Energy Pathways Through California Agriculture

How vulnerable are farmers to higher energy costs?

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Motivation

- This work has grown out of research on California’s climate policy agenda.
- Agriculture is an important emissions source and likely target of further regulation.
- To facilitate dialog, both farmers and policy makers need to better understand the sector’s energy dependence.

Agricultural Energy Needs

In California, agriculture has significant direct and indirect energy requirements;

Across product categories, patterns of energy dependence vary considerably;

So then will the incidence of price-cost effects arising from both climate policy and energy markets.

The Macro Picture, 2002

Direct	Output	VA	Emp	Energy
AgProducts	37	20	543	32
AgProcess	61	20	202	29
CA	2,281	1,389	19,831	2,649
Cumulative				
AgProducts		39	775	80
AgProcess		52	671	211
Units: Current Billions, Thousands of Jobs, Billion BTU				

Sources: Ag. Issues Center and author estimates.

Macro Picture

Shares(percent)	Output	VA	Emp	Energy
AgProducts	1.62	1.42	2.74	1.20
AgProcess	2.66	1.44	1.02	1.09
Total	4.28	2.85	3.76	2.29
Multipliers				
AgProducts		1.96	1.43	2.54
AgProcess		2.59	3.32	7.31

A Social Accounting Matrix for California, 2003

An economy-wide accounting device that captures detailed income-expenditure linkages between economic institutions. An extension of input-output analysis.

- 164 sectors/commodities
- Energy flows consistent with LBL state accounts
- Three factor types
  - Labor (2+ occupational categories)
  - Capital
  - Land
- Households (10 by tax bracket)
- Fed, State, and Local Government (very detailed fiscal instruments, 45 currently)
- Consolidated capital account
- US and ROW trading partners

Multipliers and SAMs

The basic tools are simple

$$S = \begin{bmatrix} Int & FD \\ VA & T \end{bmatrix} \rightarrow A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}$$

$$M = (I - A_{11})^{-1} = I + (M - I)$$

$$= M_1 + M_2 = Direct + Induced = Global$$

Product Energy Intensities

Economic activities consume energy directly and induce demand for energy services embodied in upstream inputs and downstream services.

Total embodied energy demand for a sector is related to direct energy demand (e) as

$$E = e\hat{x}^{-1}M = e\hat{x}^{-1}(M_1 + M_2)$$

where x denotes a vector of gross outputs.

Sectoral Composition

	Grain	TreeNuts	FruitFarm	Cotton	CattleDairy	Forest	Fishery
Own	38.14	44.47	40.52	42.94	35.02	38.89	52.41
OthAg	3.45	4.26	4.30	4.76	16.36	9.00	0.25
FoodPr	0.24	0.59	0.59	0.42	1.74	1.07	0.33
Energy	21.45	21.87	21.60	21.51	20.32	22.03	30.31
Chem	19.49	9.70	14.18	14.28	8.47	10.86	0.89
OthMfg	3.21	4.47	4.52	2.54	3.20	3.33	2.04
Transport	5.23	6.89	7.10	6.10	6.24	8.00	12.27
OthServ	8.80	7.75	7.18	7.45	8.67	6.82	1.50
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
BTU/Million	1237.48	838.85	919.79	1294.04	1569.45	407.33	2636.92

Embodied Energy: Agriculture

	BTU/Dollar of Output			Standardized (z)		
	Direct (e)	Induced	Total (E)	Direct	Induced	Total
Oilseed	482	649	1,131	-0.02	0.24	0.05
Grain	428	809	1,237	-0.07	0.71	0.13
VegMel	313	438	751	-0.18	-0.37	-0.24
TreeNuts	370	469	839	-0.13	-0.28	-0.18
FruitFarm	362	557	920	-0.13	-0.03	-0.12
GrnNursry	358	287	645	-0.14	-0.81	-0.33
Cotton	586	650	1,236	0.07	0.24	0.13
OthCrop	537	758	1,294	0.03	0.56	0.17
CattleDairy	667	832	1,499	0.15	0.78	0.33
Poultry	453	767	1,220	-0.05	0.59	0.11
OthLvstk	423	1,146	1,569	-0.08	1.69	0.38
Forest	262	728	990	-0.22	0.47	-0.06
Fishery	426	1,038	1,465	-0.07	1.38	0.30

