ETHANOL POLICY IN A CHANGING WORLD

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MOTIVATION - RELEVANCE

Variable corn production vs. inflexible conventional ethanol mandate

- 2012: corn yield down 20%, $7.63 corn price
- Reduced corn availability, world markets, primary input in U.S. protein markets

Farmer expectations matter

- Planting decisions, resulting acreage

Welfare Implications and Risk

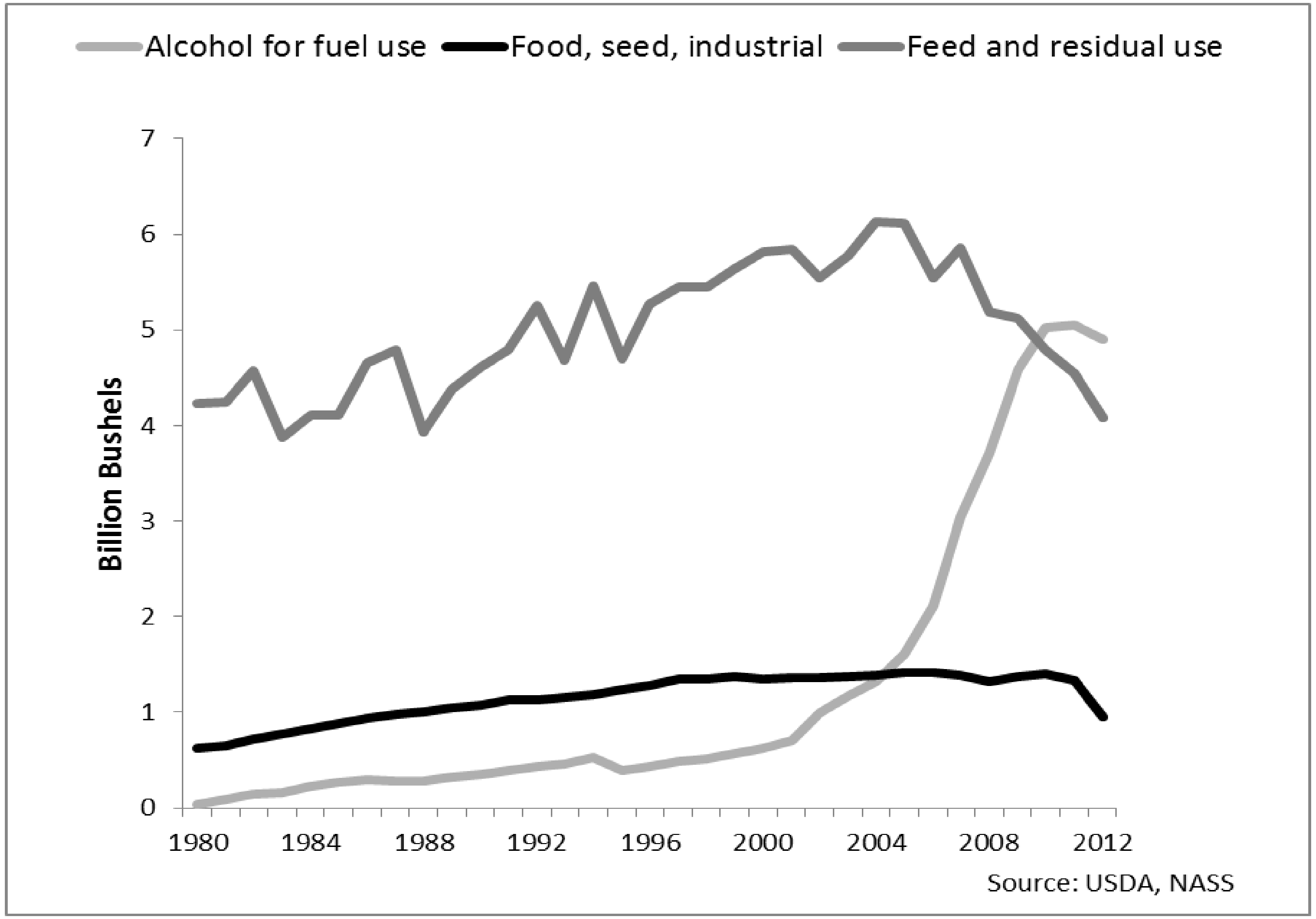
- Consumers and producers
- Who bears the risk?

Environmental Protection Agency (EPA) can issue a waiver on conventional ethanol if 'economic harm' is evident in the market

MOTIVATION – U.S. CORN USE, 1980-2012

Where does the additional corn for ethanol mandates come from?

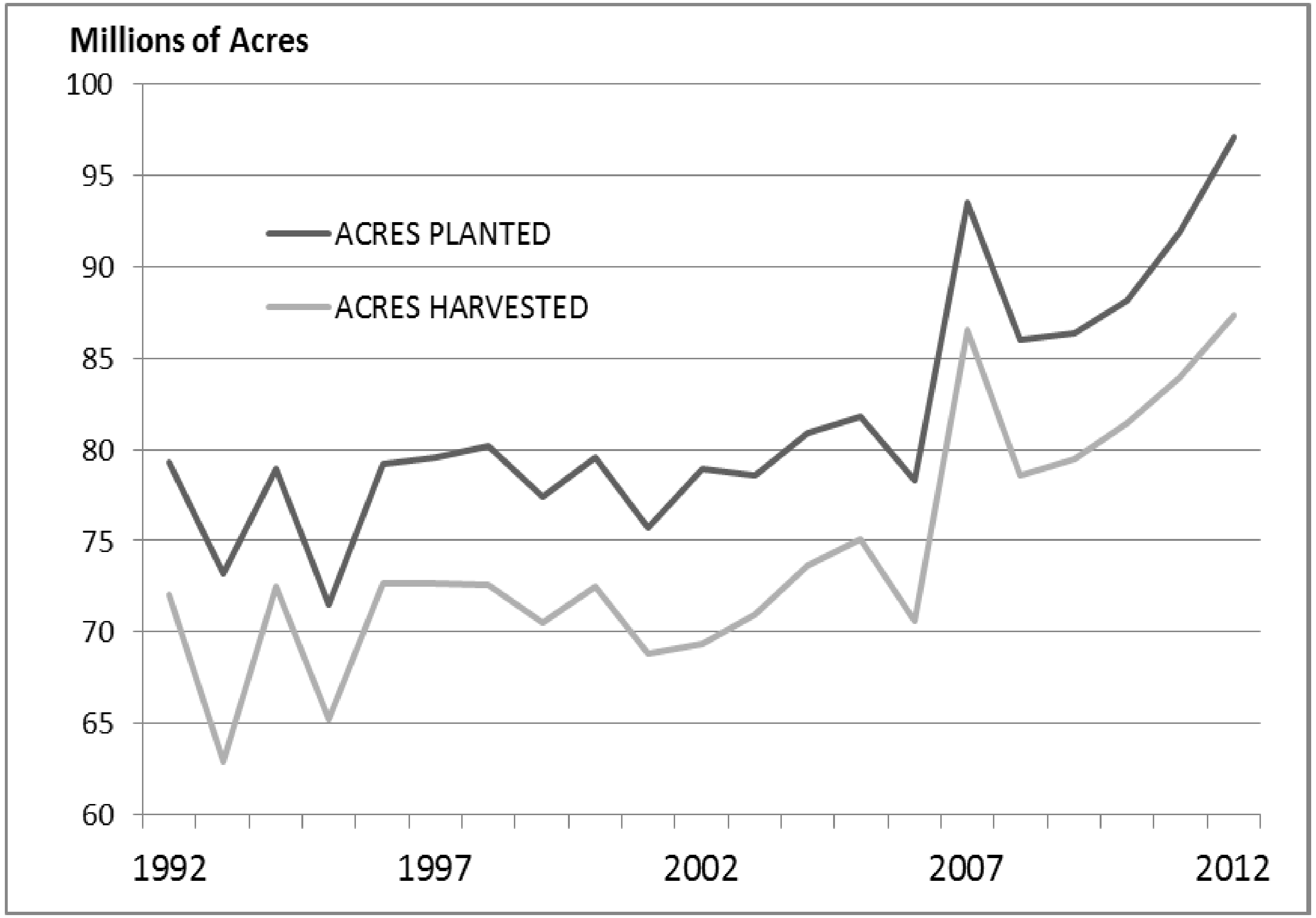
- Feed substitution
  - DDG markets offset some of this
- Technological growth



