Markets for Agricultural Greenhouse Gas Offsets: The Role of Payment Design on Abatement Efficiency

Cloé Garnache*, Pierre Mérel†,
Juhwan Lee† and Johan Six†

* Dept of Agricultural, Food and Resource Economics, Michigan State University
† Dept of Environmental Systems Science, ETHZ, Switzerland

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Growing political will to develop climate policies reducing GHG emissions

- 2009 Copenhagen Accord: “Climate change is one of the greatest challenges of our time” and “deep cuts in global emissions are required” *(UNFCC, 2010)*
- International agreements: Kyoto agreement, the European Union’s Emissions Trading System
- National: Australia, New Zealand
- Subnational agreements: 10 north eastern states (RGGI), CA (AB 32), Québec

Studies show agriculture can cost-effectively abate GHG emissions

- Large abatement potential: carbon sequestration, reduction in N_2O and CH_4 *(Lal et al., 1998; Paustian et al., 2006; Smith et al., 2008; Snyder et al., 2009)*
- Economic studies conclude agriculture can cost-effectively reduce GHG emissions *(McCarl and Schneider, 2001; Pautsch et al., 2001; Antle et al., 2007)*

California is one of the leaders in designing climate policy with Assembly Bill (AB) 32 *(Burtraw, 2013)*

- Mandate: cap the state's 2020 emissions (507Mt under BAU) to their 1990 levels (427Mt)
- Estimated 62Mt will be abated from standards (e.g., low carbon fuel standards, energy efficiency, 33% renewable energy in electricity generation)
- Estimated 18Mt will be abated from cap-and-trade
- ARB is reviewing the development of protocols to credit GHG offsets from agriculture (protocols already exist for forestry and biodigesters)

Research questions

- What is California's agriculture marginal abatement cost curve?
- How much abatement efficiency loss arises from second-best policies relative to the first-best?
  1. Payments with aggregated emission factors
     - at the Sacramento and San Joaquin Valley-level
     - at the California-level
  2. Payments targeting a single GHG
     - N_2O
     - CO_2
  3. Payments monitoring a single input
     - N fertilizer (in \$/kg of N)
     - irrigation water (in \$/m^3)
     - tillage (in \$/tillage index)

The application: California Central Valley's agriculture

- 7 crops (covering 70% of the non-perennial acreage)
- Simultaneous and continuous changes in
  - N fertilizer application rate
  - water application rate
  - tillage practices
- Crop substitution effects
- All three GHGs: N_2O, CO_2, CH_4

Results overview

Second-best policy	Abatement losses relative to first-best
Valley-level aggregated factors	small
State-level aggregated factors	small
Regulating CO_2 only	medium
Regulating N_2O only	medium
Regulating tillage only	medium
Regulating N only	large
Regulating water only	large

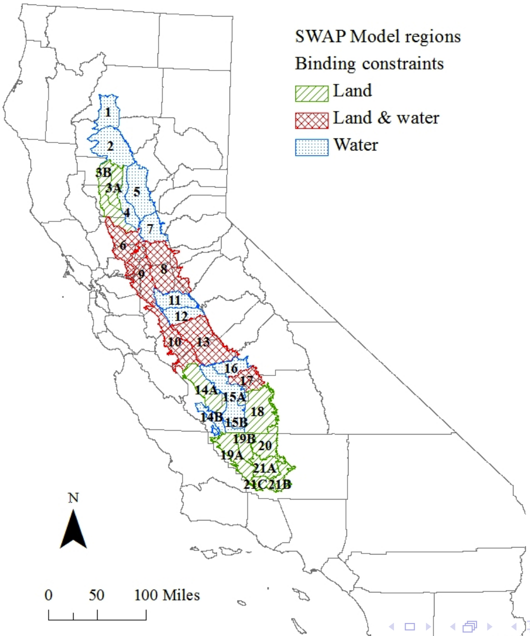
The economic and biophysical models

- The economic model
  - Positive mathematical programming
  - CES production functions with decreasing returns-to-scale
  - Calibrated to input-output crop allocation
  - Calibrated to exogenous own-price supply elasticities
- The biophysical model, Daycent
  - Process-based model
  - Calibrated to California conditions

Linking the economic and biophysical models

- The biophysical model simulates yield and GHG data
  - GHG emission responses → feed into the economic model
  - yield responses integrated into the economic model
- The CES production function is consistent with
  - economic data: reference allocation and supply elasticity
  - agronomic information at the margin

California's Central Valley 27 regions



Crop acreage distribution across the Central Valley (%)

Crop	Central Valley	Sacramento Valley	San Joaquin Valley
Alfalfa	22	24	19
Corn	21	22	21
Cotton	21	1	28
Grain	12	21	9
Other field cr.	14	9	16
Proc. tomato	10	18	7
Safflower	2	6	0
Total	100	100	100