Embodied Energy: Food

	BTU/Dollar of Output			Standardized (z)		
	Direct (e)	Induced	Total (E)	Direct	Induced	Total
FoodMfg	176	856	1,031	-0.30	0.84	-0.03
FoodProc	168	549	717	-0.31	-0.05	-0.27
Milk	115	1,007	1,122	-0.36	1.28	0.04
Meat	86	1,180	1,267	-0.39	1.79	0.15
PoultPr	115	746	861	-0.36	0.52	-0.16
SeaFood	168	1,510	1,678	-0.31	2.75	0.46
Baking	139	450	589	-0.34	-0.34	-0.37
SnackFd	126	579	705	-0.35	0.04	-0.28
CoffTea	61	628	689	-0.41	0.18	-0.29
OProcFd	93	559	652	-0.38	-0.02	-0.32
Beer	104	384	489	-0.37	-0.53	-0.44
Wine	73	505	579	-0.40	-0.18	-0.38
OthBev	71	512	583	-0.40	-0.16	-0.37

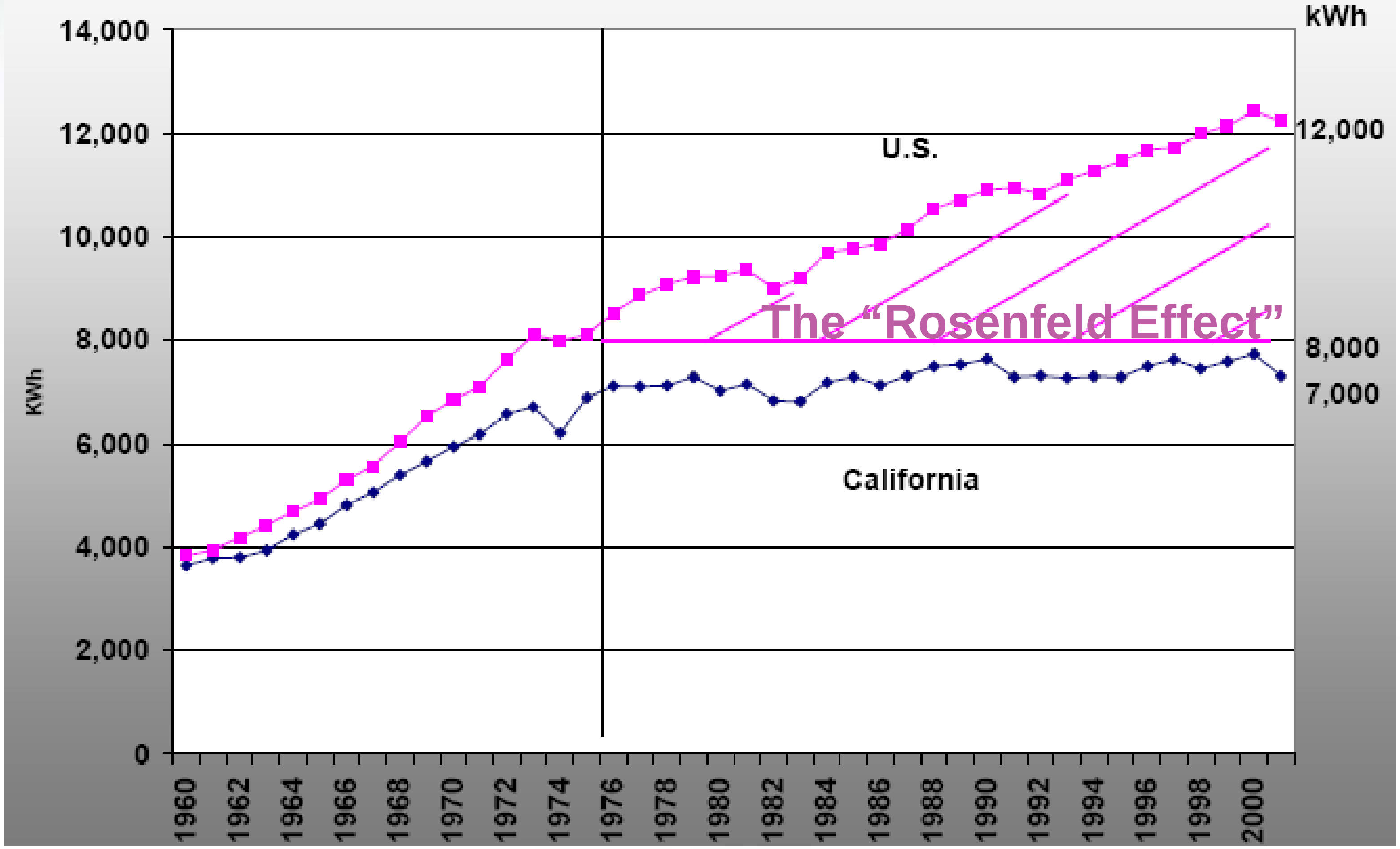
Price-Cost Vulnerability

- Energy price risk is important to California agriculture.
- The degree of this vulnerability varies substantially across product categories.
- Most of it is indirect, arising from energy costs embodied in farm inputs and product distribution services.
- This implies price changes could induce significant structural adjustment across the state's farm sectors.