MOTIVATION – U.S. CORN ACRES, 1992-2012

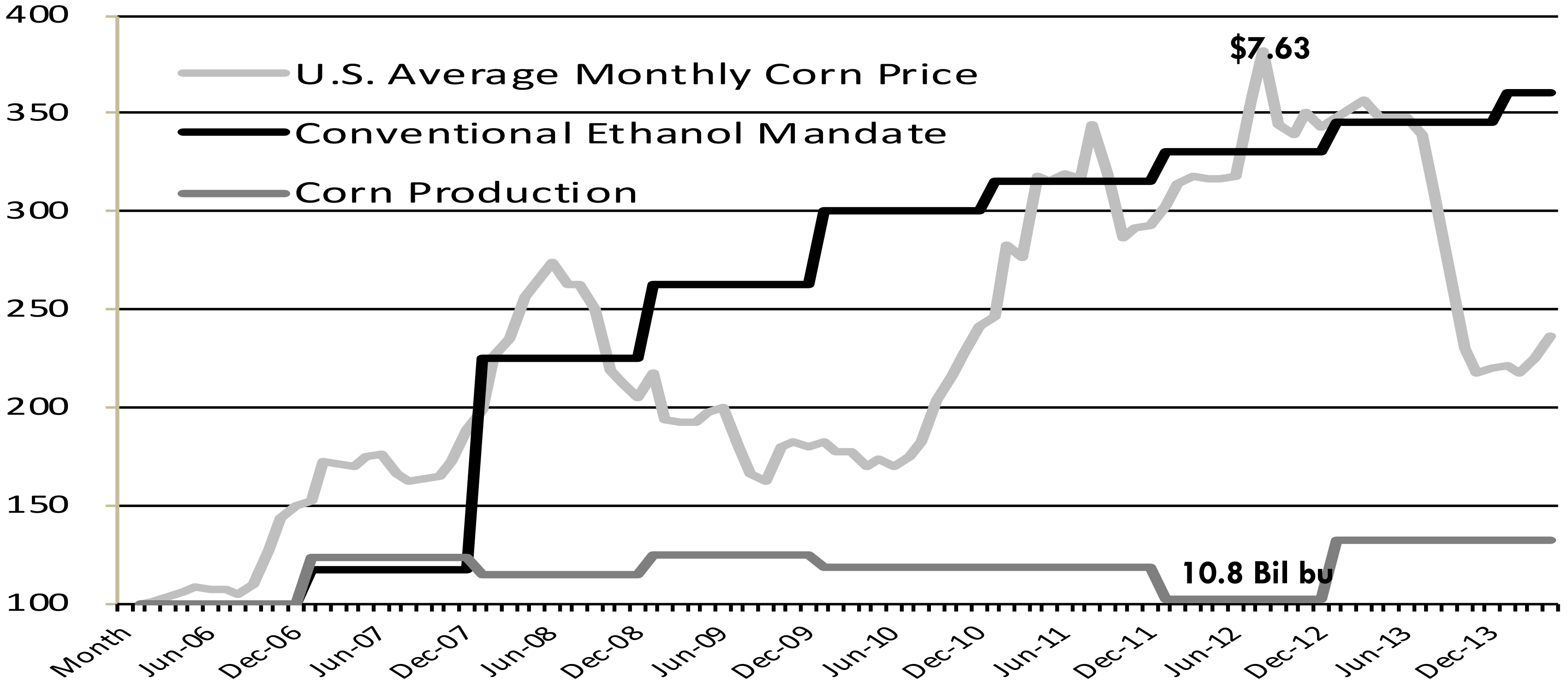
Where does the additional corn for ethanol mandates come from?

- Feed substitution
  - DDG markets offset some of this
- Technological growth
- Increased corn acreage
  - Soybean substitution
  - Pasture conversion
- Irrigation intensity



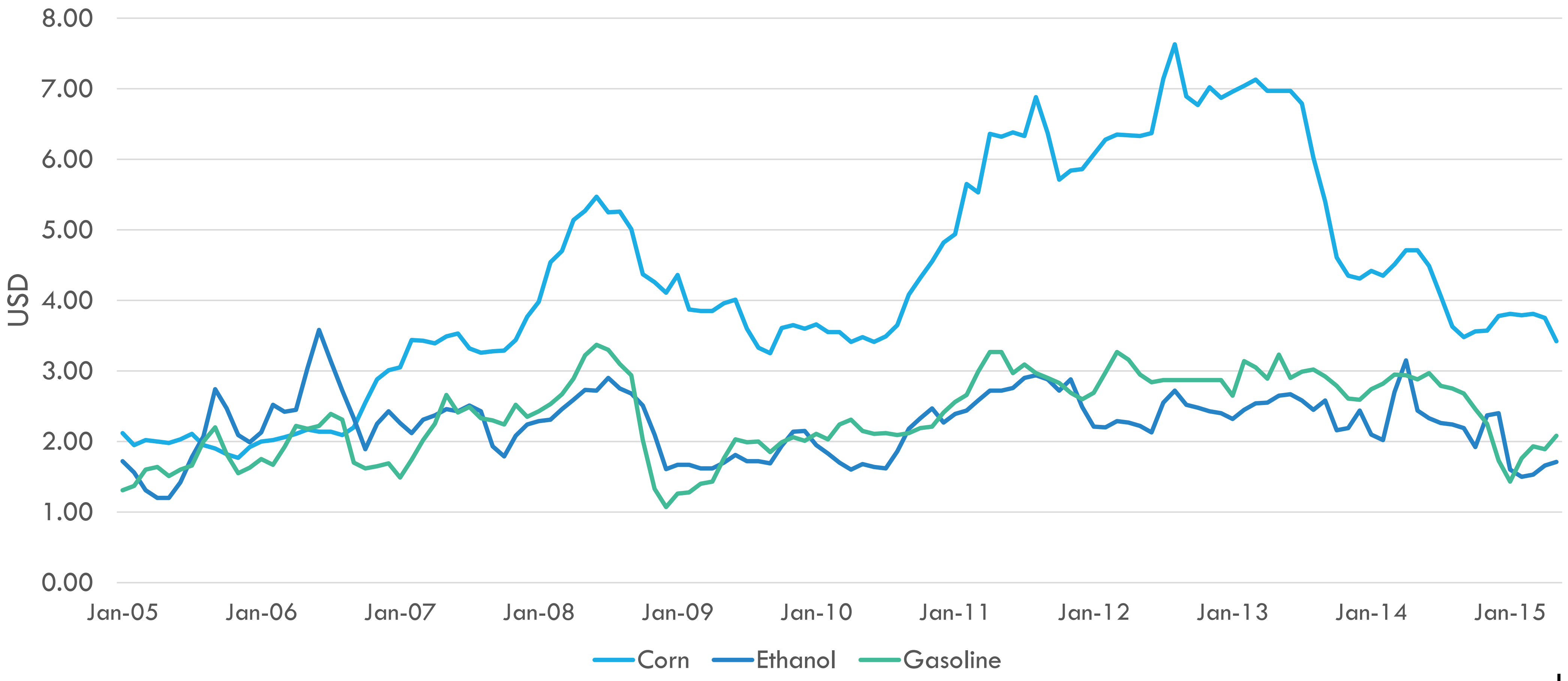
Source: USDA, NASS

MOTIVATION - MANDATES, PRICES, AND PRODUCTION



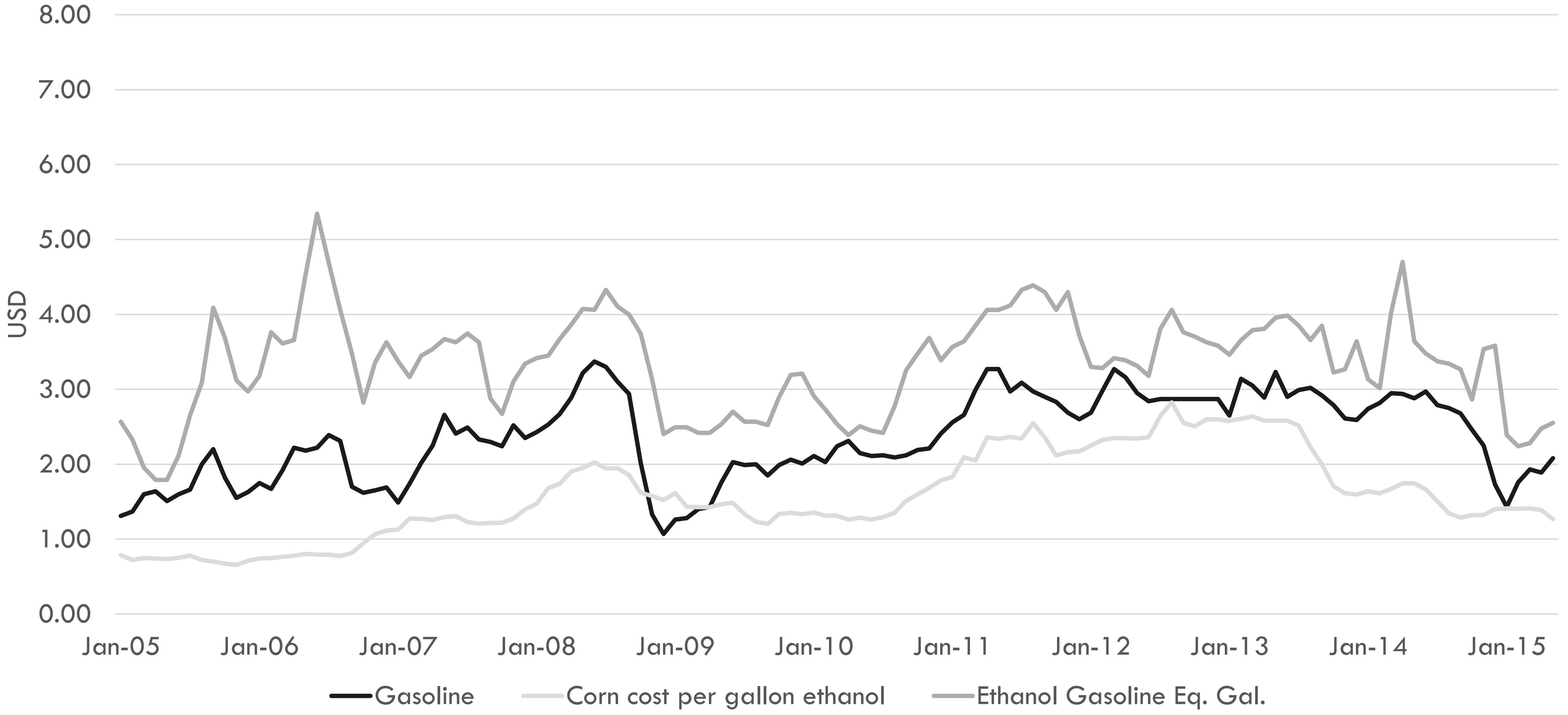
Measure	Units	Jan-06	Apr-14		Growth
U.S. National Corn Price	US Dollars	$ 2.00	$4.73	⇧	137%
Grain Ethanol Mandate	Billion Gal.	4.0	14.4	⇧	260%
Corn Production	Billion Bushels	10.5	13.9	⇧	32%

MOTIVATION - VARIABILITY



USDA

MOTIVATION – MANDATE RELEVANCE



Source: USDA, NASS

OBJECTIVE

Evaluate short- and long-run outcomes of imposing conventional ethanol waivers

<u>Policy Design</u>

In what circumstances are the waivers implemented?

