Impact of energy prices on agricultural and energy markets: an integrated modeling approach

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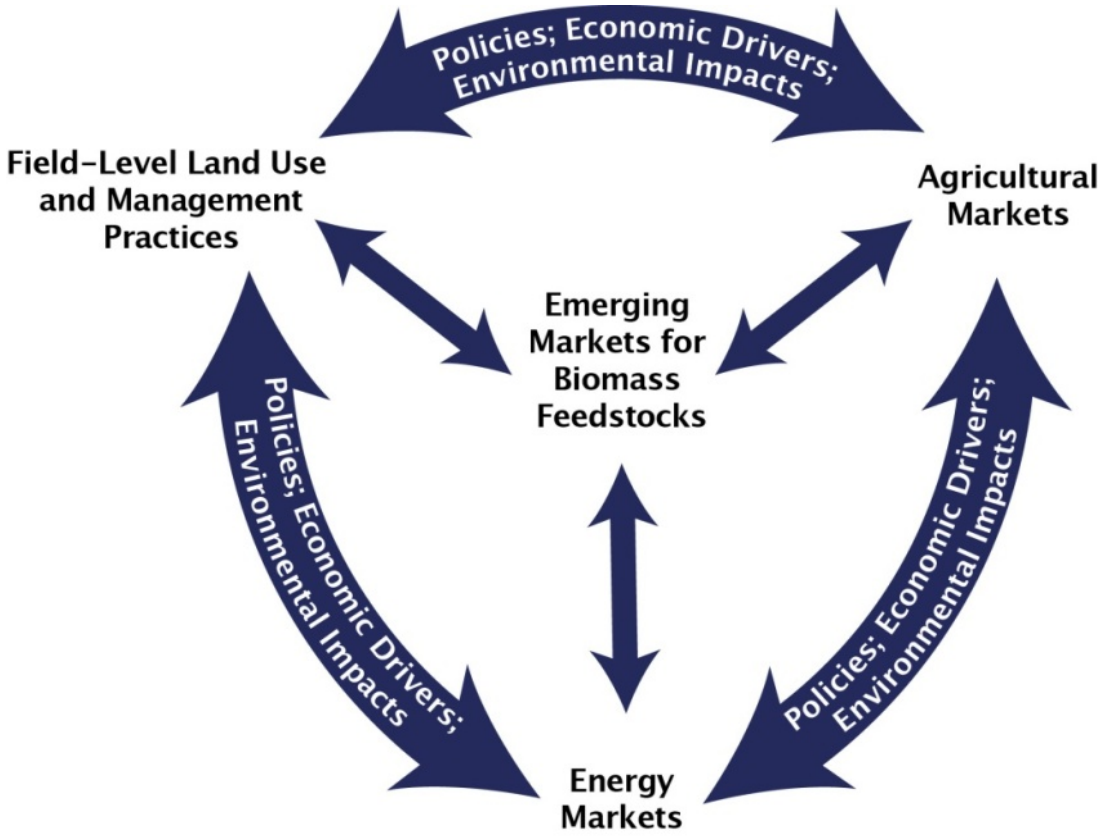
Motivation and Background

- Biofuel expansion has significantly changed the dynamics between agriculture and energy
  - Subsidies, phase out of Methyl Tertiary Butyl Ether (MTBE)
- Rising energy prices increased competition for the agricultural feedstocks in the energy market
- Crude oil and natural gas markets have impacted cost of producing and transporting agricultural commodities
- Energy prices (gasoline and biodiesel) impact demand for crops used in biofuel production[1], thus creating a price floor for these crops
- Supply of biofuels impact price and quantity of fossil fuels[2]

