Basic ASM

An empirical U.S. agricultural sector model (hereafter called ASM) forms the core of the stochastic model. ASM is based on the work of Baumes which was later modified and expanded by Burton and Martin; Tyner et al.; Adams, Hamilton, and McCarl; Tanyeri-Abur, Chang et al and Lambert et al.

Conceptually, ASM is a price endogenous, mathematical programming model of the type described in McCarl and Spreen. Constant elasticity curves are used to represent domestic consumption and export demands as well as input and import supplies. Elasticities were assembled from a number of sources including USDA through the USMP modeling team (House) and prior model versions.

ASM is designed to simulate the effects of various changes in agricultural resource usage or resources available, in turn determining the implications for prices, quantities produced, consumers' and producers' welfare, exports, imports and food processing. In doing this the model considers production, processing, domestic consumption, imports, exports and input procurement. The model distinguishes between primary and secondary commodities with primary commodities being those directly produced by the farms and secondary commodities being those involving processing. For production purposes the U.S. is disaggregated into 63 geographical subregions(Table 1). Each subregion possesses different endowments of land, labor and water as well as crop yields. Agricultural production is described by a set of regional budgets for crops and livestock. ASM crop mix is required to appear in a convex combination of historical crop mix proportions following McCarl. Marketing and other costs are added to the budgets following the procedure described in Fajardo, McCarl, and Thompson such that the marginal cost of each budget equals marginal revenue. ASM also contains a set of national processing budgets which uses crop and livestock commodities as inputs. There are also import supply functions from the rest of the world for a number of commodities. The demand sector of the model is constituted by the intermediate use of all the primary and secondary commodities, domestic consumption use and exports.

There are 33 primary commodities in the model. These are listed in Table 2. The primary commodities are chosen so as to depict the majority of total agricultural production, land use and economic value. They can be grouped into crops and livestock. The model incorporates processing of the primary commodities. The production of primary commodities are regionally specific, but the processing of secondary commodities is done in the overall aggregate sector. Table 3 lists the 37 secondary commodities that are processed in the model. These commodities are chosen based on their linkages to agriculture. Some primary commodities are inputs to the processing activities yielding these secondary commodities and certain secondary products (feeds and by-products) are in turn inputs to agriculture.

Three land types (crop land, pasture land, and land for grazing on an animal unit month basis) are specified for each region. Land is available according to a regional price elastic supply schedule with a rental rate as reported in USDA farm real estate statistics. The labor input includes family and hired labor. A region-specific reservation wage and maximum amount of family labor available reflect the supply of family labor. The supply of hired labor consists of a minimum inducement wage rate and a subsequent price elastic supply. Water comes from surface and pumped ground water sources. Surface water is available at a constant price, but pumped water is supplied according to a price elastic supply schedule.

Conceptual Stochastic Model

Regional crop yields vary by ENSO event strength. Knowledge of yield outcome is imperfect when agricultural planting decisions are made. Therefore, the model includes a yield distribution(following the modeling approach explained in Lambert et al). At the time of planting a number of yield states of nature can occur but the farmer does not know which one will occur. In fact farmers' must choose crop mix considering the weather probability distribution without knowledge of which exact weather event will occur. The model depicts this using a two stage formulation as in Dantzig; Cocks; McCarl and Parandvash; Lambert et al or Solow et al.

The analysis herein differs from the Solow et al and Adams et al analyses which used essentially the same model and approach in terms of the way ENSO events are incorporated and the way that the El Nino event is valued. Namely, in the prior work a three state definition of ENSO phase was used for the stochastic outcomes (El Nino, La Nina, Neutral). Here we do not use ENSO phase in defining states but rather define states for each of 22 historically observed years on which we have data(1972-1993). We also do not factor in producer reaction to ENSO phase information (i.e. in the prior work the value of forecasting was derived by examining the benefits of producers making crop mix decisions based on an anticipation of particular ENSO phase relative to a "average weather" expectation). Here we assumed the producer decision was done in the face of an "average weather" expectation considering the probability distribution of yields represented by the twenty-two year distribution with each of the yield events being equally likely. In turn we derived the costs of the severe El Nino event by comparing economic returns under the severe1982 El Nino with average economic returns. This yields an estimate of the economic effects that farmers and the agricultural sector would realize when an ENSO of event of the strength of the 1992 event occurs when farmers were expecting an average event across the full spectrum of ENSO phases.