How much ethanol to waive?

Are these conditions explicit to producers?

- How can producers/processors/consumers react?
- Long- vs short-run
- Alter expectations, affect decisions

OBJECTIVE

Evaluate short- and long-run outcomes of imposing conventional ethanol waivers

Evaluation Criteria

Determine the stochastic long-run impacts of imposing a pre-determined ethanol waiver conditional on corn short-fall circumstances

Prices, production, welfare

Evaluate impacts among agricultural sectors, and determine relative impacts on price variability

RISK ANALYSIS WITHIN AN OPTIMIZATION FRAMEWORK

FASOM - mathematical programming model of U.S. agricultural and forestry sectors

- Anticipate behavior in agriculture and forestry sector
- Simulates long run cropping, short run market clearing

Model ordinarily has assumption of **perfect foresight**

- Maximization procedure takes into account values of all variables into the future, even if they change (ie. technological change on yields)

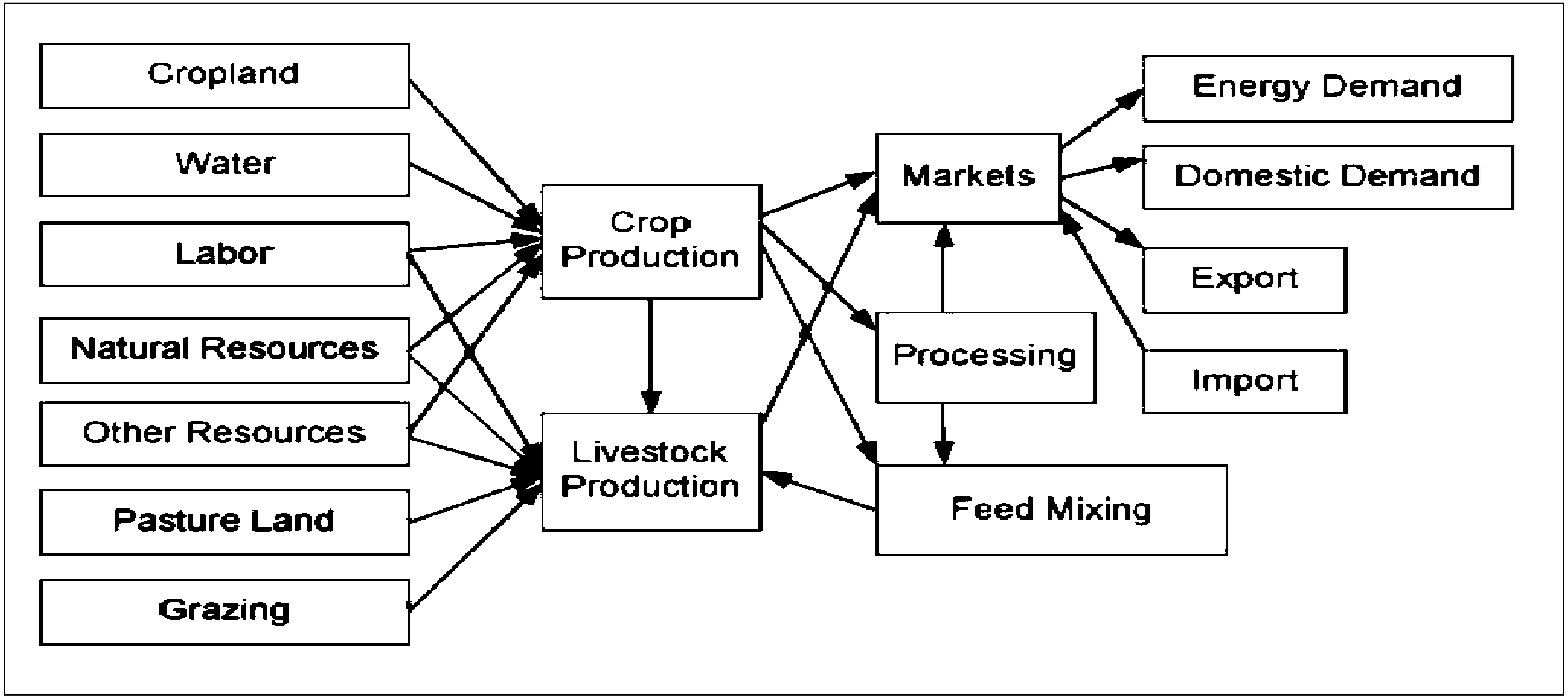
In reality nothing is deterministic

- Climate, yield mean and variance changing with climate change
- Choice
- Expectation

Two approaches to capturing waiver impacts

1. Assume an expectation, lock decision
    - Unexpected risk
    - Short-run analysis
    - Was conducted, also done previously (Babcock and Tyner)
2. Test outcomes over a distribution of outcomes or expectations
    - Allow for policy conditional on occurrence
    - Optimization, decision with recourse
    - Model agents know distribution

FASOM MODEL STRUCTURE



STOCASTIC FASOM

(Lambert et al. 1995)

Max

Total surplus $= \mathbf{E}\left(\int \mathbf{p(q)dq} - \mathbf{g'y}\right) - \boldsymbol{c'x}$

$= \sum_{s=1}^{N} \left(\theta_s \int \mathbf{p(q}_s\mathbf{)dq}_s - \mathbf{g'y}_s\right) - \boldsymbol{c'x}$

subject to

$q_s + Hy_s - N_s x \leq 0 \; for\ all\ s,$	$[\pi_{1s}]$	supply balance constraints for each state
$My_s \leq e \; for\ all\ s,$	$[\pi_{2s}]$	processing resource given each state
$Dx \leq b$	$[\pi_{3s}]$	primary agricultural production resource
$q_s, \quad y_s, \quad x \geq 0$		non-negativity constraints

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$Dx \leq b$		$[\pi_{3s}]$	primary agricultural production resource
$q_s, \quad y_s, \quad x \geq 0$			non-negativity constraints

Note: **x** (primary agricultural production) <u>does not change with state of nature</u>, e.g. corn acreage

STOCASTIC FASOM (RFS)

Max

Total surplus $= \mathbf{E}\left(\int \mathbf{p(q)dq - g'y}\right) - c'x$

$$= \sum_{s=1}^{N} \left(\theta_s \int \mathbf{p}(\mathbf{q}_s)\mathbf{dq}_s - \mathbf{g}'\mathbf{y}_s\right) - c'x$$

subject to

$q_s + Hy_s - N_s x \le 0 \; for \; all \; s,$	$[\pi_{1s}]$	➢ supply balance constraints for each state
$My_s \le e \; for \; all \; s,$	$[\pi_{2s}]$	➢ processing resource given each state
$Dx \le b$	$[\pi_{3s}]$	➢ primary agricultural production resource
$EYy_s \ge m_s \; for \; all \; s,$	$[\pi_{4s}]$	➢ RFS requirement
$q_s, \; y_s, \; x \ge 0$		➢ non-negativity constraints

Note: $\mathbf{q}_s$ (final output) and $\mathbf{y}_s$ (processing levels) do change with state of nature, e.g. ethanol production where **x** (primary agricultural production) does not, e.g. corn acreage

FASOM DATA

Processing costs for conventional and advanced ethanol (U.S. Environmental Protection Agency 2009)

- processing cost for ethanol was parameterized as $0.71 cents per gallon.

Key **macroeconomic variables** are also essential for construction of a large optimization framework for 2015.

- GDP growth, oil prices, and the rate of return on a 10 year U.S. government bonds
- USDA Long-Term Agricultural Projection Tables released February 2013.

Data on corn **ethanol production and demand**

- U.S. Energy Information Administration (U.S. Energy Information Administration August 2012).

Most of the **future baseline values** were drawn from the 2013 USDA baseline (U.S. Department of Agriculture, Office of the Chief Economist, World Agricultural Outlook Board. 2013, Long-term Projections Report OCE - 2013-1,105 pp.)

QUANTIFYING THE RISK –YIELD STATES OF NATURE

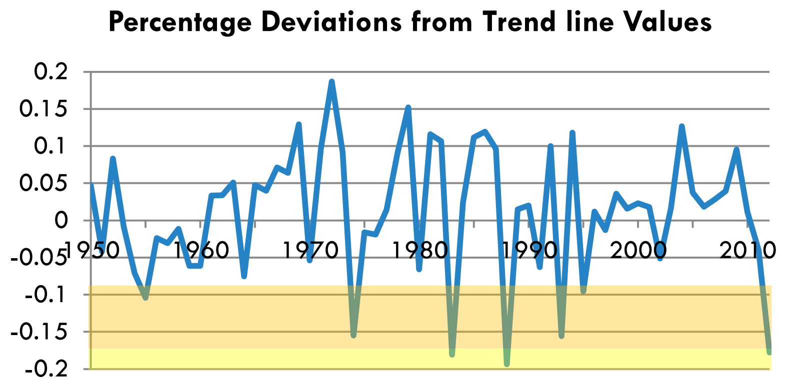
Percentage Deviations from Expected Yield of Major U.S. State-Crop Pairs, 2012

	Corn	Cotton	Hay	Oats	Sorghum	Soybeans	Wheat
California	-7.0%	12.4%	-7.9%	-5.4%			-6.0%
Iowa	-20.2%		-33.4%	-12.6%		-12.2%	1.6%
Texas	-12.2%	-1.3%	-23.3%	-2.0%	-8.2%	-14.8%	-7.3%
Nebraska	-16.9%		-36.1%	-15.5%	-36.9%	-18.7%	-7.6%
Illinois	-36.7%		-26.6%	0.6%	-42.1%	-10.5%	0.4%
Minnesota	-0.6%		-25.5%	-6.1%		-2.2%	11.2%
Kansas	-38.9%	1.6%	-38.7%	-40.3%	-50.0%	-36.5%	-3.4%
N.C.	4.2%	17.8%	3.2%	4.0%		25.8%	6.8%
Indiana	-37.6%		-31.0%	-3.5%		-10.7%	-1.3%
Missouri	-45.0%	13.9%	-28.6%	-11.1%	-40.5%	-23.7%	7.3%

Expected yields and unexplained residuals were determined with linear and log-log regressions of each crop-state pair.