Why do we care about this?

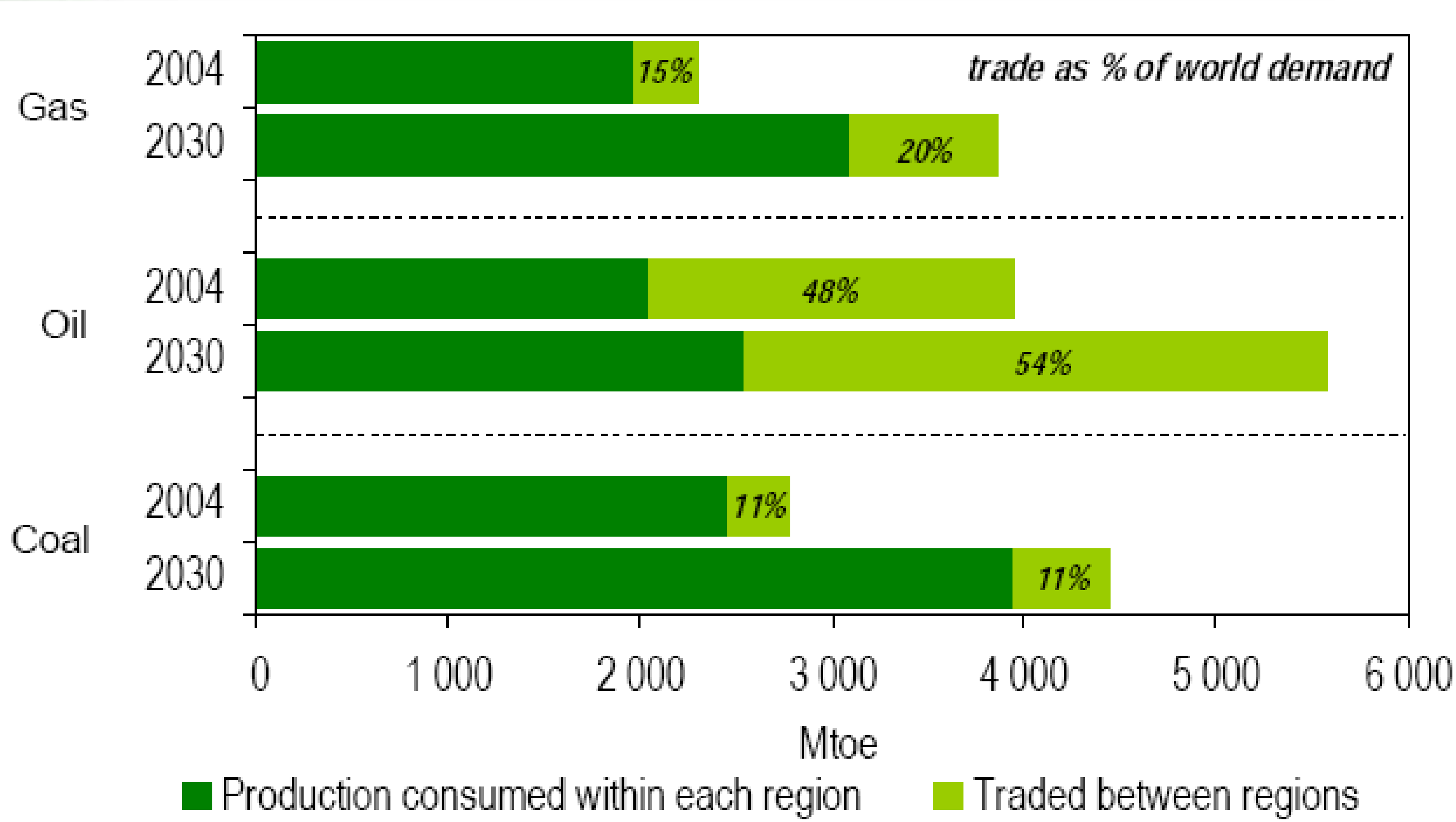
Per Capita Electricity Consumption, 1961-2000

California's domestic competition for energy will intensify.