An Algebraic Representation

The model framework is summarized by the following equations. The objective function is:

here parameters are typed in lower case or greek while variables are typed in upper case and the items

$$(1)\quad \text{Max}\ \ \&\ \underset{j}{\mathbf{j}}\ \underset{k}{\mathbf{j}}\ g_{jk}X_{jk}$$

$$\&\ \underset{k}{\mathbf{j}}\ \underset{r}{\mathbf{j}}\ \mathbf{m}\,"(R_{rk})dR_{rk}$$

$$\%\ \underset{s}{\mathbf{j}}\ p_s\ (\ [\ \ \underset{i}{\mathbf{j}}\ \mathbf{m}\, n(Q_{is})dQ_{is}$$

$$\%\ \underset{i}{\mathbf{j}}\ [\mathbf{m}\, fd(FQD_{is})dFQD_{is} \& \mathbf{m}\, fs(FQS_{is})dFQS_{is})]$$

$$\&\ \underset{i}{\mathbf{j}}\ \underset{k}{\mathbf{j}}\ \underset{s}{\mathbf{j}}\ stor_i\ \ QSTORW_{iks}\ \ ]$$

are defined as follows:

i	indexes commodities,
j	indexes production process,
k	indexes regions,
r	indexes resources,
s	indexes the state defining alternative yields,
p_s	is the probability that yield state s arises,
Q_{is}	consumption of i^{th} product under yield state s,
FQD_{is}	excess demand quantity for commodity i under yield state s,
FQS_{is}	excess supply quantity for commodity i under yield state s,
R_{rk}	factor supply for U.S. region k of resource r,
$n(Q_{is})$	inverse U.S. demand function for commodify i consumed under yield state s,
g_{jk}	production cost when producing using alternative j in region k
X_{jk}	production acreage under alternative j in region k
$"(R_{rk})$	inverse U.S. factor supply function for factor r in region k,
$fd(FQD_{is})$	inverse excess demand function for commodity i,
$fs(FQS_{is})$	inverse excess supply function for commodity i,
g_{jk}	cost of j^{th} production process per acre in U.S. region k,
X_{jk}	acreage of j^{th} production process in U.S. region k,
$stor_i$	Storage cost in the U.S. for commodity i, and
$QSTORW_{iks}$	quantity withdrawn from storage of commodity i in U.S. region k under yield state s.

The first two lines (just for now ignoring the stochastic, yield state dimension) contain the perfectly elastic production costs associated with production process j ($C_{jk}X_{jk}$) less the area under the regional (k) factor supply curves. The next two lines are the area under the U.S. national demand equations ($IR(Q_{is})\ d\ Q_{is}$), the area under the ROW excess demand curves minus the area under excess supply curve for commodity i in region c. Finally the last line gives the cost of storage.

The model is stochastic in that the yields occur with varying frequency and consequences. It also is a multiple stage model in that all terms and variables but those in the first two lines are yield state dependent while the first line is not. This assumes that production and factor use are set before the specific yield state is known, but that demand and trade are set afterward given knowledge of production (for more explanation see Lambert et al.). The third line includes multiplication by the relevant probabilities. This renders the objective function a maximization of expected welfare and also yields production choices where expected marginal revenue is equated with marginal cost.

The model contains commodity balances in the U.S. as follows

$$(2) \quad -\sum_{j}\sum_{k}\left(y_{ijk}+yr_{ijks}\right)\left(X_{jk}\right) - FQS_{i,s} - QSTORW_{i,s} + Q_{is} + FQD_{i,s} + QSTORA_{i,s} \le 0 \text{ fo}$$

where supply from production on average (y) plus the difference due to yield state (yr) times acreage (X) plus that imported(FQS) plus withdrawals from storage (QSTORW) is balanced off against domestic demand (Q), exports (FQD) and additions to storage (QSTORA) for a commodity (i) under yield state (s).

The factor constraint for region k in the U.S. is

$$(3) \qquad \sum_{j} f_{rjk}X_{jk} - R_{rk} \le 0, \qquad \text{for all } k,\ r.$$

where f_{rjk} is the resource usage per acre for j^{th} production processing in region k for resource r. This equation balances factor supply (R) against usage by production (fX) in region k for factor r.

The storage balance is

$$(6) \qquad \sum_{s} p_s \left[QSTORW_{is} - QSTORA_{is}\right] = 0 \text{ for all } i$$

where probabalistically weighted net additions and withdrawals are equal.

