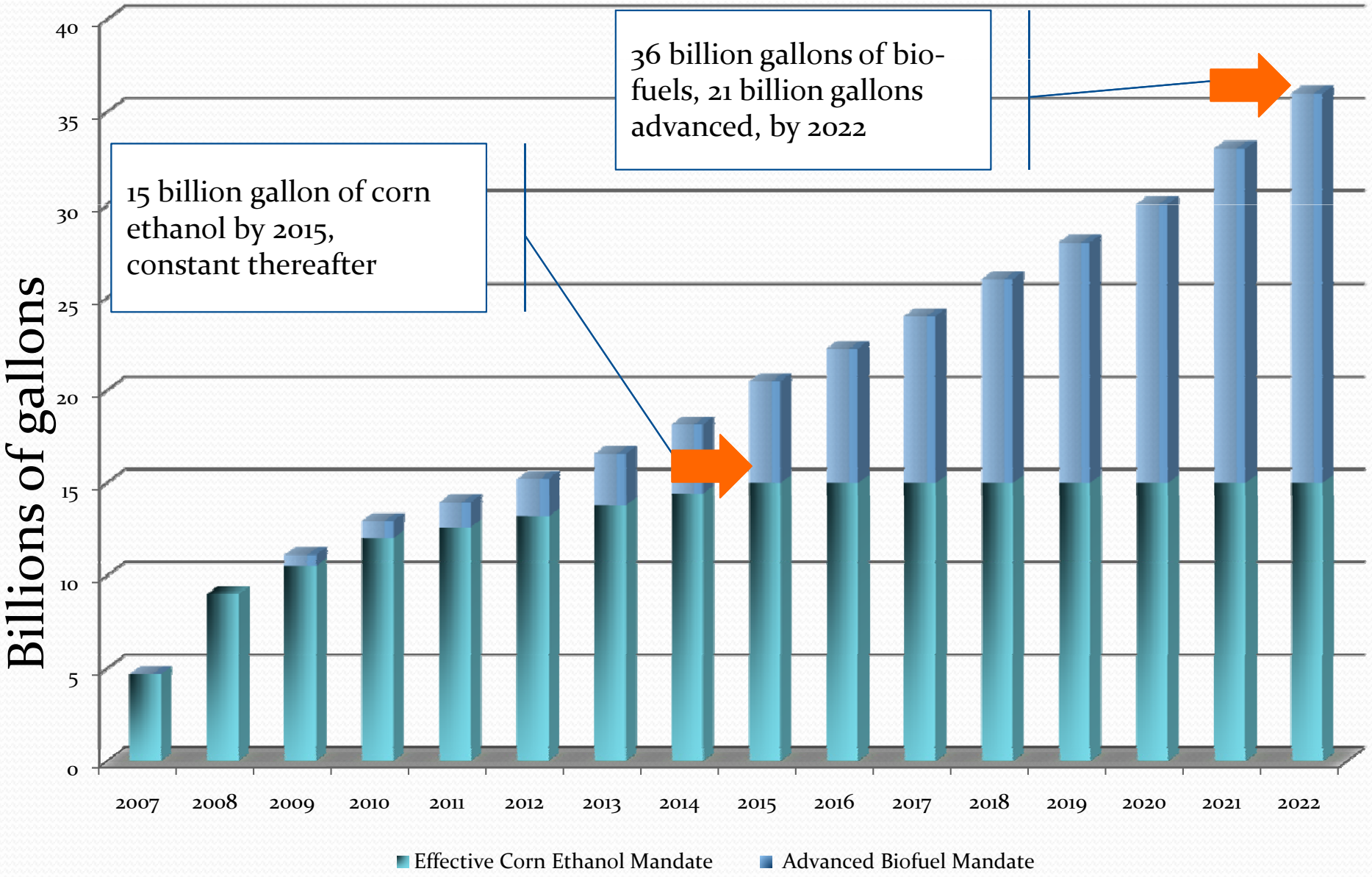
Efficiency Effects of Increased U.S. Biofuels Mandates

Antonio M. Bento and Joel R. Landry

August 13th, 2009

Overview of the Renewable Fuel Standard (EISA, 2007)



Key Questions

- What is the economy-wide (gross) cost of the corn ethanol mandate?
  - Given:
    - The pre-existing volumetric ethanol excise tax credit ($0.51 in 2008; $0.45 in 2009)
    - A pre-existing tax on blended fuel ($0.47)
    - A pre-existing payment to land held in the Conservation Reserve Program (CRP)

Key Questions

- What is the impact of the mandate on land use change?
  - Impact on the extensive margin (changes in cropland and land held under the CRP)
  - Impact on intensive margin (changes in crops, rotation practices, and tillage systems)
- What is the impact of the mandate on the volume of crop exports? (relevant to measure indirect land use impacts)

Key Questions

- What is the impact of the mandate on blended fuel, regular gasoline and ethanol consumption?
- What is the impact of the mandate on vehicle miles traveled (VMT) and fuel economy?
- What is the impact of the mandate on the volume of crude oil imports?