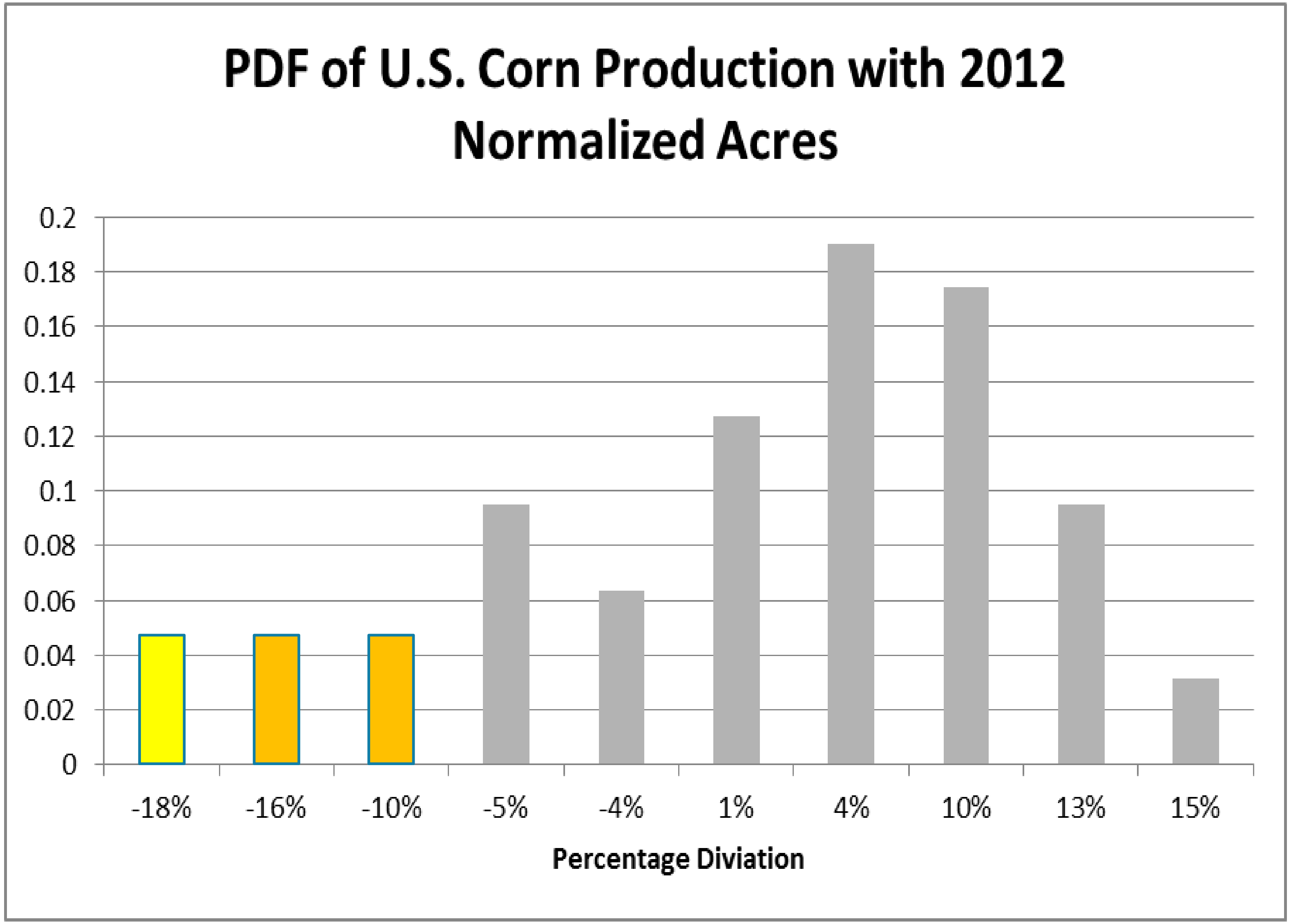
1950-,1975-,1980-,1990-2013

QUANTIFYING THE RISK – ETHANOL WAIVER TRIGGERS

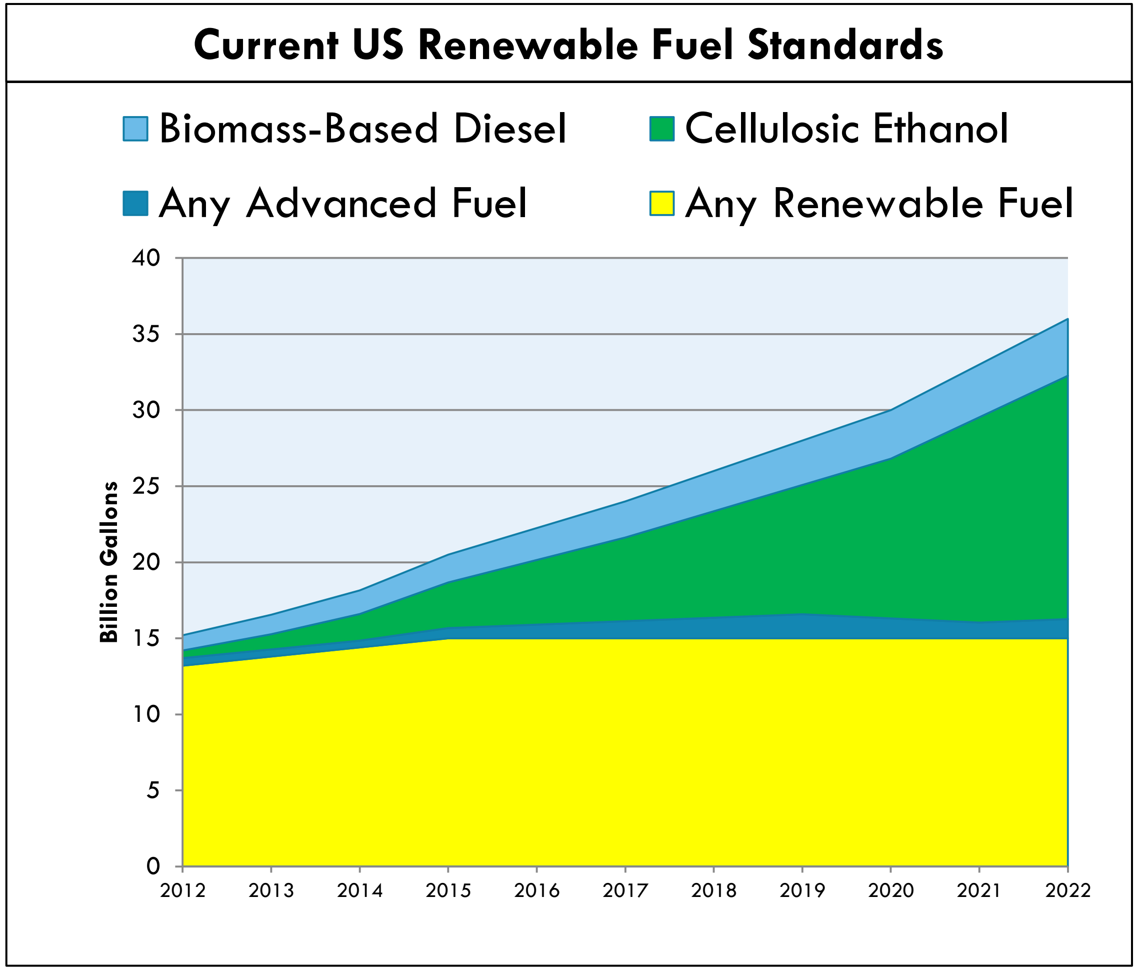


1975 Stocastic Yield Representative Scenarios

Year	Percentage Variation from Expected Production	Frequency of Occurrence
2012	-18%	4.76%
1993	-16%	4.76%
1995	-10%	4.76%
2002	-5%	9.52%
2011	-4%	6.35%
2010	1%	12.70%
2008	4%	19.05%
2009	10%	17.46%
2004	13%	9.52%
1979	15%	3.17%



WAIVER SCENARIOS



Production-Dependent Conventional Renewable Fuel Standard Scenarios

	Conventional Ethanol Mandate in Billion Gallons		
Scenario	Normal	Moderate Shortfall	Extreme Shortfall
Baseline(1)	15	15	15
2	15	15	14
3	15	15	13
4	15	14	14
5	15	14	13
6	15	13	13

PRICE RESULTS

U.S. Corn Price by Representative State of Nature Given the Smaller Waiver Scenarios, 1-6