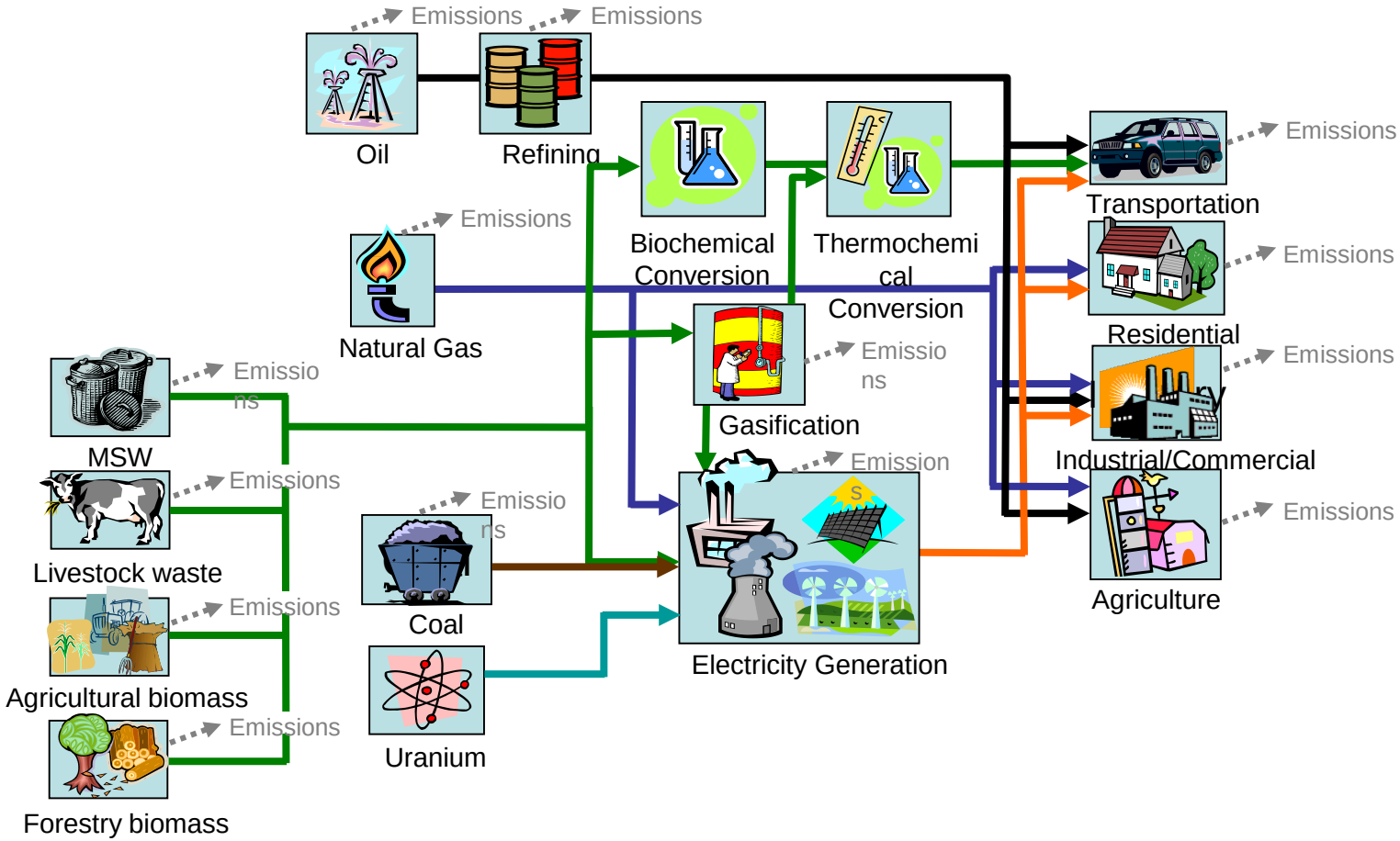
1. Tokgoz et al. 2008, Hayes et al 2009
2. Hochman et al. 2010; Rajagopal et al. 2011, Thompson et al. 2011

Need for integrated modeling framework



The integrated modeling of agricultural and energy markets facilitates the analysis of a range of scenarios capturing the role of biomass feedstocks in expanding market for bio-based fuels and energy