Overview of the Simulation Model: Economic Agents

- The economic agents in the model are:
  - Households (Representative Agent)
  - Producers of Agricultural Crops
  - Producers of Ethanol
  - Suppliers of Regular Gasoline
  - Suppliers of Blended Fuel
  - Producers of Food
  - Government
- Trade with the Rest Of the World:
  - Crude Oil Imports
  - Crop Exports

Key Features of Simulation Model

Feature	Capability
Integrated treatment of agricultural and fuel markets	Establishes a relationship between the prices of corn, ethanol, regular gasoline, crude oil, and blended fuel.
Attention to detail of agricultural practices and land use allocation	Consider adjustments in intensive and extensive margins.
Integrated treatment of trade in crops and crude oil	Measure changes in crop exports and crude oil imports; allows one to assess crop and fuel displacement abroad.
Ability to capture important dynamical trends	Allow agricultural yields, CRP rental rates, efficiency of ethanol production to adjust.
Consider pre-existing policies (tax credit, fuel tax and CRP payment)	Allows us to measure the interactions between the mandate and pre-existing policies.

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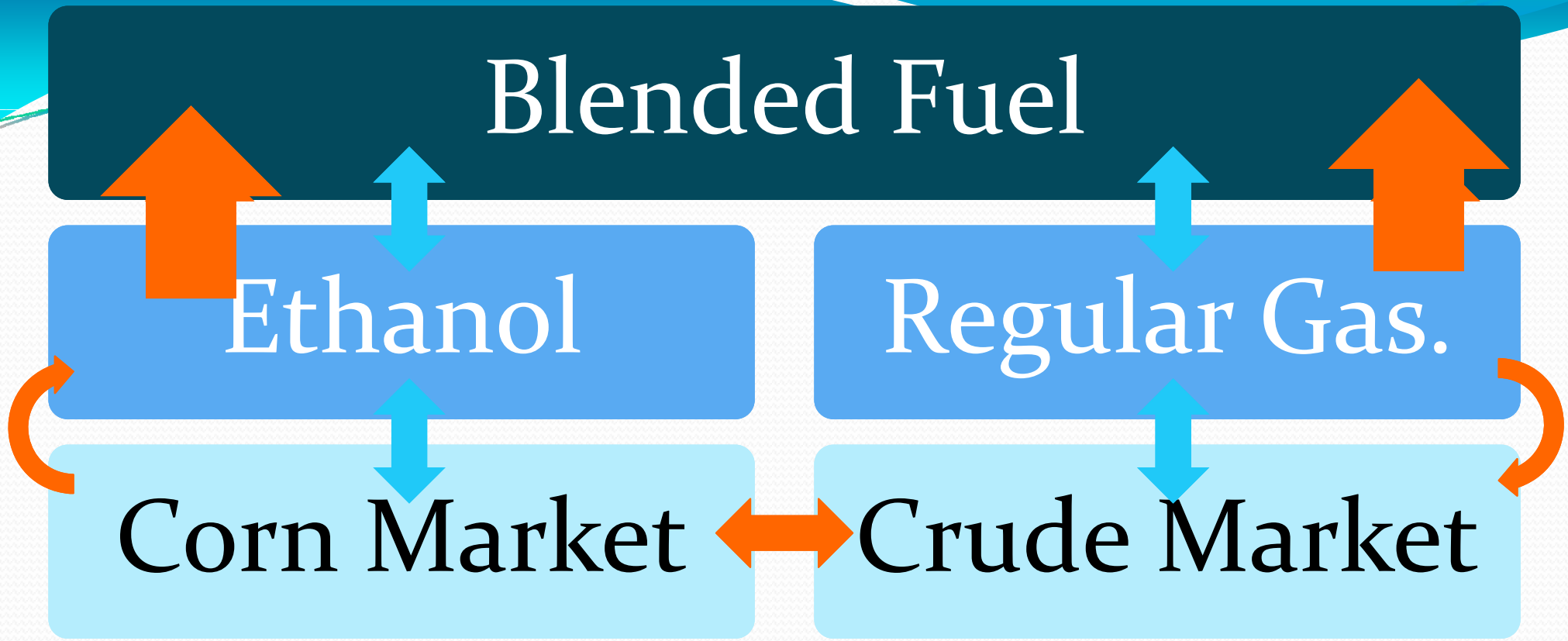

In the absence of a mandate, the amount of ethanol blended into fuel is chosen until the price of ethanol (less VEETC) equals the price of regular gasoline.

This implies a linkage between the price of crude oil and the price of corn.

With the mandate, each gallon of blended fuel requires a specified share of ethanol be added.

This implies both an increase in the price of ethanol, but also a decrease in the price of regular gasoline (and thus crude oil).