	Conventional Ethanol Waiver Scenarios					
State of Nature	Base	2	3	4	5	6
son2012	11.56	10.74	9.50	11.16	9.86	10.09
son1993	7.86	7.89	8.09	7.33	7.59	7.04
son1995	6.40	6.54	6.74	5.97	6.04	5.55
son2002	6.63	6.64	6.76	6.75	6.83	6.93
son2011	4.98	4.98	5.01	5.01	5.05	5.11
son2010	3.82	3.91	3.95	3.95	4.07	4.14
son2008	4.76	4.75	4.78	4.77	4.81	4.80
son2009	3.52	3.59	3.61	3.62	3.62	3.64
son2004	3.48	3.49	3.50	3.50	3.51	3.59
son1979	3.13	3.13	3.14	3.14	3.14	3.14
Mean	4.61	4.61	4.60	4.60	4.59	4.58
COV	50.92%	48.57%	46.11%	48.78%	45.72%	45.43%

Expected (mean) prices are nearly equal, slight decrease

Prices decrease with waivers, increase slightly in states of nature that do not experience waivers

Coefficient of variation decreases with the size of waiver

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COV	50.92%	48.57%	46.11%	48.78%	45.72%	45.43%

Equal mean price with less variance in the case where waivers are only implemented during extreme shortfalls

Shortening intervals and increasing states of nature would refine analysis

ACREAGE RESULTS

U.S. Crop Acreage in Millions of Acres from Stochastic Model

	Conventional Ethanol Waiver Scenario											
Crop	Base	2	3	4	5	6	7	8	9	10	11	12
Corn	96.1	95.7	95.4	95.2	94.8	94.6	94.9	94.5	94.3	93.9	93.4	93.3 ⬇
Soybeans	92.3	92.3	92.3	92.2	92.2	92.3	92.4	92.3	92.5	92.3	92.4	92.6
Wheat*	44.7	44.9	45.3	45.9	46.2	46.4	45.9	46.4	46.5	47.1	47.3	47.6 ⬆
Cotton	22.9	22.5	22.2	22.0	21.6	21.2	21.4	20.8	20.6	20.9	20.4	20.3 ⬇
Sorghum	7.3	7.4	7.3	7.3	7.5	6.9	7.9	7.6	7.2	7.6	7.6	7.5

Note: *Includes hard red winter, soft red winter, durum, and hard red spring varieties.

Increasing waiver sizes and frequency causes decrease in expected future corn price causes corn acreage to decrease

Soybeans relatively unchanged/ rotation constraints

Increase in wheat, increase in pasture land

SHORT- VS. LONG-RUN

SR – waivers are unexpected by producers

LG – waiver details are known and producers react

Model calibration slightly off

Remember-less corn is planted in long-run with known waivers

Most feed-crop acreages change

Feed mixes

Regional shifts

An interesting result, still under investigation.

U.S. Corn Price, 2012-like drought in 2015

Crop Ethanol Mandate (billion gallons)	Unknown waivers – Short-run	Known waivers – Long-run
No Waiver - 15	*$11.65*	*$11.56*
14	$10.83	$10.74
13	$10.30	$9.50
12	$9.76	$8.46
11	$9.33	NA
10	$8.69	$7.09
9	$8.21	NA
8	$7.84	NA
7	$7.53	$5.61*
Relaxed (0)	$6.61	

*7.5 billion gallon requirement

SR VS. LR

SR – waivers are unexpected by producers

LG – waiver details are known and producers react

Model calibration slightly off

Remember-less corn is planted in long-run with known waivers

Most feed-crop acreages change

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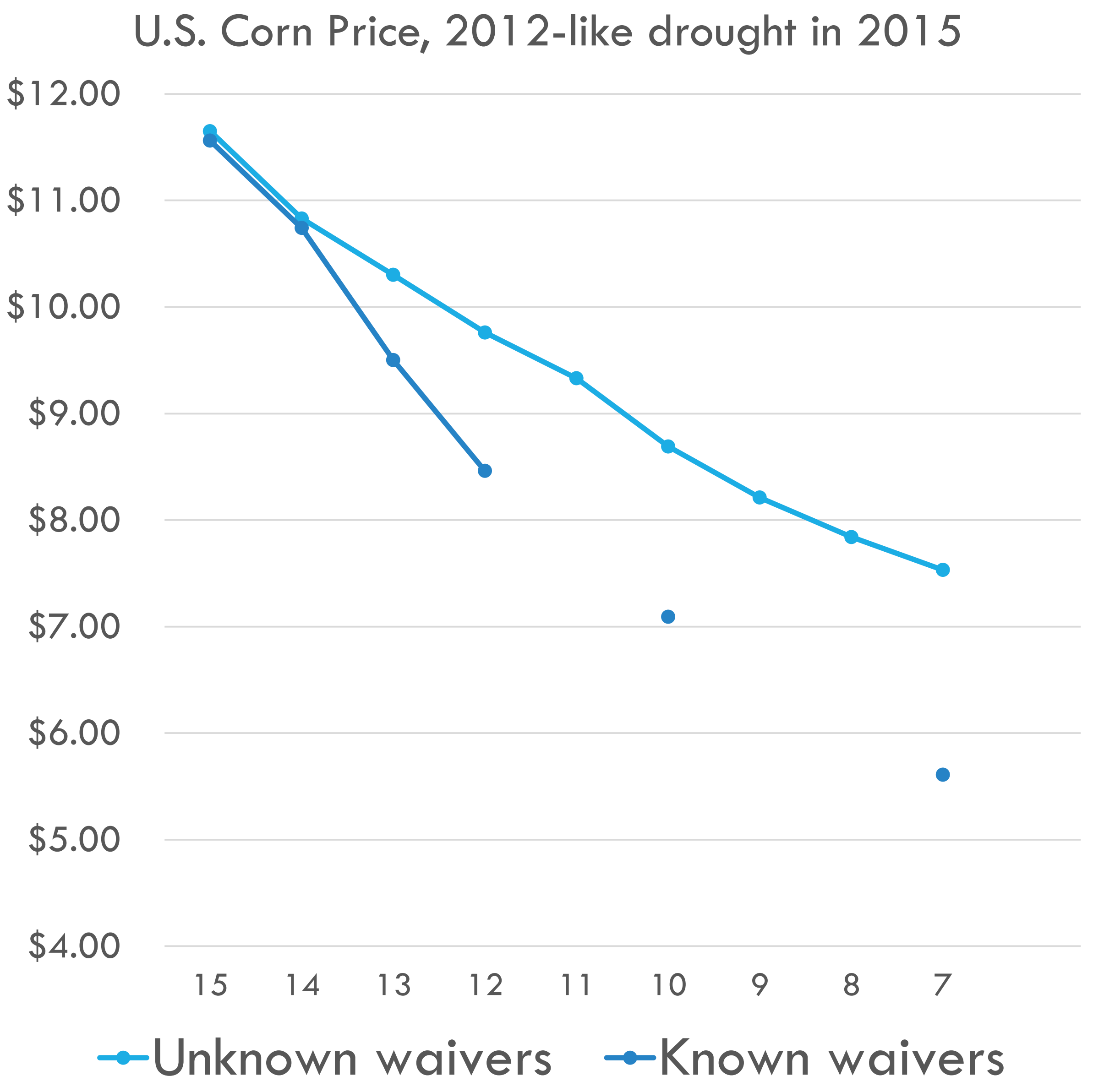

DISCUSSION

Minimal change in expected price caused LR welfare analysis to be uninteresting

Policy Risk - Contrast b/w SR and LR results

- SR – economic burden, severe impacts
- LR – broader perspective, impacts during non-shortfall years
- Showed that predicting ethanol waiver outcomes has many relevant dimensions
  - Expectations, when to implement, at what amount

Distributional

- Welfare analysis assuming risk aversion coefficients across crop-ag, livestock, energy sector
  - Requires inclusion of gasoline markets

Framework

- Investigate the if, when, where, how much
- Risk preferences will impact decisions, need to rerun with modified objective function
- Incorporate climate change, alter distributions

QUESTIONS AND FEEDBACK GREATLY APPRECIATED

OVERALL CONCLUSIONS

Ethanol waivers during shortfall years have substantially different impacts based on expectations and LR vs. SR

- Waivers decrease corn price equally during extreme years
  - ~$0.80 first bil. to ~$0.30 at 7.5, averaging ~$0.5.
- During all other SONs in the LR analysis between $0 and $0.14/bu increase in corn price
  - counterbalance the effects on future expected price.