Modeling technology change with MARKAL



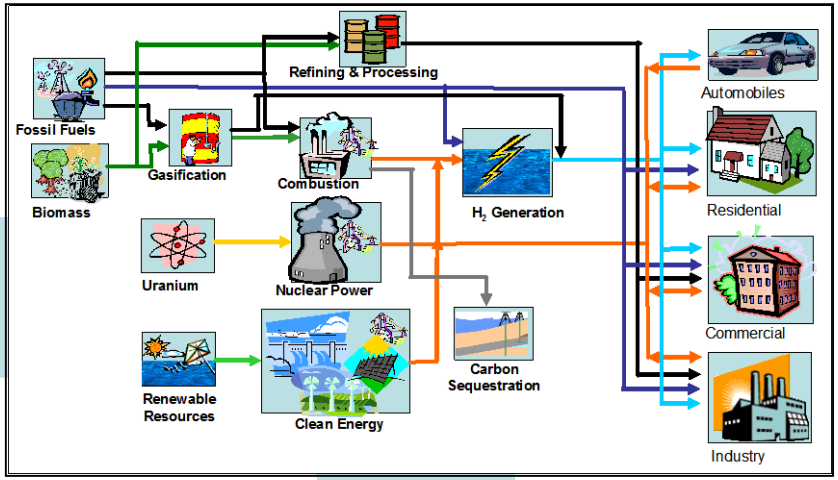
- Developed by Brookhaven National Laboratories in 1970s with major funding from DOE and IEA
- Bottom-up, technology rich, dynamic, linear programming optimization framework
- Currently used by ~200 institutions and governments in 70 countries

  Including Department of Energy and U.S. Environmental Protection Agency

Modeling technology change with MARKAL

MARKAL Inputs:

- Future-year energy service demands
- Primary energy resource supply curves
- Technology Characteristics
  - capital cost, O&M, efficiency, emission factors
- Current regulations (e.g., CAIR, CAFÉ)



•Through linear optimization MARKAL finds the least cost set of technologies

MARKAL Outputs:

- Technology penetrations for meeting industrial, residential, commercial, and transportation demands
- Fuel use by type and region
- Sectoral and system-wide emissions

  NOx, SO_2, PM_{10}, Hg, CH_4, N_2O, CO_2
- Cooling water consumption and withdrawal quantities in EGUs
- Marginal fuel and emissions reduction prices

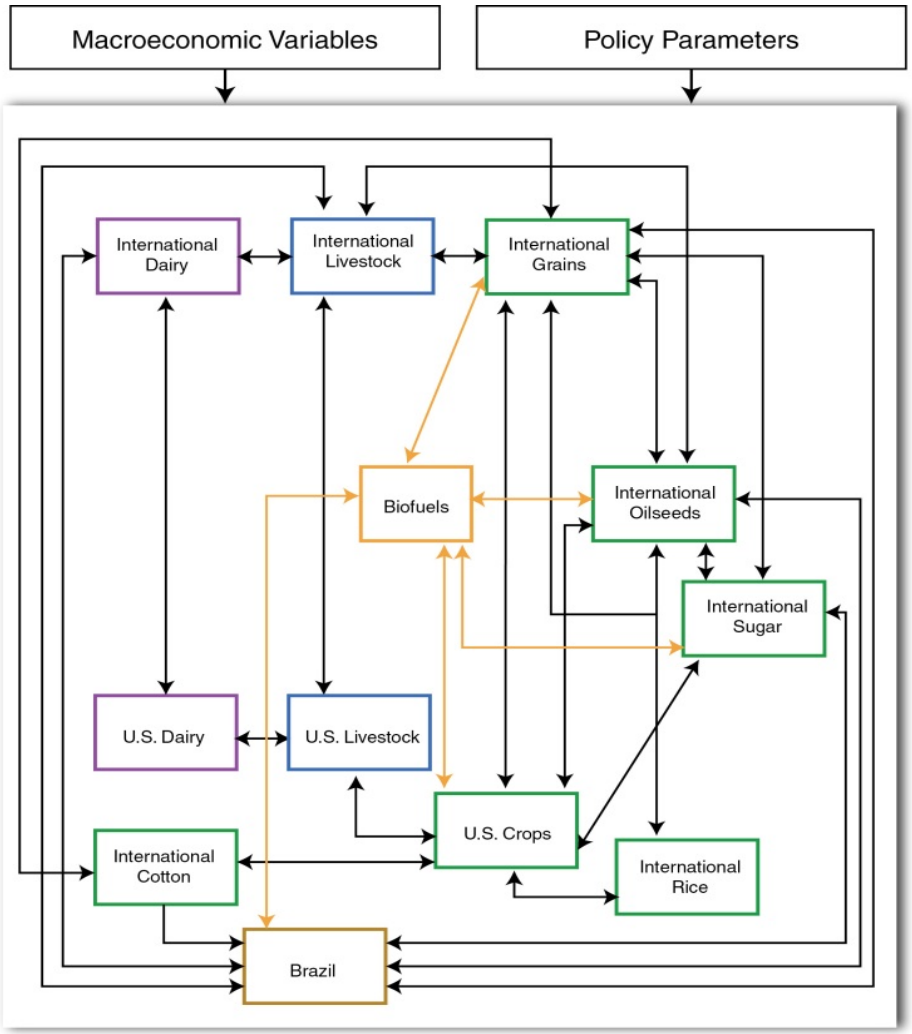
The EPA's U.S. nine-region database (EPAUS9r_12, version 1.0) is used for the MARKAL input data. The database is calibrated to AEO 2012.