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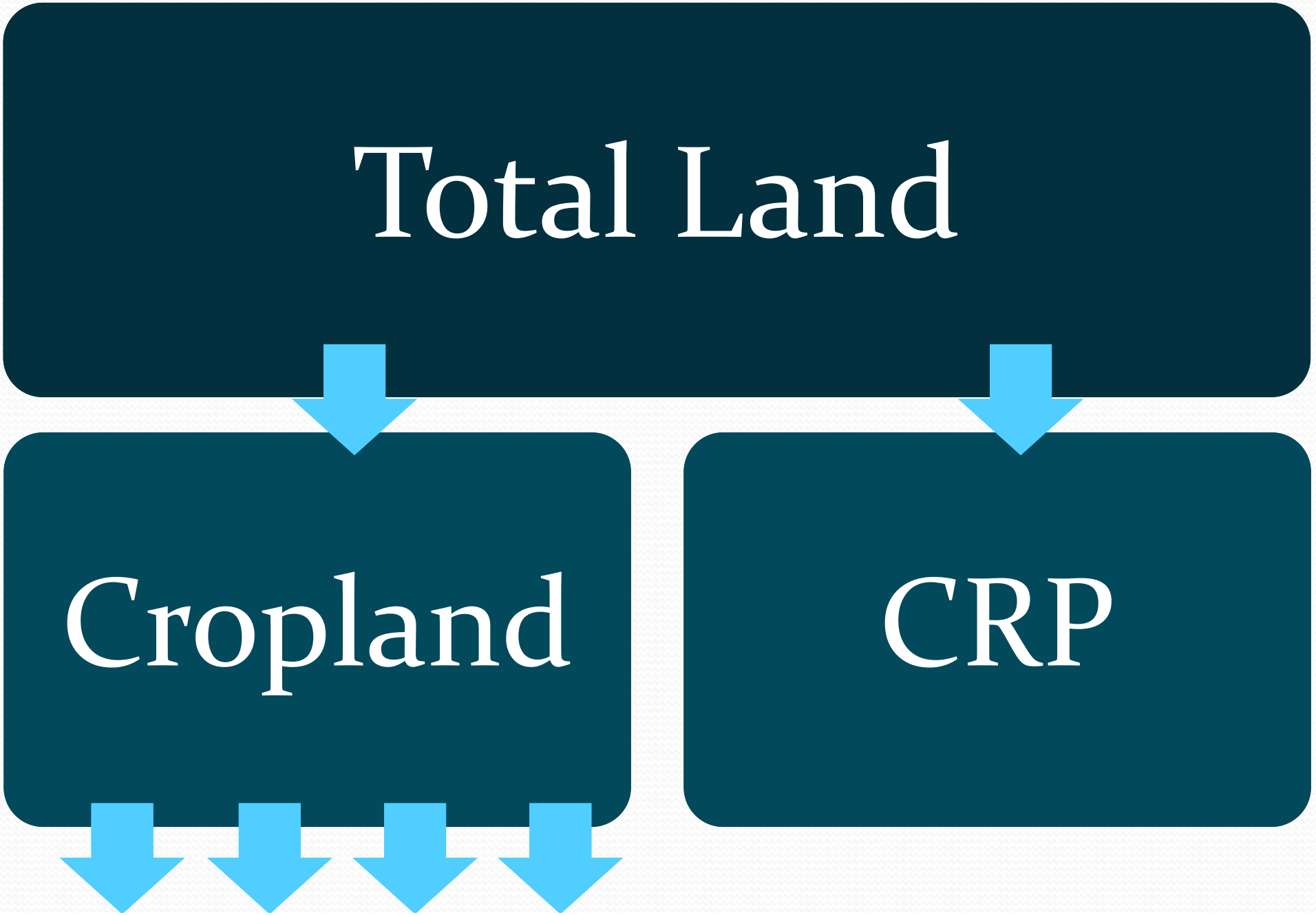