Welfare loss for unexpected waivers but potential welfare gains associated with flexible RFS mandates

- Reduction of price variability without impacting expected prices
- Requires risk preference assumptions

LIMITATIONS

Blend wall, environmental and other issues could change RFS2 policy by 2015

Stochastic model

- include all 63 states, looses considerable variability of regional effects when representative states are used
- assume attitudes regarding risk/ stochastic dominance

Yield variability modelling

- technology such as drought resistant corn or climate change adaptation strategies are not exogenous increases in yields
- the variability of existing yields drives these improvements

FUTURE RESEARCH

Incorporate climate change research into future yield projections

RFS2 is not perfect, but the economic and environmental impacts of the policy are substantial

- quantity control is one of many policy options that could be implemented
- economic analysis are required of other policy mechanisms
  - flexible price supports
  - increasing/modification to RIN market
- need to quantify the current policy risk
- although less flexible relative to crop producers, similar impacts are expected on ethanol processors

STOCASTIC FASOM (RFS)

Max

Total surplus $= \mathrm{E}\left(\int \mathrm{p(q)dq} - \mathrm{g'y}\right) - c'x$

$$= \sum_{s=1}^{N} \left(\theta_s \int \mathrm{p}(\mathbf{q}_s)\mathrm{d}\mathbf{q}_s - \mathrm{g'}\mathbf{y}_s\right) - c'x$$

subject to

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$Dx \leq b$ [π_{3s}] – primary agricultural production resource

$EYy_s \geq m_s \; for \; all \; s,$ [π_{4s}] – RFS requirement

$q_s, \; y_s, \; x \geq 0$ – non-negativity constraints

Note: $\mathbf{q}_s$ (final output) and $\mathbf{y}_s$ (processing levels) do change with state of nature, e.g. ethanol production where **x** (primary agricultural production) does not, e.g. corn production

PRICE RESULTS

Renewable Fuel Standards

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9	15	15	7.5
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U.S. Corn Price by Representative State of Nature given Waiver Scenarios, 7-12

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son2009	3.52	3.62	3.64	3.65	3.73	3.79	3.85
son2004	3.48	3.50	3.57	3.62	3.67	3.69	3.73
son1979	3.13	3.14	3.14	3.14	3.15	3.15	3.15
Mean	4.61	4.59	4.57	4.56	4.56	4.54	4.53
COV	50.92%	44.42%	42.89%	42.22%	41.73%	39.07%	37.91%

Same trends as in Waiver Scenarios 2-6

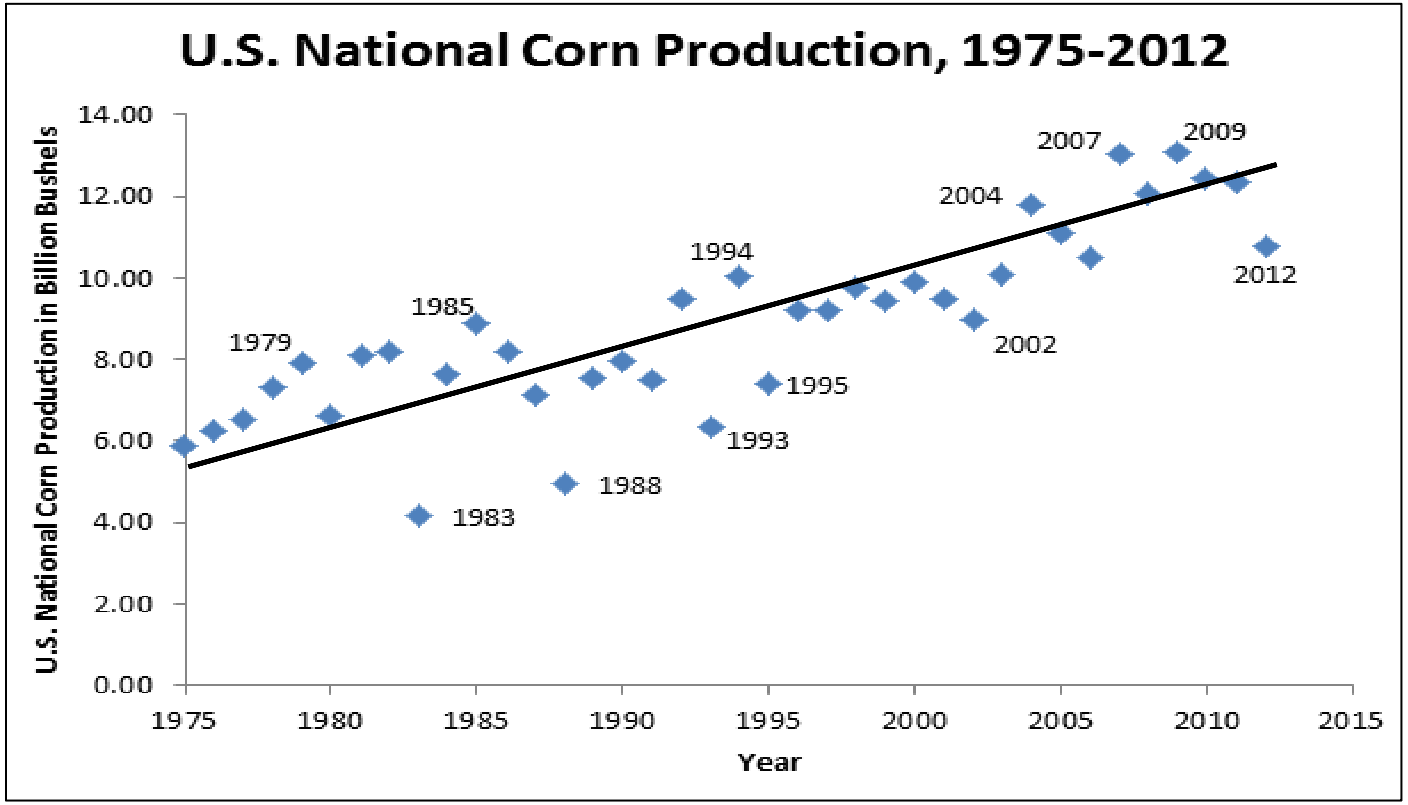
Comparing 7,8,9 and 10,11,12

- impact of a waiver on 'extreme shortfall' is diminished with 'moderate shortfall' waiver existence

By scenario 11 and 12, the highest expected corn price is no longer during a 'short-fall' year

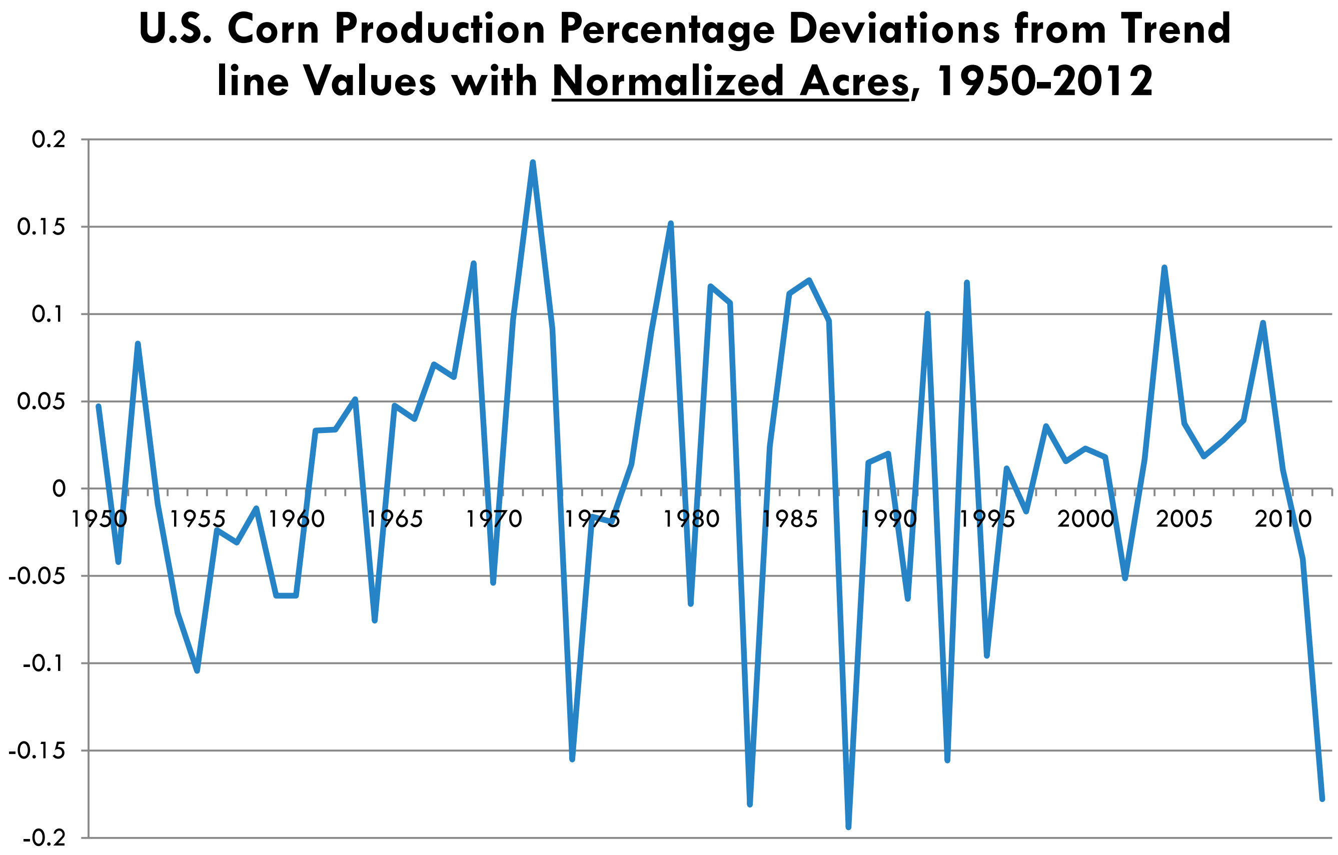
IDENTIFYING YIELD STATES

In addition to yields, total corn production is required to identify short-fall years