U.S. Agricultural market model

- Part of a broad modeling system of the world agricultural markets
  - U.S. and international multi-market
- Non-spatial, partial-equilibrium simulation models includes major agricultural commodities[1]
  - temperate crops, sugar, dairy, livestock, and biofuels with by-products
- Behavioral equations for crop harvested acreage, domestic food, animal feed, and industrial uses such as biofuels production, trade, and stocks
- Calibrated to the latest historical data from various sources on supply, utilization, and prices
  - USDA-NASS, WASDE, and EIA
- Solves for prices that balance supply and demand annually with reduced form equations that mimic trade responses from world markets
- Generates annual ten-to-fifteen-year projections for agricultural commodity supply, utilization, and prices

1. Elobeid et al. 2013, Fabiosa et al. (2010), Tokgoz et al. (2008)

U.S. Agricultural market model



- U.S. crops model uses variable costs of production (COP) from a model which projects these costs by crop and by region
  - Linked to CARD agricultural model and MARKAL energy model
- COP model uses energy prices from MARKAL
  - Crude oil, natural gas, electricity

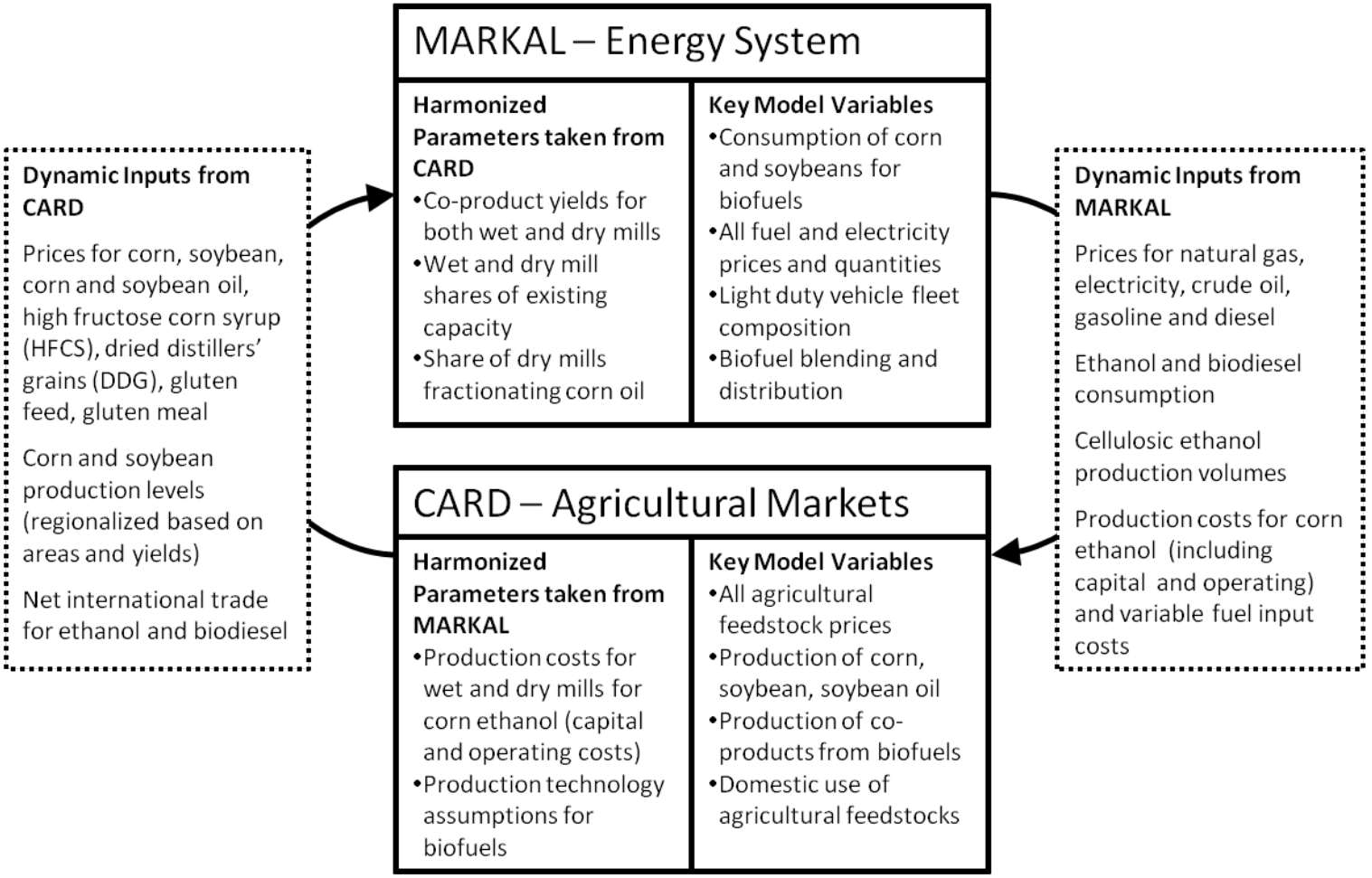
Comparison of modeling frameworks

	EPAUS9r - MARKAL	CARD
System	U.S. energy system	U.S. agricultural crop and biofuel markets
Main use	Does not provide forecasts, scenario analysis	Provides market outlook and policy analysis
Geographic coverage for supply/demand functions	Regional supply curves for domestic supply and imports of crude oil, refined petroleum products, natural gas and coal	Regional supply curves and national demand levels with reduced form trade linkages