World Fossil Fuel Supply

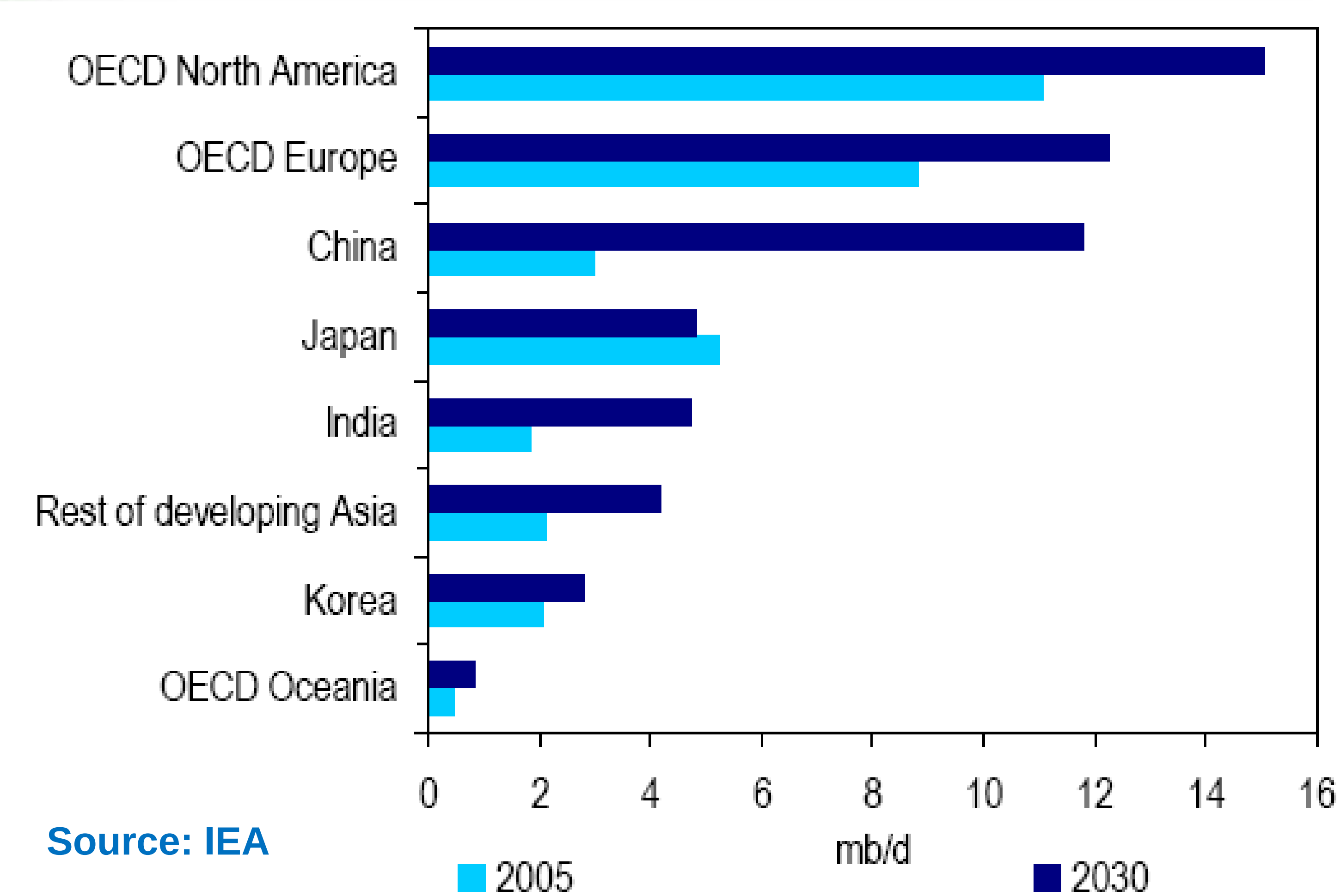
Energy prices will increasingly be determined by global markets.



Source: IEA

Net Oil Imports

Demand side pressures will continue to escalate.