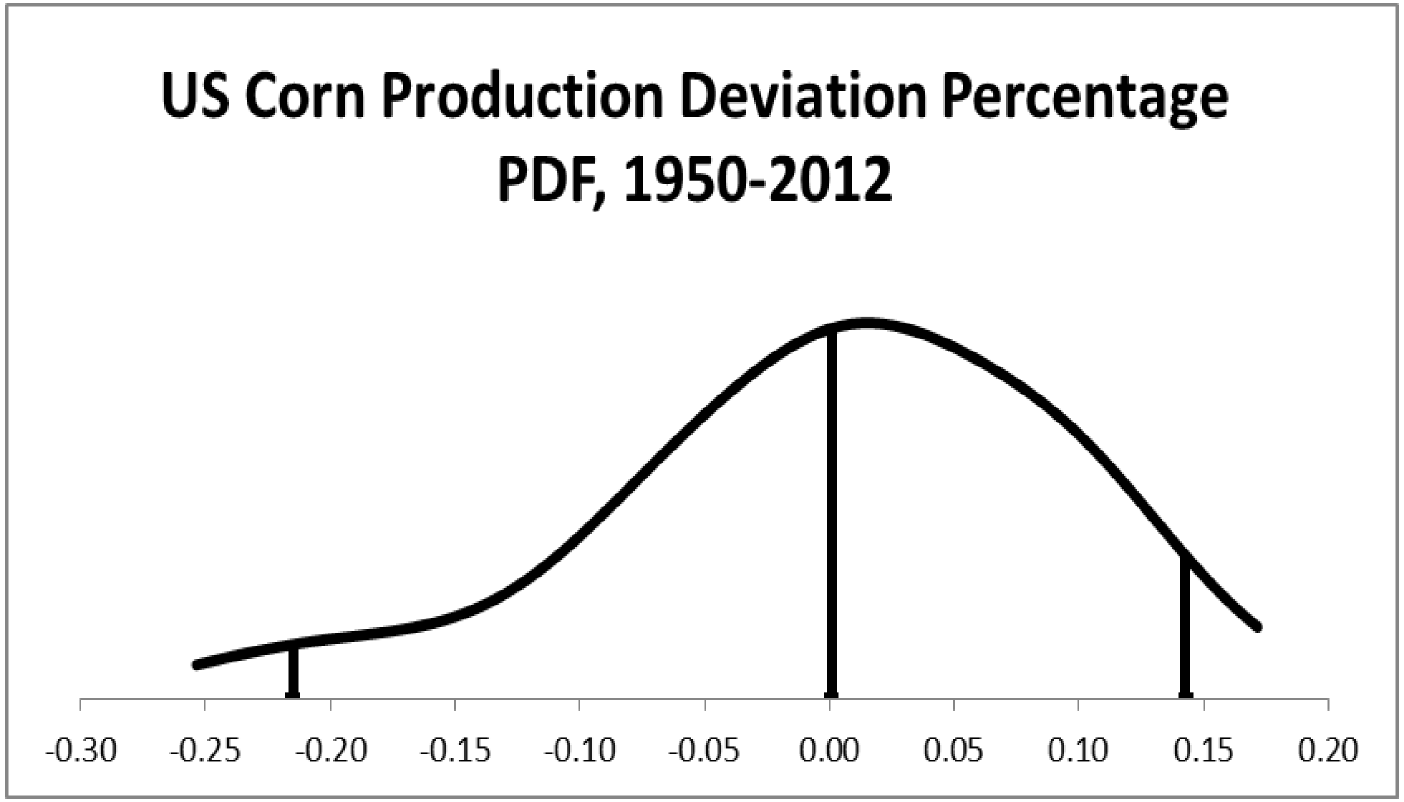
IDENTIFYING YIELD STATES

Using deviations from the trend line



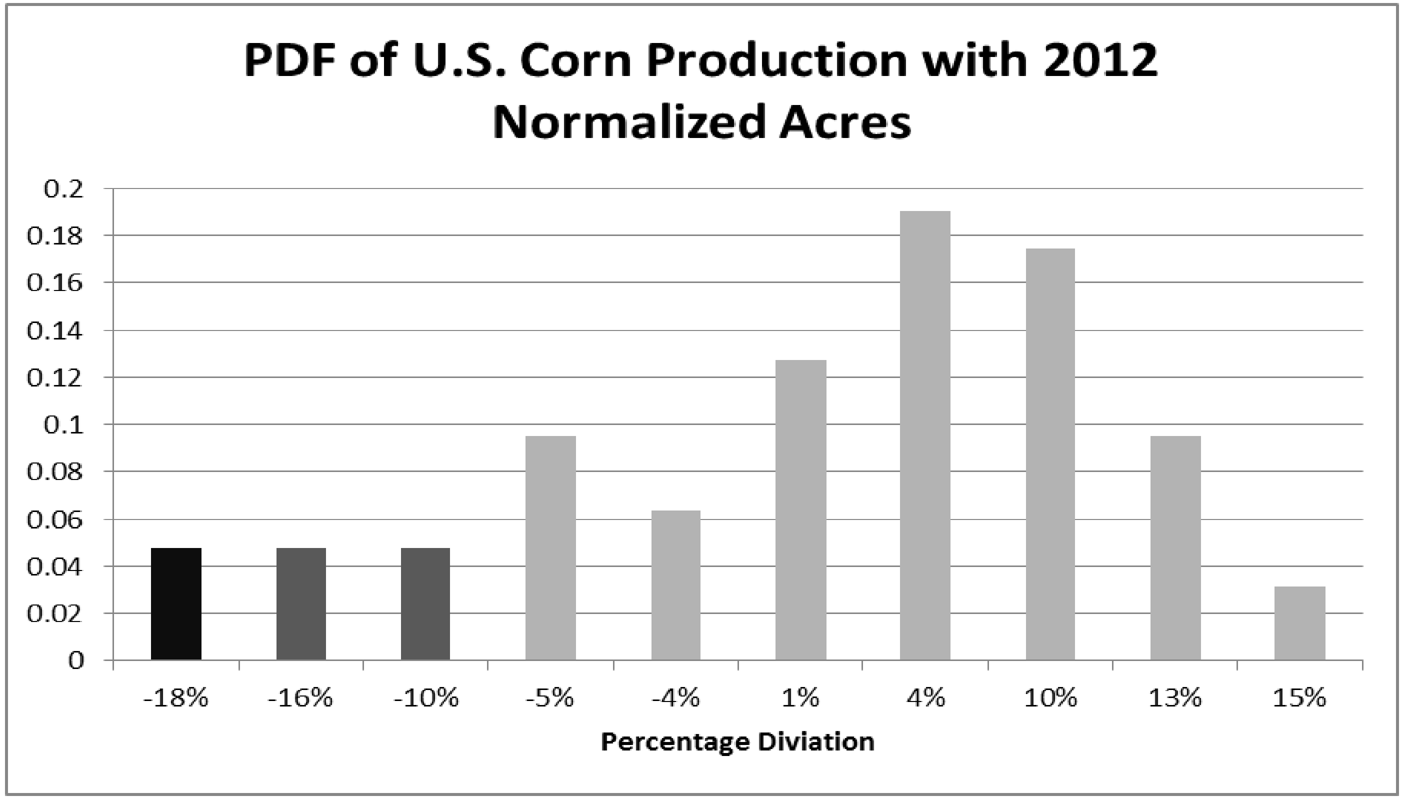
IDENTIFYING YIELD STATES

Nationally aggregated using acreage data, to identify production short-falls



IDENTIFYING YIELD STATES

Empirical distribution of 10 representative years was formulated



IDENTIFYING YIELD STATES

Most recent years selected to reflect each interval

Allowed for 1975 and 1980 regression deviations to be used to populate each respective scenario

1975 Stocastic Yield Representative Scenarios

Year	Percentage Variation from Expected Production	Frequency of Occurrence
2012	-18%	4.76%
1993	-16%	4.76%
1995	-10%	4.76%
2002	-5%	9.52%
2011	-4%	6.35%
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2008	4%	19.05%
2009	10%	17.46%
2004	13%	9.52%
1979	15%	3.17%

1980 Stocastic Yield Representative Scenarios

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2012	-18%	4.76%
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1995	-10%	4.76%
2002	-5%	9.52%
2011	-4%	6.35%
2010	1%	12.70%
2008	4%	19.05%
2009	10%	17.46%
1994	12%	6.35%
2004	13%	6.35%

	Forestry	Land from Forest	Land to Forest	Prog Crop Prod	Non Prog Crop Prod	Livestock Prod	Crop Mix	LiveMix	Land Sup	WaterSup	Labor Sup	Input Purch	Process	Demand	Export Dem	Import Sup	CCC Loan	Def Pay	OtherFP Pay	
Obj	+	-		-	-	-			-	-	-	-	-	+	+	-	+	+	+	
Forest Land	+	+1	-1																	< +
Crop Land		-1	1	1	1				-											< 0
Max Crop									+											< +
Pasture Land		-1	1			+			-											< 0
Max Past									+											< +
Water				+	+					-										< 0
Fixed Water										+										< +
Labor				+	+	+					-									< 0
Family Labor											+									< 0
Ag Inputs				+	+	+						-	+							< 0
Primary Products				-	-	+/-							+	+	+	-	+			< 0
Secondary Products						+							-	+	+	-	+			< 0
Farm Program Products				-														+		< 0
Other Farm Products				-															+	= 0
Crop Mix				+	+		-													= 0
Livestock Mix						+		-												= 0

Adams et al. 1996

FASOM CON'D

Includes over 100 commodity types, including 40 crops, 25 livestock units, and over 50 processed goods

Factor markets; irrigation, fertilizer, and labor.

Product markets; production/supply, consumption/demand, and international trade

FASOM CON'D

Supply - determined by technological assumptions, available land, inputs, import markets, and alternative production options for the producer

Demand - determined by domestic demand, the intermediate product market, and export demand

FASOM CON'D

$$\max \quad \sum_t \{[\sum_h \int_0^{Z_{ht}} P_{dht}(Z_{ht})dZ_{ht} - \sum_i \int_0^{X_{it}} P_{sit}(X_{it})dX_{it}](\frac{1}{1+r})^t\}$$

$$\begin{aligned}
s.t. \quad & Z_{ht} & & - \sum_\beta \sum_k c_{h\beta kt} Q_{\beta kt} \le 0, && \forall h,t \\
& - & X_{it} & + \sum_\beta \sum_k a_{i\beta kt} Q_{\beta kt} \le 0, && \forall i,t \\
& & & \sum_k b_{j\beta kt} Q_{\beta kt} \le Y_{j\beta t}, && \forall j,\beta,t \\
& Z_{ht}, & X_{it}, & \quad Q_{\beta kt} \ge 0, && \forall i,h,\beta,k,t
\end{aligned}$$

- Each firm/farm (β) has a finite set of production processes (k). t=2015
- Each production process (k) illustrates a particular way of using fixed factors (j) and purchased factors (i) to produce commodities (h).