Regional resolution	9 U.S. Census Divisions for all outputs	National with some regional/state level results
Modeling philosophy	Provide prescriptive scenarios; perfect foresight Optimizes on discounted total energy system cost	Provide forward looking projections based on long-term historical and econometric relationships
Modeling horizon	2005-2055, 5-year increments	2010-2025, 1-year increments

Comparison of modeling frameworks

	EPAUS9r - MARKAL	CARD
Sectors	Transportation, industrial, residential, commercial, electric and refineries	Crop commodities and biofuels
Biofuel coverage	Corn-ethanol, cellulosic ethanol, biodiesel, bioenergy (electricity and heat/steam production from biomass)	Corn-ethanol, biodiesel, cellulosic ethanol (imported advanced/sugarcane ethanol
Biomass feedstocks	Corn, soybean, corn stover, other agricultural residues, forest residues, primary mill residues, urban wood waste, grassy energy crops, municipal solid waste	Corn, soybean oil, canola oil, sugarcane (imported from Brazil as part of advanced biofuels)
Other details	Technological detail for light duty vehicles including a suite of flex fueled vehicle technologies	Harvested area and yield, and variable costs of production for major crops by region/state

Integrated MARKAL-CARD modeling framework



The impacts of higher energy prices on the agricultural and biofuel sectors using the unlinked models will be similar to the impacts when using the integrated model in terms of direction but are larger in terms of magnitude.