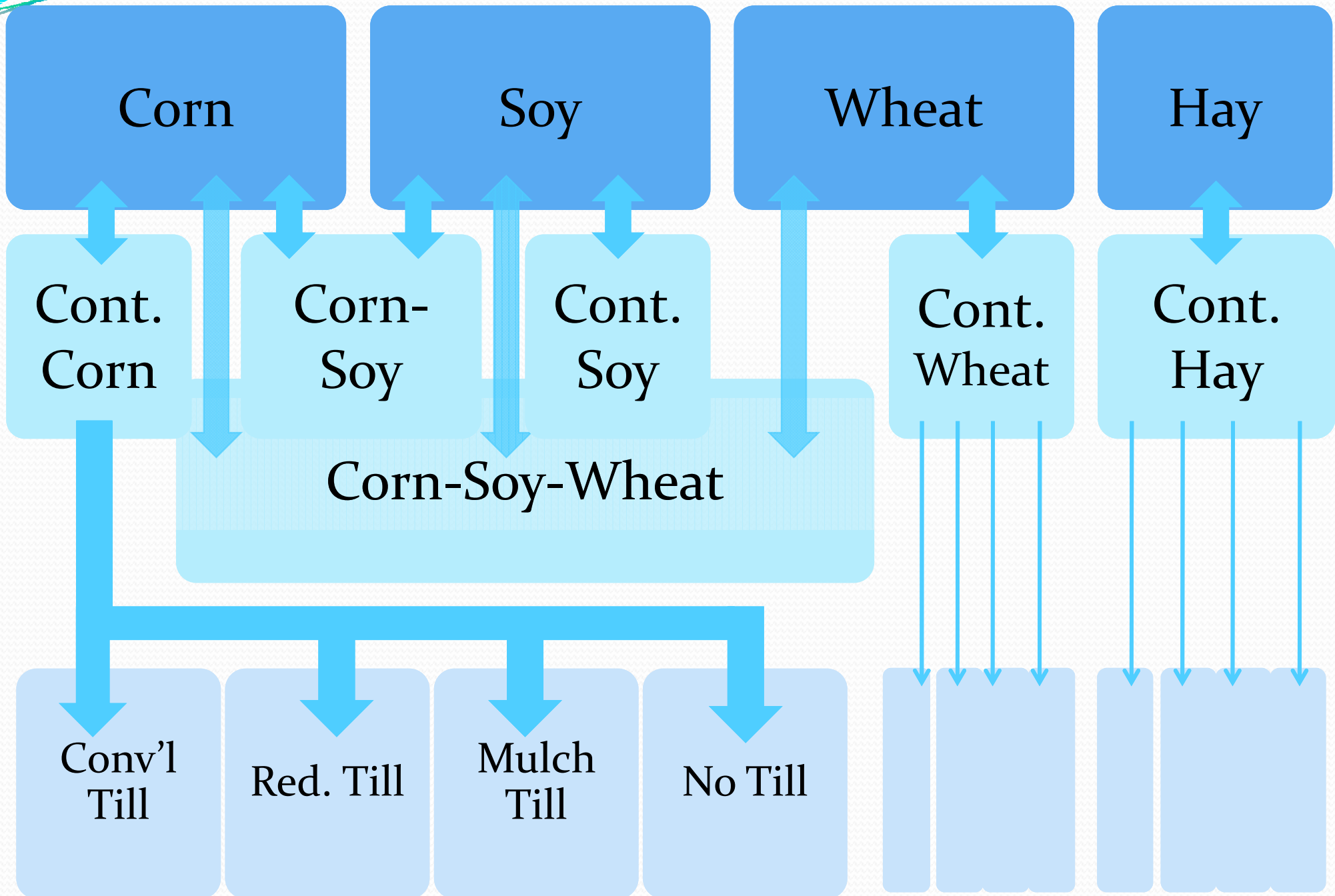
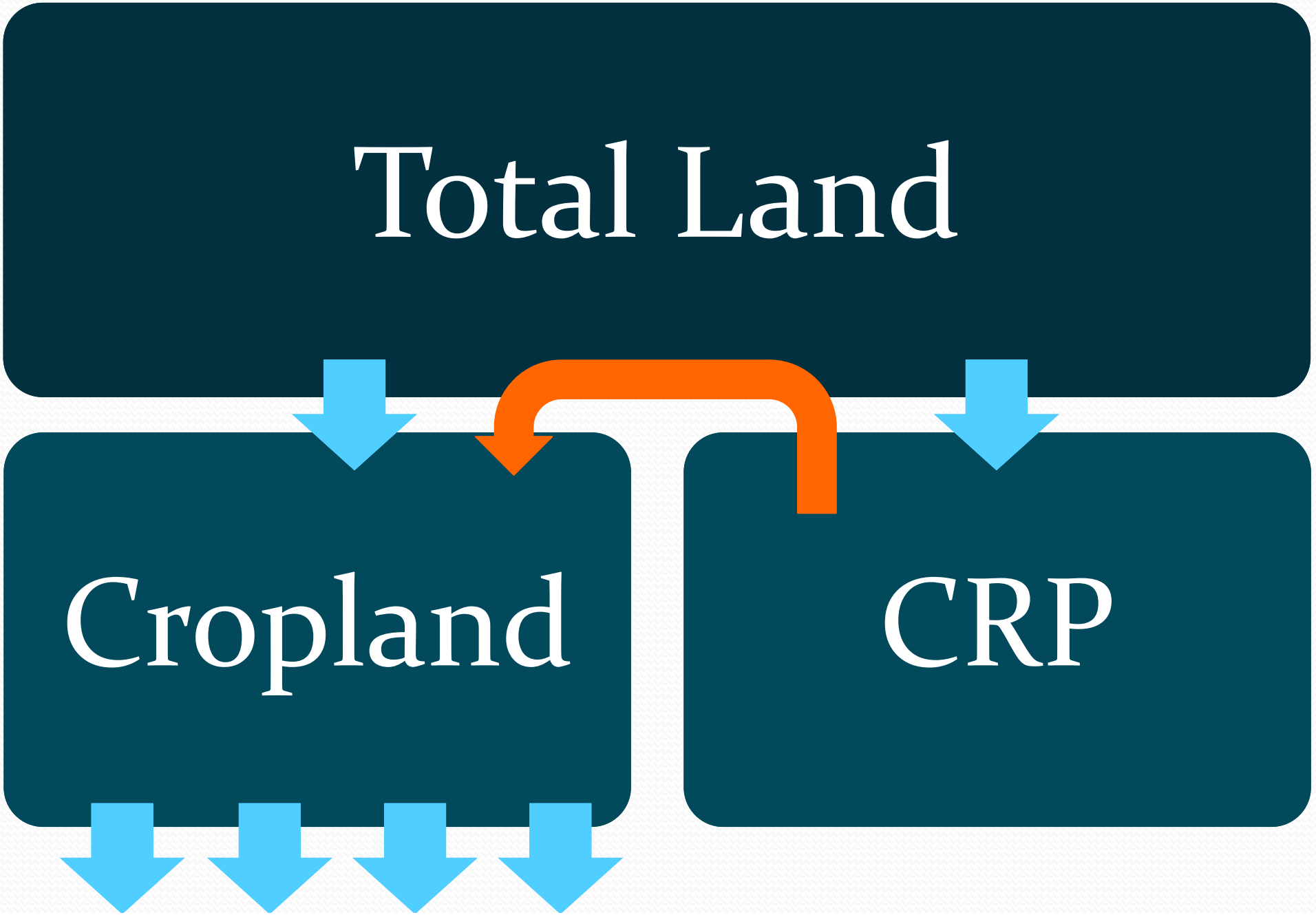