STOCASTIC FASOM

(Lambert et al. 1995)

Max

Total surplus $= \mathbf{E}\left(\int \mathbf{p}(\mathbf{q})\mathbf{dq} - \mathbf{g}'\mathbf{y}\right) - \boldsymbol{c}'\boldsymbol{x}$

$= \sum_{s=1}^{N} \left(\theta_s \int \mathbf{p}(\mathbf{q}_s)\mathbf{dq}_s - \mathbf{g}'\mathbf{y}_s\right) - \boldsymbol{c}'\boldsymbol{x}$

subject to

$q_s + Hy_s - N_s x \leq 0 \; for\ all\ s,$ $[\pi_{1s}]$ supply balance constraints for each state

$My_s \leq e \; for\ all\ s,$ $[\pi_{2s}]$ processing resource given each state

$Dx \leq b$ $[\pi_{3s}]$ primary agricultural production resource

$q_s, \quad y_s, \quad x \geq 0$ non-negativity constraints

STOCASTIC FASOM

Max

Total surplus $= \mathrm{E}\left(\int \mathrm{p(q)dq} - \mathrm{g'y}\right) - c'x$

$$= \sum_{s=1}^{N} \left(\theta_s \int \mathrm{p}(\mathrm{q}_s)\mathrm{dq}_s - \mathrm{g'y}_s\right) - c'x$$

subject to

$q_s + Hy_s - N_s x \le 0 \; for \; all \; s,$	$[\pi_{1s}]$	supply balance constraints for each state
$My_s \le e \; for \; all \; s,$	$[\pi_{2s}]$	processing resource given each state
$Dx \le b$	$[\pi_{3s}]$	primary agricultural production resource
$q_s, \; y_s, \; x \ge 0$		non-negativity constraints

Note: x (primary agricultural production) does not change with state of nature, e.g. corn production

STOCASTIC FASOM

Max

Total surplus $= \mathbf{E}\left(\int \mathbf{p(q)dq} - \mathbf{g'y}\right) - \boldsymbol{c'x}$

$= \sum_{s=1}^{N} \left(\theta_s \int \mathbf{p(q_s)dq_s} - \mathbf{g'y_s}\right) - \boldsymbol{c'x}$

subject to

$\boldsymbol{q_s + Hy_s - N_s x \le 0 \; for \; all \; s,}$	$[\boldsymbol{\pi_{1s}}]$	supply balance constraints for each state
$\boldsymbol{My_s \le e \; for \; all \; s,}$	$[\boldsymbol{\pi_{2s}}]$	processing resource given each state
$\boldsymbol{Dx \le b}$	$[\boldsymbol{\pi_{3s}}]$	primary agricultural production resource
$\boldsymbol{q_{s'}} \quad \boldsymbol{y_{s'}} \quad \boldsymbol{x \ge 0}$		non-negativity constraints

Note: **q** (final output) and **y** (processing levels) do change with state of nature, e.g. ethanol production

STOCASTIC FASOM (RFS)

Max

Total surplus $= \mathrm{E}\left(\int \mathrm{p(q)dq} - \mathrm{g'y}\right) - c'x$

$$= \sum_{s=1}^{N} \left(\theta_s \int \mathrm{p}(\mathrm{q}_s)\mathrm{dq}_s - \mathrm{g'y}_s\right) - c'x$$

subject to

$q_s + Hy_s - N_s x \leq 0 \; for\, all\, s,$	$[\pi_{1s}]$	supply balance constraints for each state
$My_s \leq e \; for\, all\, s,$	$[\pi_{2s}]$	processing resource given each state
$Dx \leq b$	$[\pi_{3s}]$	primary agricultural production resource
$EYy_s \geq m_s \; for\, all\, s,$	$[\pi_{4s}]$	RFS requirement
$q_s, \; y_s, \; x \geq 0$		non-negativity constraints

Note: EY per unit ethanol yield, $\mathbf{m_s}$ state dependent minimum ethanol amount. Also dependent on process.

STOCASTIC FASOM FOC (RFS)

Processing

$$\frac{\partial L}{y_s} = -\theta_s \boldsymbol{g} + \boldsymbol{H}\boldsymbol{\pi}_{1s} - \boldsymbol{M}'\boldsymbol{\pi}_{2s} - \boldsymbol{EY}\,\boldsymbol{\pi}_{4s} \leq 0$$

$$\boldsymbol{\pi}_{1s} = \theta_s\, \boldsymbol{g} + \boldsymbol{M}'\boldsymbol{\pi}_{2s} + \boldsymbol{EY}\,\boldsymbol{\pi}_{4s}$$

- commodity price also equals the cost of producing ethanol **g** plus the cost of the resources used, plus the cost of mandate times the ethanol yield.

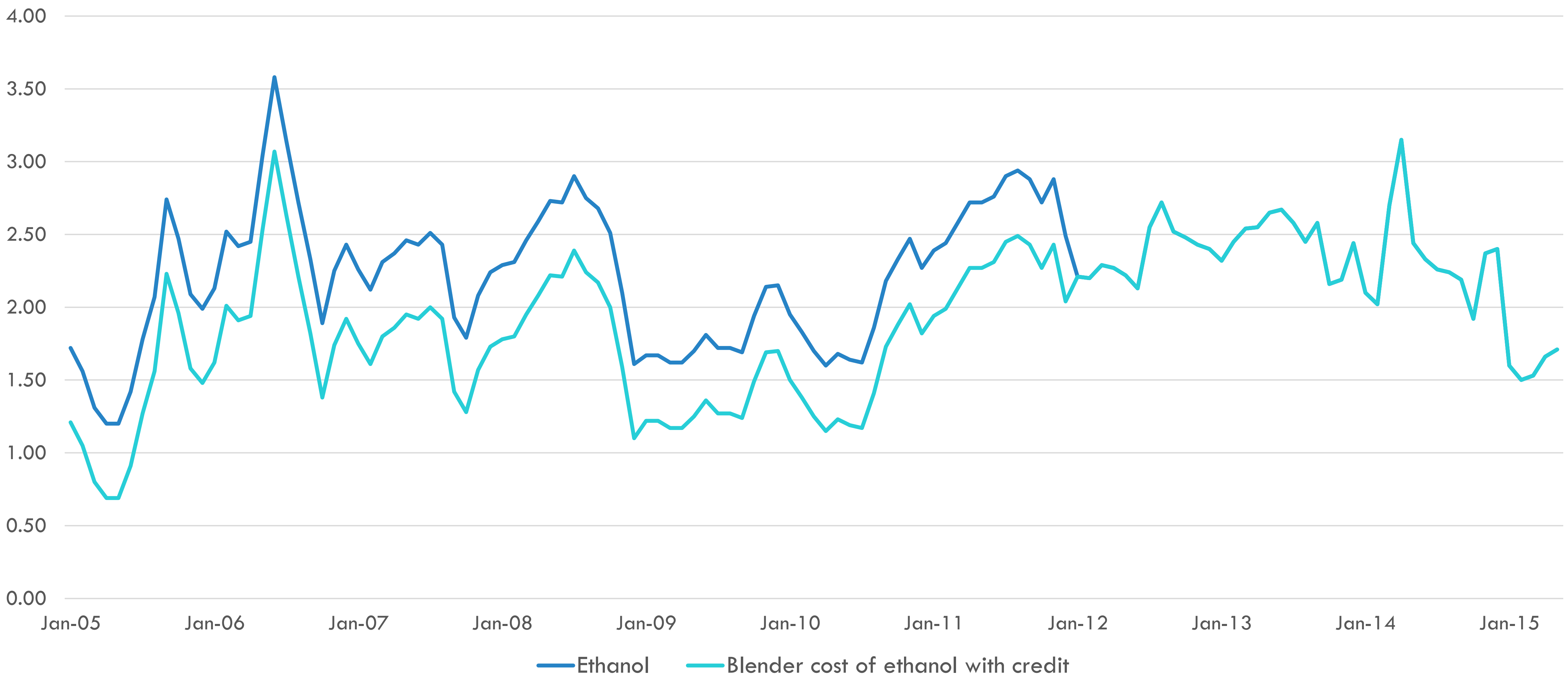
Primary Production

$$\frac{\partial L}{\partial x} = -\boldsymbol{c} + \textstyle\sum_s \boldsymbol{N}_s\boldsymbol{\pi}_{1s} - \boldsymbol{D}'\boldsymbol{\pi}_3 \leq 0$$

$$\frac{\partial L}{\partial x} = -\boldsymbol{c} + \textstyle\sum_s \theta_s\boldsymbol{N}_s(\boldsymbol{g} + \boldsymbol{M}'\boldsymbol{\pi}_{2s}/\theta_s + \boldsymbol{EY}\,\boldsymbol{\pi}_{4s}/\theta_{s)} - \boldsymbol{D}'\boldsymbol{\pi}_3 \leq 0$$

- primary production decision **x** responds to the expected demand curve price and the state specific cost of the biofuel mandate, represented by $\boldsymbol{\pi}_{4s}$
- decisions made prior to yield realization are affected by state specific mandates (assuming they are binding)

ETHANOL CREDITS



ETHANOL PRICE – CORN INPUT PRICE