Generating baseline and scenarios in the integrated MARKAL-CARD modeling framework

1. Harmonization of modeling inputs (updated historical data) and assumptions (e.g., regarding technology and policy representations)
2. Identification of variables to be included in data exchanges
3. Generation of the integrated baseline by running the two models iteratively until they converge on corn ethanol production volumes
4. Running scenarios using the integrated modeling framework

Scenario descriptions

- Scenario 1: 25% increase in crude oil prices
- Scenario 2: 25% increase in both crude oil and natural gas prices
  - Run CARD and MARKAL separately for each scenario
  - Run each scenario in CARD-MARKAL integrated modeling framework
  - Compare results for the model year 2025/2026

Results – Acres and Bushels

		Baseline	Scenario 1: 25% increase in Crude Oil Price		Scenario 2: 25% increase in Crude Oil and NG Prices	
			CARD Only	Integrated	CARD Only	Integrated
Harvested acres						
Corn	M acres	92.5	6.11	3.66	3.26	3.46
Soybeans	M acres	73.5	-3.74	-2.27	-2.06	-2.16
Wheat	M acres	42.5	-1.69	-0.92	-1.11	-1.01
Production						
Corn	M bushels	17,581	6.31	3.94	3.28	3.68
Soybeans	M bushels	3,602	-4.00	-2.36	-2.28	-2.26
Wheat	M bushels	1,999	-1.86	-0.90	-1.33	-1.05
Soybean Oil	M pounds	21,997	-1.98	-1.24	-1.09	-1.19

- % change in corn acreage is almost halved in the integrated results for Scenario 1. The effects of crude oil price increase is dampened by the integrated modeling framework's feedback mechanisms.
- Increase in crude oil prices created a good competition for biofuels, however simultaneous increase in natural gas prices increased the cost of production and thus dampened the increase in corn production in Scenario 2 relative to Scenario 1.

Results – Prices and Cost of Production

		Baseline	Scenario 1: 25% increase in Crude Oil Price		Scenario 2: 25% increase in Crude Oil and NG Prices	
			CARD Only	Integrated	CARD Only	Integrated
Price						
Corn	$/bushel	4.76	10.93	4.64	7.03	4.74
Soybeans	$/bushel	11.07	2.50	1.34	1.48	1.29
Wheat	$/bushel	5.98	5.08	2.34	3.30	2.43
Soybean Oil	cents per pound	54.35	1.01	0.44	0.60	0.48
Gasoline, retail	$/gallon	3.75	20.20	10.42	20.37	9.17
Biodiesel	$/gallon	5.10	0.50	0.21	0.30	0.22
Ethanol (conv.)	$/gallon	1.92	8.41	4.34	9.61	5.91
Variable production expenses						
Corn	$/acre	405.21	1.27	0.19	3.89	2.74
Soybeans	$/acre	165.36	1.51	0.07	1.83	0.40
Wheat	$/acre	159.55	2.02	0.21	2.90	1.17
Fertilizer Prices (Calendar Year 2025)						
Nitrogen	Prices Paid Index (1990-92=100)	399.83	0	0.01	9.27	8.76
Potash & Phosphate	Prices Paid Index (1990-92=100)	538.78	0	0.41	1.62	2.25