Total Land
Cropland
CRP


Corn
Soy
Wheat
Hay
Cont. Corn
Corn-Soy
Cont. Soy
Cont. Wheat
Cont. Hay
Corn-Soy-Wheat
Conv'l Till
Red. Till
Mulch Till
No Till

Change in the Extensive Margin



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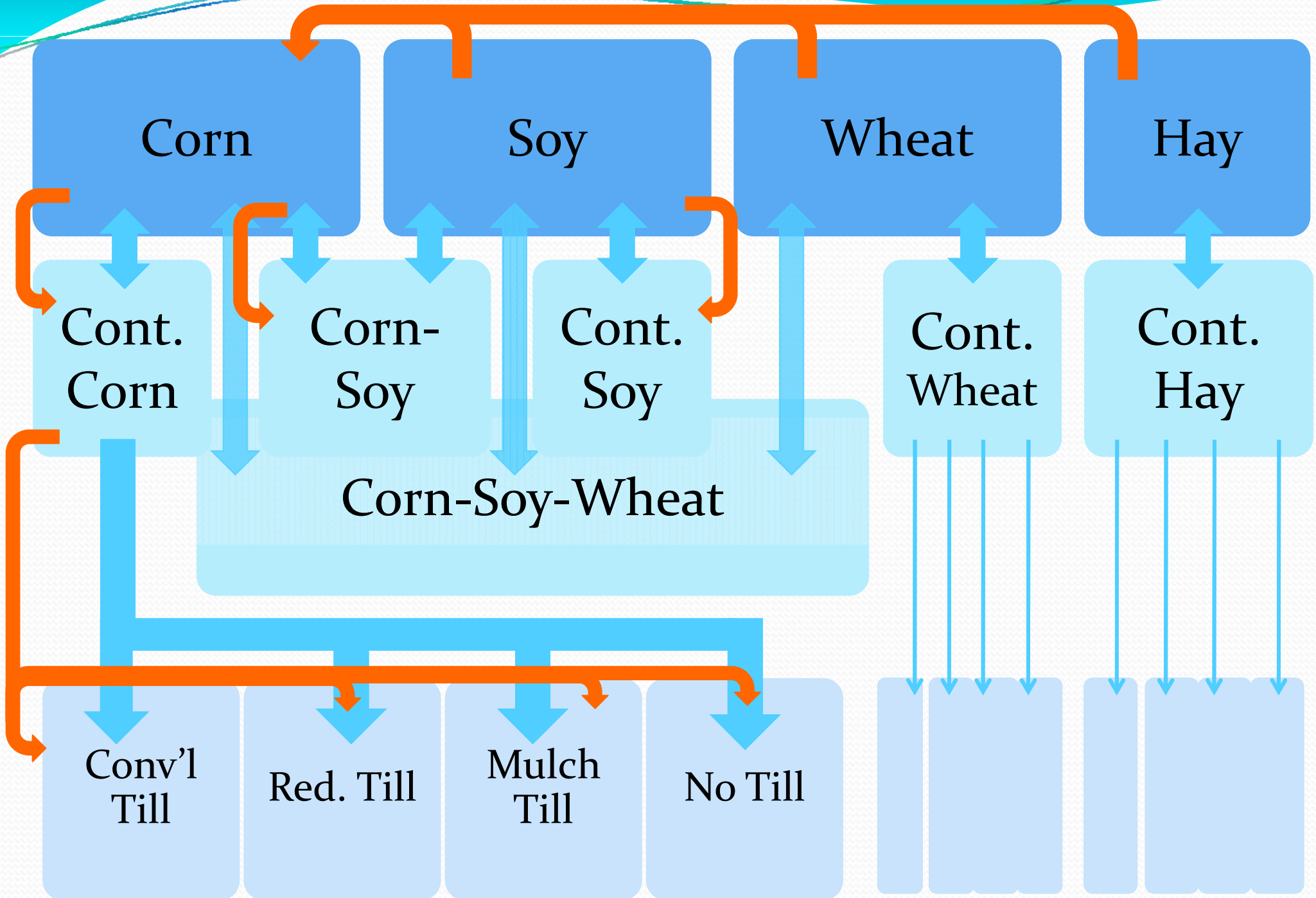