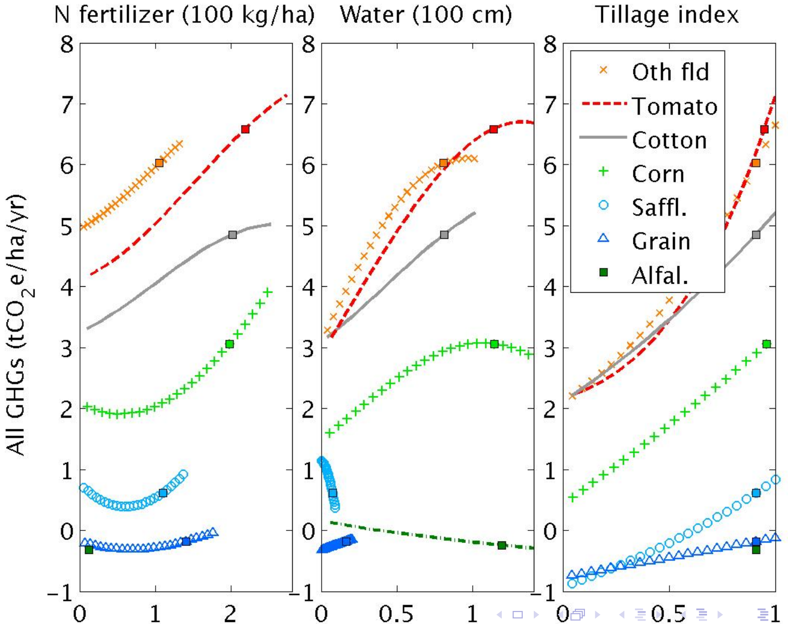
Constructing the tillage index T

- Six tillage practices identified in California *(Mitchell et al., 2009)*

Practice	Description	Residue cover	Chisel, subsoil	T
Conv. tillage	high soil disturbance	none	yes	1
CA conv. tillage	medium soil disturbance	none	yes	0.91
Reduced tillage	tractor passes cut by 25%	15-30%	no	0.64
Mulch tillage	tractor passes cut by 75%	>33%	no	0.54
Strip tillage	only seed row is tilled	>30%	no	0.41
No till	disturb. only at planting	>30%	no	0

- Extrapolate T from the 6 data points: T continuous on the interval $[0, 1]$

GHG responses to N, water&tillage - Region 6



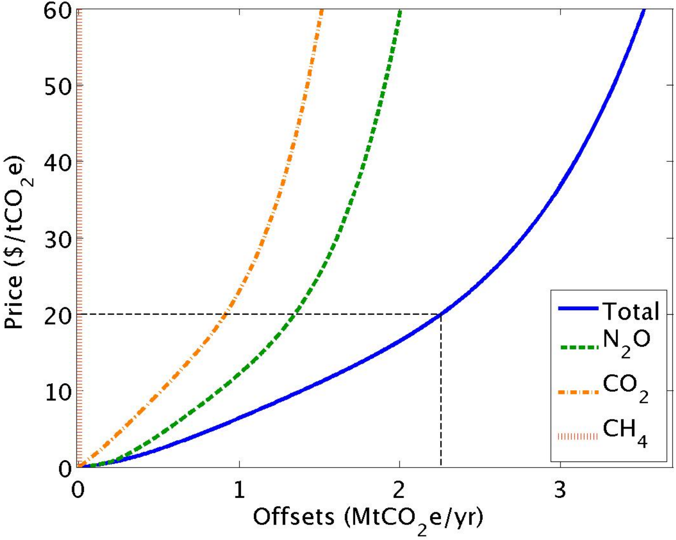
Model specification under the first-best policy

$$\max_{x_{ij}\geq 0, T_i \geq 0} \sum_i \left(p_i q_i - \sum_j (c_{ij} + \lambda_{ij}) x_{ij} - (c_{iT} + \lambda_{iT} T_i) x_{i1} - t \sum_k E_{ik} x_{i1} \right)$$

