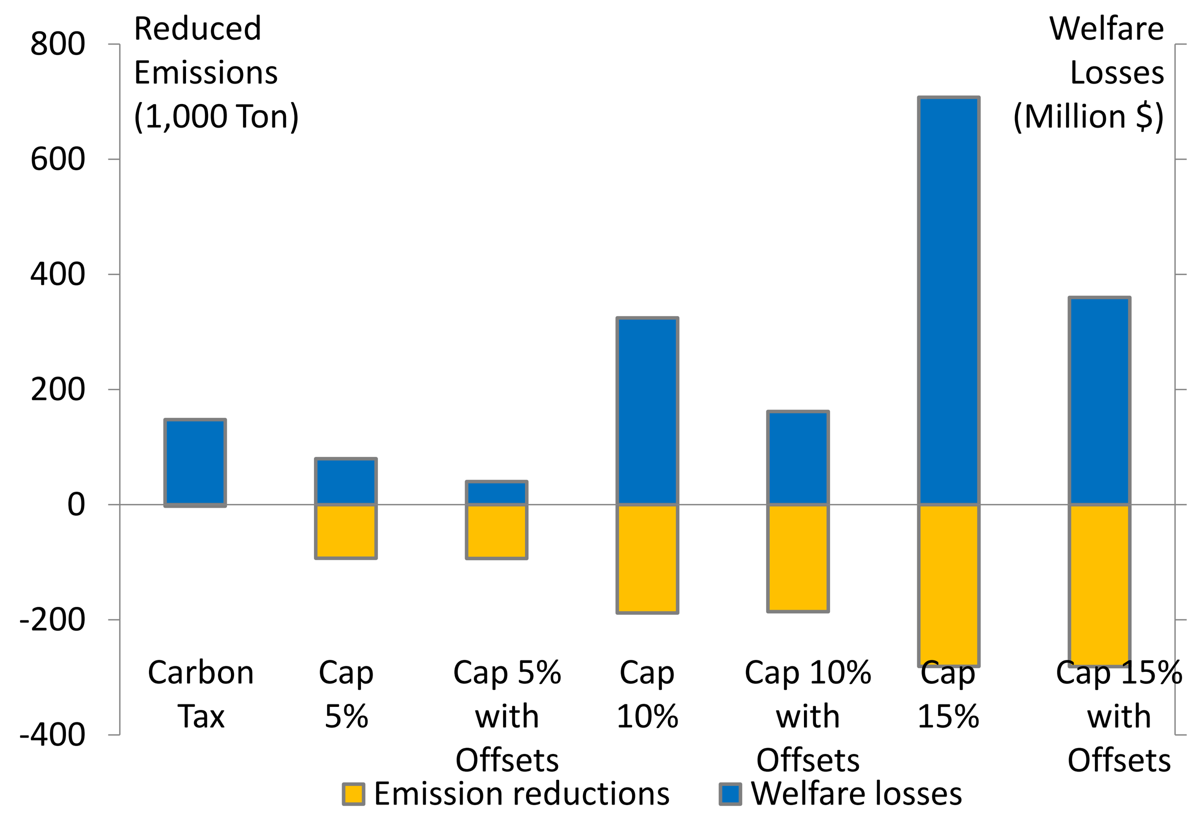
** See supplementary pages for details*

Simulations

Assumptions:

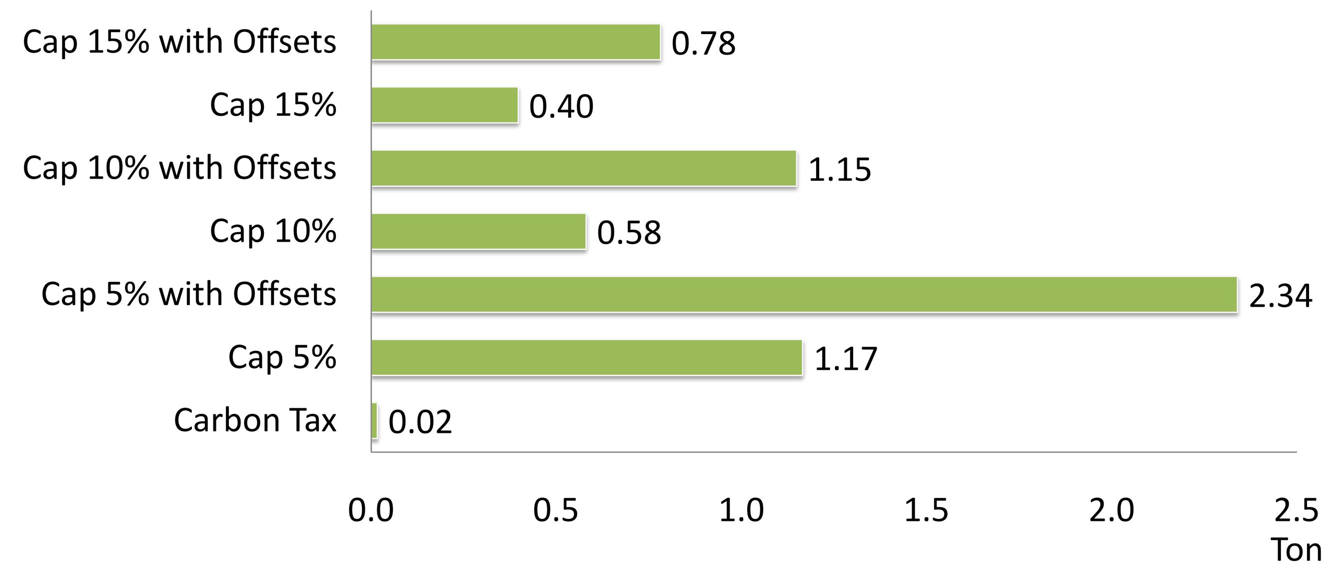
1. Permit price = Emission tax = Offset Credits = $20
2. Maximum Offset: 30% of emission cuts

Annual Emission Reductions and Welfare Losses



Simulations (continued)

Annual Per-dollar Emission Reduction



Production Changes from Alternative Policies (million lbs.)

State	Baseline	Carbon Tax	Cap-and-Trade without Offsets			Cap-and-Trade with Offsets		
			5%	10%	15%	5%	10%	15%
California	117	115	93	61	46	95	91	57
Michigan	269	269	246	24	202	253	243	241
New York	675	674	659	646	645	666	646	645
Pennsylvania	128	128	120	119	118	121	119	119
Virginia	32	32	30	30	29	30	30	30
Washington	4,119	4,117	3,965	3,807	3,670	4,015	3,893	3,794

Conclusions

1. A carbon tax may have modest impacts on emission reductions and on supply chain structure (e.g. production decisions)
2. Cap-and-Trade schemes with offsets appear to be more effective than Cap-and-Trade schemes without offsets
3. The impacts of emission policies may be largest in California due to its higher production costs

References

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2. Guajardo, R.G.,and H.A. Elizondo. 2003. "North America Tomato Market: A Spatial Equilibrium Perspective," *Applied Economics* 35: 315-322