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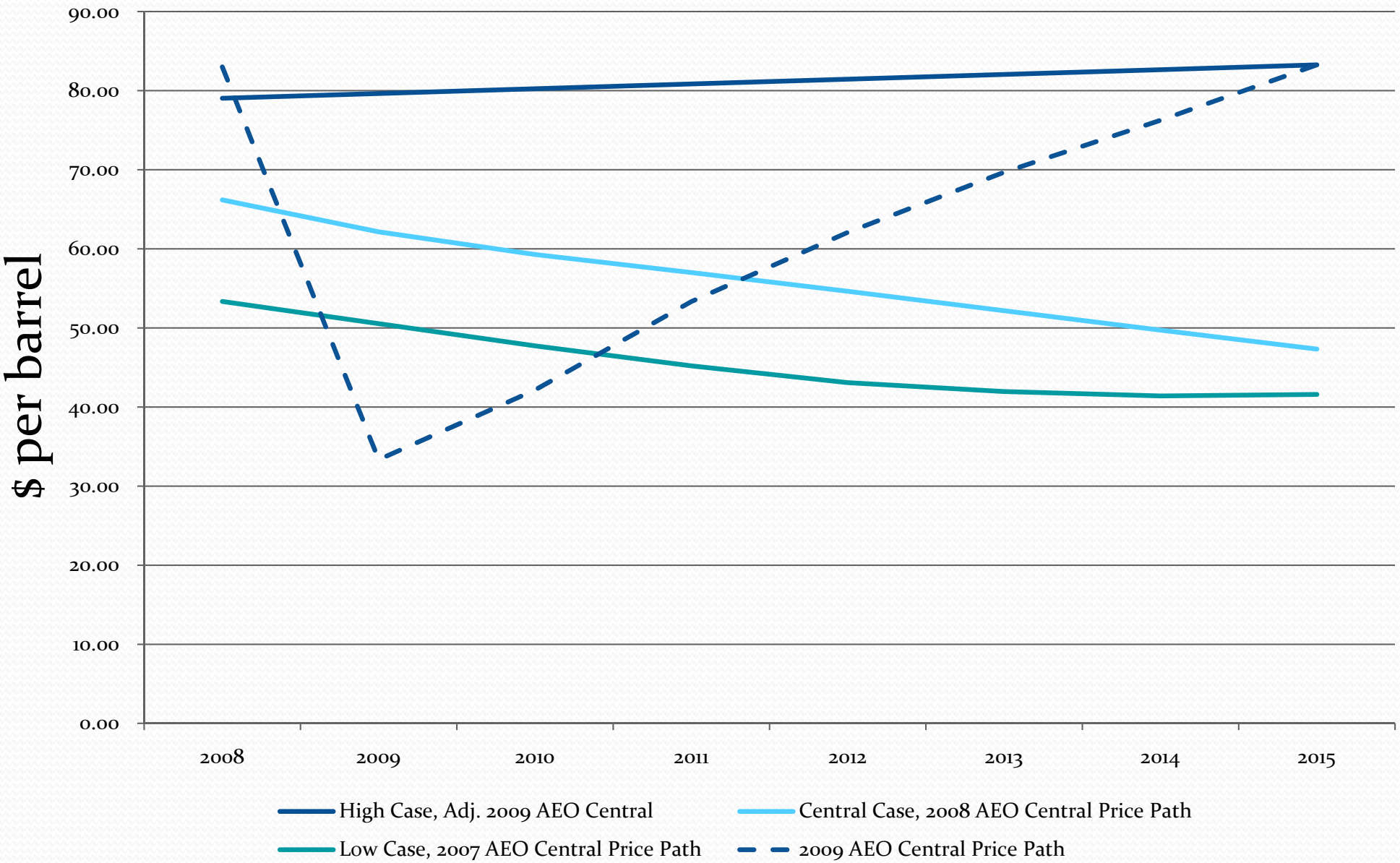
Crude Oil Price Paths



Source: EIA, adj. to constant 2003 prices

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Data Sources

Database Name	Source	Data Provided
National Income and Product Accounts (NIPA)	DOC Bureau of Economic Analysis	Size of sectors relative to total GDP.
Benchmark Input-Output Tables	DOC Bureau of Economic Analysis	Share of labor, capital, and other inputs used by sector.
Highway Statistics Dataset (HSD)	DOT Federal Highway Administration	VMT, fuel economy, fuel taxes.
Agricultural Resource Management Survey (ARMS),Commodity Cost and Return (CCR), Regional Environment and Agricultural Programming Model (REAP)	USDA Economic Research Service	Input usage (ag sector), shares of crop acreages by crop, rotation and tillage.
Agricultural Statistics Database (ASD)	USDA National Agricultural Statistics Service	Crop yields, total acreages by crop.
Production, Supply and Distribution Online	USDA Foreign Agricultural Service	Crop export levels.
Conservation Reserve Program Reports	USDA Farm Service Agency	CRP acreages and average rental rate.
GREET 1.8b, EBAMM 1.1, 2002 Ethanol Cost-of-Production Survey	Wang (2008), Farrell et al. (2006), and Shapouri and Gallagher (2005) (of USDA), respectively.	Input usage (ethanol sector), co-product conversion rates.
Gasoline Components History, Refinery and Blender Net Input Datasets, US Crude Oil Supply and Disposition Datasets	DOE Energy Information Administration	Crude oil expenditure share, ethanol and crude quantities.

Model Calibration

Parameter	Value
Own price elasticity of demand for miles	-0.22
Ratio of per mile fuel cost to total cost of driving	0.4
Own-price elasticity of demand for blended fuel	-0.55
Own price elasticity of demand for food	-0.08
Own price elasticity of corn supply	0.25
Cross price elasticities of soybeans, wheat and hay respect to the price of corn	-0.13, -0.09, and -0.05, respectively
Elasticity of CRP land with respect to crop returns	-0.06
Bushels of corn required per gallon of ethanol	0.39
Natural gas (thousand cubic feet) required per gallon of ethanol	0.042
Labor cost required per gallon of ethanol	$0.06
Capital cost required per gallon of ethanol	$0.19
Own price elasticity of crude supply (central case)	0.5
Share of per gallon crude oil cost to total cost of gasoline	0.61

Baseline and Mandated Ethanol (Billion Gallons)

High Crude Price Path

	2008	2009	2010	2011	2012	2013	2014	2015
Ethanol EISA 2007 Mandate Quantities	9.00	10.50	12.00	12.60	13.20	13.80	14.40	15.00
Ethanol Baseline Quantities	13.68	15.10	16.75	17.69	18.63	18.96	19.29	19.63
Difference in Mandate Relative to Baseline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Does Mandate Bind?	No	No	No	No	No	No	No	No

Central Crude Price Path

	2008	2009	2010	2011	2012	2013	2014	2015
Ethanol EISA 2007 Mandate Quantities	9.00	10.50	12.00	12.60	13.20	13.80	14.40	15.00
Ethanol Baseline Quantities	9.19	10.54	12.31	12.67	12.81	12.32	11.78	11.17
Difference in Mandate Relative to Baseline	0.00	0.00	0.00	0.00	0.38	1.47	2.60	3.81
Does Mandate Bind?	No	No	No	No	Yes	Yes	Yes	Yes