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Table 1. Regional and Subregional Disaggregation in the Sector Model

NORTHEAST	CORNBELT	SOUTHERN PLAINS
Connecticut	North Illinois	Oklahoma
Delaware	South Illinois	Texas Central Blacklands
Maine	North Indiana	Texas Coast Bend
Maryland	South Indiana	Texas East
Massachusetts	North East Iowa	Texas Edwards Plateau
New Hampshire	Central Iowa	Texas High Plains
New Jersey	South Iowa	Texas Rolling Plains
New York	West Iowa	Texas South
Pennsylvania	Missouri	Texas Trans Pecos
Rhode Island	North East Ohio	
Vermont	North West Ohio	
	South Ohio	
MOUNTAIN	LAKE STATES	SOUTHEAST
Arizona	Michigan	Alabama
Colorado	Minnesota	Florida
Idaho	Wisconsin	Georgia
Montana		South Carolina
New Mexico		
Utah		
Wyoming		
Nevada		
NORTHERN PLAINS	DELTA STATES	PACIFIC
Kansas	Arkansas	North California
Nebraska	Louisiana	South California
North Dakota	Mississippi	Oregon
South Dakota		Washington
APPALACHIAN		
Kentucky		
North Carolina		
Tennessee		
Virginia		
West Virginia		

Table 2. Primary Commodities

	Crop Commodities	Units		Livestock Commodities	Units
1	Cotton	Bales	21	Cull Dairy Cows	Head
2	Corn	Bushel	22	Cull Dairy Calves	Head
3	Soybeans	Bushel	23	Cull Beef Cows	Cwt, LW
4	Wheat	Bushel	24	Calves	Cwt, LW
5	Sorghum	Bushel	25	Yearlings	Cwt, LW
6	Rice	Cwt	26	Non-Fed Beef	Cwt, LW
7	Barley	Bushel	27	Fed Beef	Cwt, LW
8	Oats	Bushel	28	Veal Calves	Cwt, LW
9	Silage	Ton	29	Cull Sows	Cwt, LW
10	Hay	Ton	30	Hogs	Cwt, LW
11	Sugar Cane	1000 lbs	31	Feeder Pigs	Cwt, LW
12	Sugar Beets	1000 lbs	32	Cull Ewws	Cwt, LW
13	Potatoes	Cwt	33	Wool	Cwt
14	Fresh Tomatoes	25 lb. boxes	34	Feeder Lambs	Cwt, LW
15	Processed Tomatoes	Tons	35	Slaughter Lambs	Cwt, LW
16	Fresh Oranges	90 lb. boxes	36	Unshorn Lambs	Cwt, LW
17	Processed Oranges	Tons	37	Wool Subsidy	$
18	Fresh Grapefruits	85 lb. boxes	38	Other Livestock	GCAU
19	Processed Grapefruits	85 lb. boxes	39	Broilers	Cwt, LW
20	Milk	Cwt	40	Turketys	Cwt, LW
			41	Eggs	Thous. dozen

Note: LW indicates live weight
GCAU is grain consuming animal unit.

Table 3. Secondary Commodities

	Crop Commodities	Units		Livestock Commodities	Units
1	Soybean Meal	Cwt	25	Sheep Protein Feed	Cwt
2	Soybean Oil	1000 lbs	26	Egg Protein Feed	lb
3	Raw Sugar	1000 lbs	27	Broiler Protein Feed	lb
4	Refined Sugar	1000 lbs	28	Turkey Protein Feed	lb
5	Corn Starch	1000 lbs	29	Fluid Milk	lb
6	Corn Gluten Feed	1000 lbs	30	Skim Milk	lb
7	Corn Oil	1000 lbs	31	Non Fat Dry Milk	lb
8	Ethanol	1000 lbs	32	Cream	lb
9	HFCS	1000 lbs	33	Butter	lb
10	Corn Syrup	1000 lbs	34	Ice Cream	Cwt,CW
11	Dextrose	1000 lbs	35	American Cheese	Cwt,CW
12	Confectioneries	1000 lbs	36	Other Cheese	Cwt,CW
13	Beverages	1000 lbs	37	Cottage Cheese	Cwt,CW
14	Baked Goods	1000 lbs	38	Fed Beef	Cwt,CW
15	Canned Goods	1000 lbs	39	Non Fed Beef	Cwt,CW
16	Dried Potatoes	Cwt	40	Veal	Cwt,CW
17	Chipped Potatoes	Cwt	41	Pork	Cwt,CW
18	Frozen Potatoes	Cwt	42	Chicken	Cwt,DW
19	Feed Grains	1000 lbs	43	Whole Turkeys	Cwt,DW
20	Dairy Concentrate	1000 lbs	44	Orange Juice	1000gals
21	Swine Protein Feed	1000 lbs	45	Grapefruit Juice	1000gals
22	Cattle Protein Feed	1000 lbs			
23	Range Cubes	1000 lbs			
24	Cow Protein Feed	1000 lbs			

Note: Cw means carcass weight.