Source: IEA

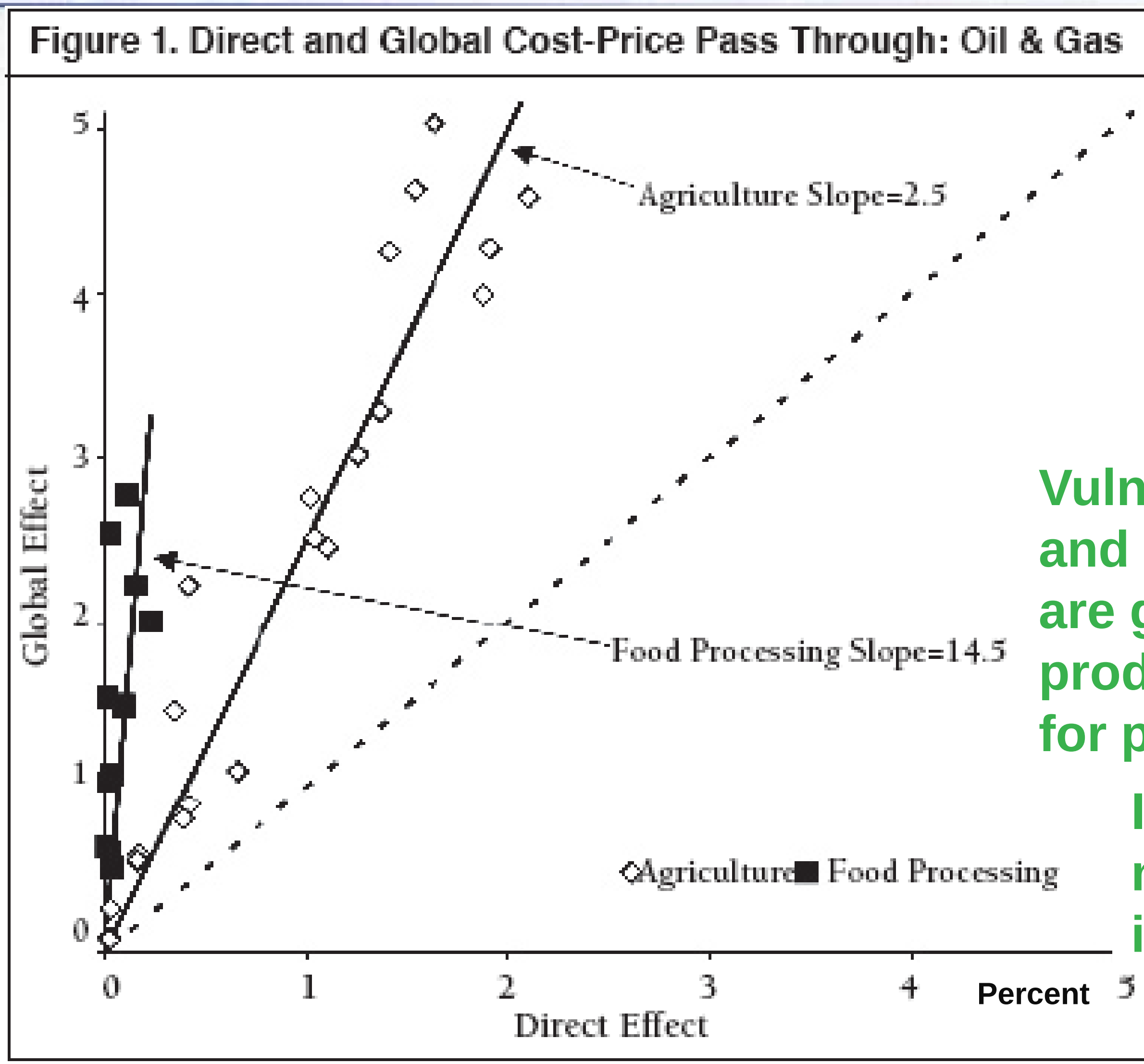
Measuring Price-Cost Effects

For domestic prices p and factor and import prices w, we have the cost decomposition

$$p = p\,A_{11} + wA_{21} = p\,A_{11} + v = v\,(I\text{-}A)^{-1} = v\,M$$

linking direct (v) costs and their global pass-through to prices.

Energy and Cost Multipliers



Dispersion is much greater for global than for direct effects.

Vulnerability and dispersion are greater for products than for processing.

Indirect effects much stronger in processing.