Low Crude Price Path

	2008	2009	2010	2011	2012	2013	2014	2015
Ethanol EISA 2007 Mandate Quantities	9.00	10.50	12.00	12.60	13.20	13.80	14.40	15.00
Ethanol Baseline Quantities	7.73	8.87	9.41	9.68	9.78	9.67	9.58	9.87
Difference in Mandate Relative to Baseline	1.27	1.63	2.59	2.92	3.41	4.12	4.81	5.13
Does Mandate Bind?	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Baseline and Change in Cropland and CRP (Million Acres)

	2012	2015
Baseline CRP	33.04	33.25
% Change	-0.14%	-1.33%
Baseline Cropland	266.92	266.71
% Change	0.001%	0.164%
CRP Acres Displaced per 1,000 Gallons of Mandated Ethanol	-0.117	-0.116

Baseline and Change in Crops (Million Acres)

	2012	2015
Baseline Corn	81.36	80.62
% Change (Int. + Ext. Adjmt.)	0.22%	2.09%
% Change (Int. Adjmt. Only)	0.17%	1.54%
Baseline Other Crops	185.56	186.10
% Change	-0.08%	-0.67%
Corn Acres Expanded per 1,000 Gallons of Mandated Ethanol	0.471	0.442

Baseline and Change in Rotation Acreages (Million Acres)

	2012	2015
Baseline Continuous Corn	20.14	19.61
% Change	0.68%	6.50%
Baseline Corn-Soybeans	108.87	108.36
% Change	0.10%	0.96%
Baseline Corn-Soybeans-Wheat	27.52	27.73
% Change	-0.23%	-2.08%

Baseline and Change in Fuel

	2012	2015
Baseline Ethanol (billion gallons)	12.81	11.17
% Change in Ethanol	3.00%	34.11%
Baseline Regular Gasoline (billion gallons)	113.33	121.46
% Change in Regular Gasoline	-0.33%	-3.01%
Baseline Blended Fuel (billion gallons)	126.14	132.64
% Change in Blended Fuel	0.01%	0.11%
Ratio of Mandated Ethanol to Regular Gasoline Displaced	-0.961	-0.960
Ratio of Mandated Ethanol to Blended Fuel Expanded	0.039	0.040

Efficiency Costs

	2012	2015
Gross Cost (million $):	116.31	1,620.53
Gross Cost per Gallon of Mandated Ethanol ($)	0.31	0.43
Primary Costs of Policy	3.70	387.74
Ethanol Sector	3.70	387.69
Blended Fuel Sector	0.00	0.05
Additional Costs from Pre-Existing Distortions	112.61	1,232.79
Additional Subsidy Payments	118.15	1,295.63
Reduced Fuel Tax Collections	-3.83	-43.18
Reduced CRP Rental Payments	-1.71	-19.66

Main Findings

- The overall efficiency cost of meeting the mandate by 2015 is $1.62 billion.
- The efficiency cost per gallon of newly mandated ethanol is is $0.31 to $0.43.
  - The share of primary costs to total gross costs increases to 23.9% by 2015.
- For each gallon of ethanol mandated the amount of regular gasoline displaced is 0.96 gallons.
- For every 1000 gallons of ethanol mandated the amount of CRP displaced is 0.12 acres.

Conclusions

We develop a framework that embraces supply- and demand-side responses to biofuels mandates in fuel and land markets

- On the demand side, vehicle use (fuel economy and fuel consumption) and food demand are integrated

- On the supply side, we account for the decisions of crop, rotation practice, and tillage system as well as conversion of land from CRP

- Account for international trade in crops and crude oil
- Model important dynamic adjustments

Prospects and Caveats

- Prospects:
  - Model has potential to investigate other policies aimed at reducing gasoline consumption and GHG emissions (carbon tax, fuel taxes)
  - Model has the potential to extend lifecycle analyses that calculate the GHG emissions resulting from biofuels mandates
  - Model has the potential to include second generation of biofuels

Thanks!

- Questions?

APPENDIX

Contribution from Crop Stocks is Likely Small

- Corn stocks account for about 12% of annual production in 2008.
  - USDA predicts that about 1% of 2010 production will come from stock changes.
- Wheat stocks account for about 15% of annual production in 2008.
  - USDA predicts a 1% increase in wheat stocks relative to 2010 production.
- Soybean stocks account for about 8% of annual production in 2008.
  - USDA predicts a 2% increase in soybean stocks relative to 2010 production.

Ethanol Imports are Small Compared to Domestic Production

- Ethanol imports accounted for only 5.8% of total ethanol demanded by the US in 2008.
- This share has increased from 2.1% in 2003.

Limitations of Food Sector

- Excludes an explicit model of the livestock sectors.
  - This will be a future addition.
- We treat food production as a composite good tied to the crop sector.
  - Share of food expenditures reflects BEA NIPA data.
  - Price level is calibrated to 2003 Food Price CPI.

E-85 Usage

- According to the EIA, E-85 fuel consumption in 2007 accounted for about 1% of total ethanol consumed.