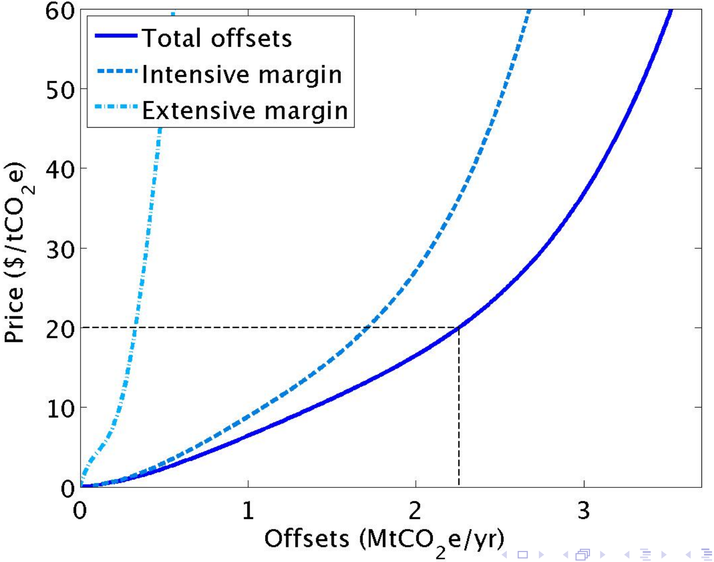
subject to

$$\begin{cases} \sum_i x_{ij} \leq v_j & j = 1, 2 \\ q_i = \mu_i \gamma_i \left(\sum_j \beta_{ij} x_{ij}^{\rho_i} \right)^{\frac{\delta_i}{\rho_i}} & \forall i \in I \\ E_{ik} = f_{ik}(a_{ij}, T_i) & \forall i \in I \text{ and } k = CO_2, N_2O, CH_4 \end{cases}$$

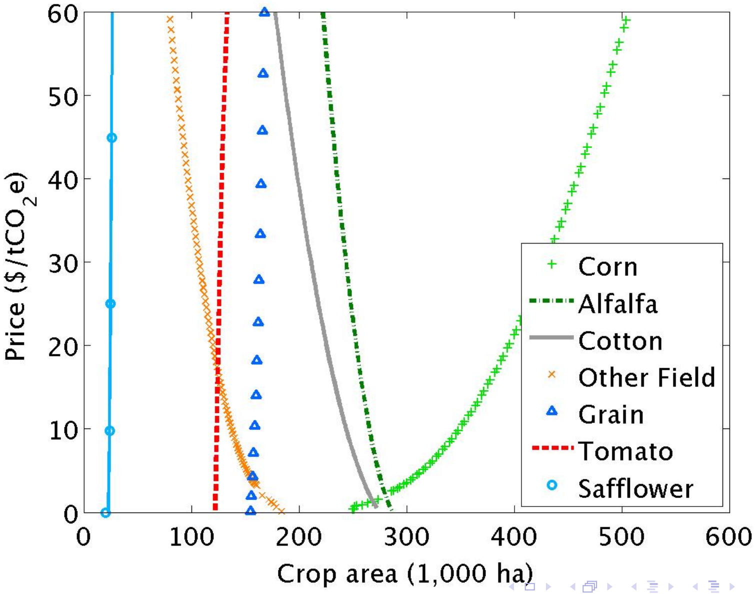
California's agriculture offset supply curve (first-best policy)



Adjustments at both the intensive and extensive margins contribute substantially to total abatement



Large crop substitution effects, including corn acreage expansion



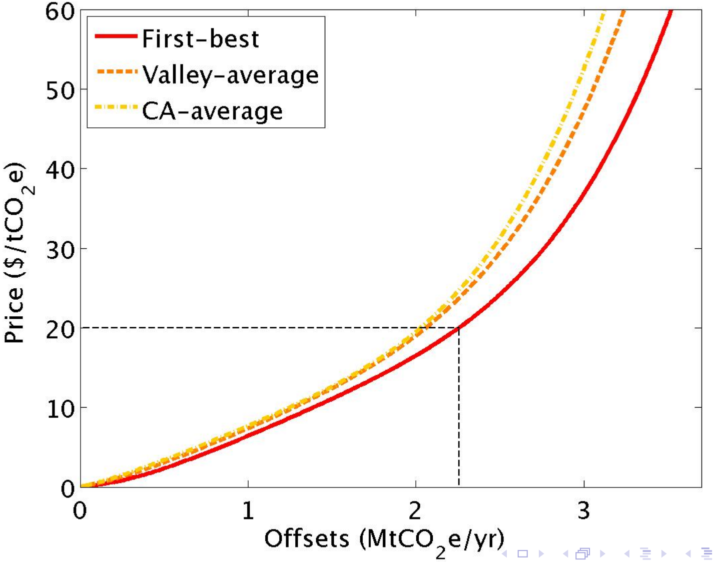
Crop average emission rates in the baseline and net changes at a price of $\$20/tCO_2e$

	Sacramento Valley		San Joaquin Valley	
Crop	Baseline	Δ GWP	Baseline	Δ GWP
Alfalfa	-0.3	0.0	4.3	-0.8
Corn	3.0	-2.5	1.5	-2.0
Cotton	3.8	-0.4	5.0	-1.3
Grain	-0.1	-0.1	-0.3	0.0
Other field cr.	5.7	-2.2	4.3	-1.5
Proc. tomato	6.6	-2.7	6.7	-3.1
Safflower	1.0	-2.0	0.0	-0.3
Weighted average	2.3	-1.4	3.7	-1.8