Selected Sector Results

Agriculture	Global	Global/Direct
Cattle	5.0	3.1
OthLvstk	4.6	3.0
Hay	4.3	2.2
Cotton	4.0	2.1
Citrus	3.3	2.4
Grapes	3.0	2.4
Tree Nuts	3.0	2.4
Berries	2.5	2.4
Poultry	2.2	5.5
Forest	1.5	4.3
Floral	0.6	3.4
Nursery	0.6	3.4

Livestock and dairy are for local markets.

Low value, energy intensive crops may come under pressure.

Higher value, higher tech crops look most promising.

Tracing Energy Pathways

Consider a pair <*i,j*> of transactions indices and define a ***path*** as a sequence s of indices *s*=<*i,k,l,…,m,j*> decomposable into consecutive arcs <*i,k*>, <*k,l*>,…, <*m,j*>, then the influence of *i* on *j* through path *s* is denoted $(i\text{->}j)_s$. For any given path *s*=<*i,k,…,m,j*> the *direct demand* influence is the composite

$$D_{(i\to j)s} = a_{ki}\ldots a_{jm} \text{ for } \frac{\partial y_j}{\partial y_i} = a_{ji}$$

In any given path *s* there may exist feedback effects among its indices, each of which can be represented by a multiplier μ_s (the ji entry in the multiplier matrix ***M)***. All of such feedback effects taking place along the path amplify the direct influence to produce total influence:

$$T_{(i\to j)s} = D_{(i\to j)s}\mu_s$$

Pathways

Finally, note that more than one elementary path may span two indices *i,j* and the global effect sums total effects over all paths:

$$G_{(i\to j)s} = \sum_{s\in S} T_{(i\to j)s} = \sum_{s\in S} D_{(i\to j)s}\mu_s$$

Direct, total, and global induced demand are three distinct components that make up the transmission mechanism linking final production and upstream intermediate, factor, and resource use.

Energy Pathways and Cost

The Grain sector's energy dependence arises primarily from fuels and agrochemicals.

Target	<-Sector1	<-Sector2	<-Sector3	Global	Local	Percent	Cumulative
Grain	DISTELECT	OILGAS		0.058	1.292	1.6	1.6
Grain	DISTGAS	OILGAS				1.8	3.4
Grain	OILREF	OILGAS				47.5	50.9
Grain	ChemFert	OILGAS				22.5	73.4
Grain	ChemFert	DISTGAS	OILGAS			2.3	75.7
Grain	CHEMSBASIC			0.073	1.699	25.2	25.2
Grain	OILREF	CHEMSBASIC				1.7	26.9
Grain	ChemFert	CHEMSBASIC				17.4	44.3
Grain	ChemPest	CHEMSBASIC				34.3	78.6
Grain	PLASTICS	CHEMSBASIC				3.1	81.7
Grain	AgServ	ChemPest	CHEMSBASIC			1.3	83.1

Upstream Pathways

Target	<-Sector1	<-Sector2	<-Sector3	<-Sector4	Global	Local	Percent	Cumulative
Cotton	DISTELECT	OILGAS			0.055	1.214	2.9	2.9
Cotton	DISTGAS	OILGAS					4	6.9
Cotton	OILREF	OILGAS					50.8	57.7
Cotton	ChemFert	OILGAS					9.8	67.5
Cotton	AgServ	OILREF	OILGAS				1.6	69.1
Cotton	AgServ	ChemFert	OILGAS				4.5	73.5
Cotton	ChemPest	OILREF	OILGAS				1.5	75
Cotton	ChemPest	CHEMSBASIC	OILREF	OILGAS			1.9	76.9
CattleDairy	DISTELECT	OILGAS			0.06	1.522	4	4
CattleDairy	OILREF	OILGAS					38.1	42.1
CattleDairy	Grain	OILREF	OILGAS				6.1	48.2
CattleDairy	Grain	ChemFert	OILGAS				2.9	51.1
CattleDairy	OthCrop	OILREF	OILGAS				13.6	64.8
CattleDairy	OthCrop	ChemFert	OILGAS				5.7	70.5

Cotton resembles grain, but livestock energy dependence also comes back to grains and fodder.

The Way Ahead

Agriculture has three ways to adapt:

1. Structural change within the sector – changing crops/products
2. Structural change in supply chains – shifting upstream and down stream relationships
3. Technological change

Farm policy can facilitate all these, or hinder them.

Things to Come

- Price pass-though is really mediated by markets and scarcity, so all this is being embedded in a CGE framework.
- This will enable more extensive scenario analysis with respect to
  - farm, food, and climate policy
  - external food/fuel price trends
  - technological change

Thank you

Generation Portfolio, 2005