	Million Acres	Input Expenditures ($/acre)					Fertilizer Components ($/acre)					
		Labor	Capital	Energy	Fertilizer	Total	N	P	K	Seed	Chemicals	Other
Continuous Corn	17.01	30.81	58.44	23.86	161.09	274.20	43.19	8.77	7.52	34.21	24.08	43.32
Conventional	7.33	34.30	62.64	26.25	158.85	282.04	41.92	8.46	7.50	34.24	23.41	43.32
Reduced	2.92	28.75	57.42	22.46	161.03	269.66	44.03	9.49	7.10	33.80	23.29	43.32
Mulch	5.43	28.75	54.81	22.46	164.59	270.61	44.90	9.08	7.71	34.52	25.06	43.32
No-Till	1.32	24.47	52.20	19.54	159.28	255.49	41.29	7.72	7.80	33.70	25.45	43.32
Continuous Soybean	11.18	19.78	45.19	9.55	86.70	161.22	1.05	2.22	3.41	27.66	18.12	34.25
Conventional	4.26	26.30	49.35	12.42	85.57	173.64	0.93	1.84	3.12	27.92	17.51	34.25
Reduced	1.94	18.59	45.23	9.03	86.39	159.24	1.01	2.81	3.90	26.84	17.58	34.25
Mulch	1.19	18.34	43.18	8.92	85.83	156.27	1.01	2.16	3.12	27.81	17.48	34.25
No-Till	3.79	13.51	41.12	6.79	88.40	149.82	1.20	2.37	3.57	27.74	19.27	34.25
Corn Soybean	106.78	23.69	50.33	15.75	119.96	209.73	17.65	5.39	5.45	30.86	21.83	38.79
Conventional	20.96	30.32	56.00	19.34	118.34	223.99	17.62	5.47	5.36	30.32	20.78	38.79
Reduced	25.77	23.53	51.33	15.68	120.53	211.06	18.36	5.70	5.46	30.86	21.36	38.79
Mulch	32.37	23.54	49.00	15.68	119.43	207.65	17.51	5.29	5.66	31.13	21.05	38.79
No-Till	27.68	19.01	46.66	13.18	121.26	200.10	17.16	5.14	5.26	30.93	23.97	38.79
Corn Soybean Wheat	29.24	21.60	50.65	13.72	99.16	185.12	16.74	4.96	3.78	22.89	14.92	35.88
Conventional	7.03	28.85	56.37	17.59	97.93	200.74	16.62	5.07	3.72	22.57	14.06	35.88
Reduced	6.76	21.65	51.67	13.76	99.48	186.57	17.29	5.09	3.87	22.93	14.43	35.88
Mulch	4.20	21.67	49.32	13.77	98.88	183.64	16.80	4.91	3.95	23.11	14.23	35.88
No-Till	11.26	17.01	46.97	11.25	99.84	175.07	16.47	4.82	3.69	22.98	16.00	35.88
Continuous Hay	63.38	19.86	52.66	10.95	62.02	145.49	8.14	6.15	3.11	7.60	6.94	30.07
Conventional	25.00	25.25	56.67	13.75	62.25	157.91	8.52	6.36	2.81	7.60	6.90	30.07
Reduced	16.62	17.45	51.94	9.70	61.20	140.30	7.91	5.68	3.50	7.60	6.44	30.07
Mulch	12.77	17.49	49.58	9.72	61.36	138.14	8.22	5.97	2.83	7.60	6.66	30.07
No-Till	8.99	12.70	47.22	7.23	63.81	130.96	7.41	6.70	3.65	7.60	8.37	30.07
Continuous Wheat	38.86	20.44	53.07	11.25	70.42	155.18	19.30	4.56	1.07	7.60	7.81	30.07
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No-Till	5.51	13.10	47.59	7.45	70.89	139.03	17.57	4.97	1.26	7.60	9.42	30.07

Model Calibration

- Use a calibration base-year of 2003 as this was the year for which the most complete ARMS survey existed when we first started this project.

Model Calibration

- Key Parameters—
  - Other Sectors—
    - Corn export demand elasticity is –0.27, the mean value from Gardiner and Dixit (1987).
    - Soybean export demand elasticity is –0.96, again from Gardiner and Dixit (1987).
    - Wheat export demand elasticity is –0.60, again from Gardiner and Dixit (1987).
    - Central crude oil supply elasticity is 0.5

Model Dynamics

- *Increased Domestic Demand:*
  - We allow income to increase by 1% per year.
- *Ethanol Conversion Improvements:*
  - Following GREET 1.8b, we allow per gallon corn to ethanol conversion efficiency for dry milling to improve by 0.4% per year, and wet milling to improve by 0.5% per year.
  - With regard to the per gallon energy to ethanol conversion parameter , we allow dry milling to improve by 0.3% per year through 2010, and then held constant. Wet-milling is allowed to improve by 0.1% per year until 2008 and then held constant.

Model Dynamics

- *Yield Growth:*
  - Following the USDA's 2009 Long Term Projections for corn, soybean and wheat yields. Hay yields remain fixed.
- *CRP Rental Rate:*
  - We allow CRP rental rates to increase by 2% per year.
- *Increased Crop Export Demand:*
  - We allow crop export demand to increase by 1% per year.

Model Dynamics

- *Exogeneous Fuel Economy Growth*
  - Our exogeneous trends in fuel economy are based upon Table 3-4 of the National Research Council's 2002 report on CAFE standards and Table 5-1 of Bento et al (2008).
  - This results in a weighted average annual change in fuel economy of 0.2245% per year.
  - This value takes into account the initial vehicle composition across both weight class and new and used vehicle stocks.