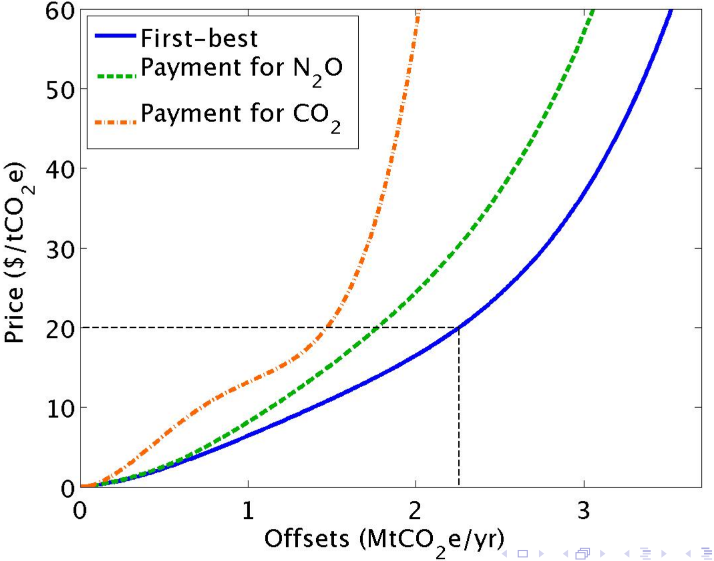
Crop average production practices and acreages in the baseline and net changes at a price of $20/tCO_2e$

Crop	Area (10^3ha) $\bar{x}_1$	Δx_1	Water (cm) $\bar{a}_2$	Δa_2	N (kg/ha) $\bar{a}_3$	Δa_3	Tillage index $\bar{T}$	ΔT
Alfalfa	283	-29	125	10	10	-	0.91	-
Corn	271	125	121	-29	218	-58	0.96	-0.78
Cotton	269	-42	79	6	201	-27	0.91	-0.29
Grain	146	-4	37	2	202	13	0.91	-0.07
Oth field cr	176	-56	83	10	105	-59	0.91	-0.29
Pr. tomato	122	3	112	-4	218	-26	0.95	-0.32
Safflower	20	-3	16	4	113	7	0.91	-0.73

Second-best policies using aggregated emission factors perform well relative to the first-best

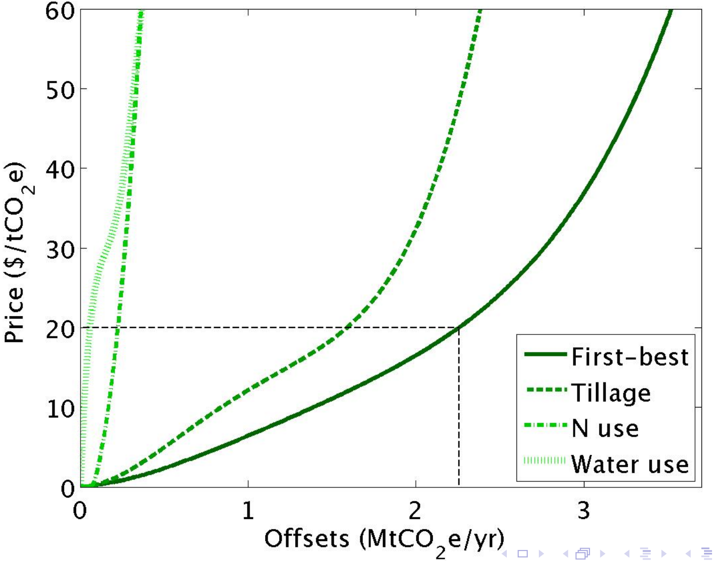


Second-best policies targeting a single GHG lead to substantial abatement efficiency losses



Second-best policies monitoring a single production practice perform poorly relative to the first-best

Offset price



Abatement efficiency losses under second-best policies relative to the first-best at \$20/tCO_2e

Second-best policy	Abatement loss relative to first-best
Valley-level aggregated factors	$\approx$ 9%
State-level aggregated factors	$\approx$ 10%
Regulating CO_2 only	$\approx$ 31%
Regulating N_2O only	$\approx$ 21%
Regulating tillage only	$\approx$ 30%
Regulating N only	$\approx$ 90%
Regulating water only	$\approx$ 95%

Conclusion

- California agriculture's abatement: $\approx 2.3 \text{Mt}CO_2\text{e/year}$ at $\$20/\text{t}CO_2\text{e}$
- First study that systematically quantify deadweight loss from implementing second-best policies
- Limitations
  - Estimate of economic abatement potential (mandatory participation, no transaction costs)
  - Assume biophysical model predicts GHG with certainty.

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