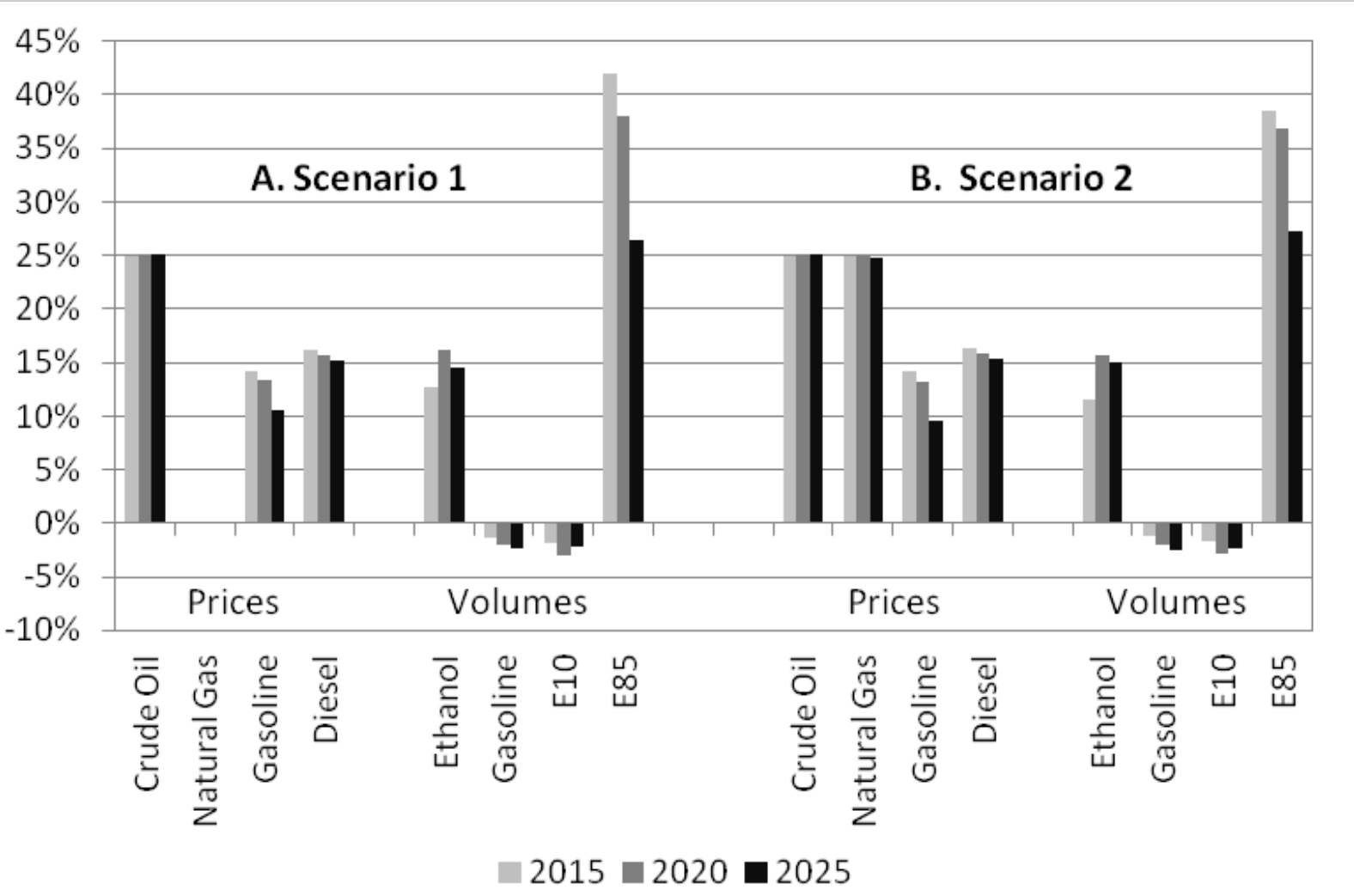
- increased natural gas prices increase the fertilizer prices thus increase the cost of production for corn.

Results – Volumes

	Baseline	Scenario 1: Crude Oil Price			Scenario 2: Crude Oil plus NG Prices		
	M gal	MARKAL Only	CARD Only	Integrated	MARKAL Only	CARD Only	Integrated
Total ethanol production	22,451	18.2	36.97	16.6	17.3	21.03	17.1
Corn ethanol	17,324	25.9	38.69	18.7	23.7	21.89	18.0
Cellulosic ethanol	5,127	-7.7	N/A	9.5	-4.4	N/A	14.1
Soybean oil biodiesel	1,009	0.0	-0.87	-0.5	0	-0.52	-0.5

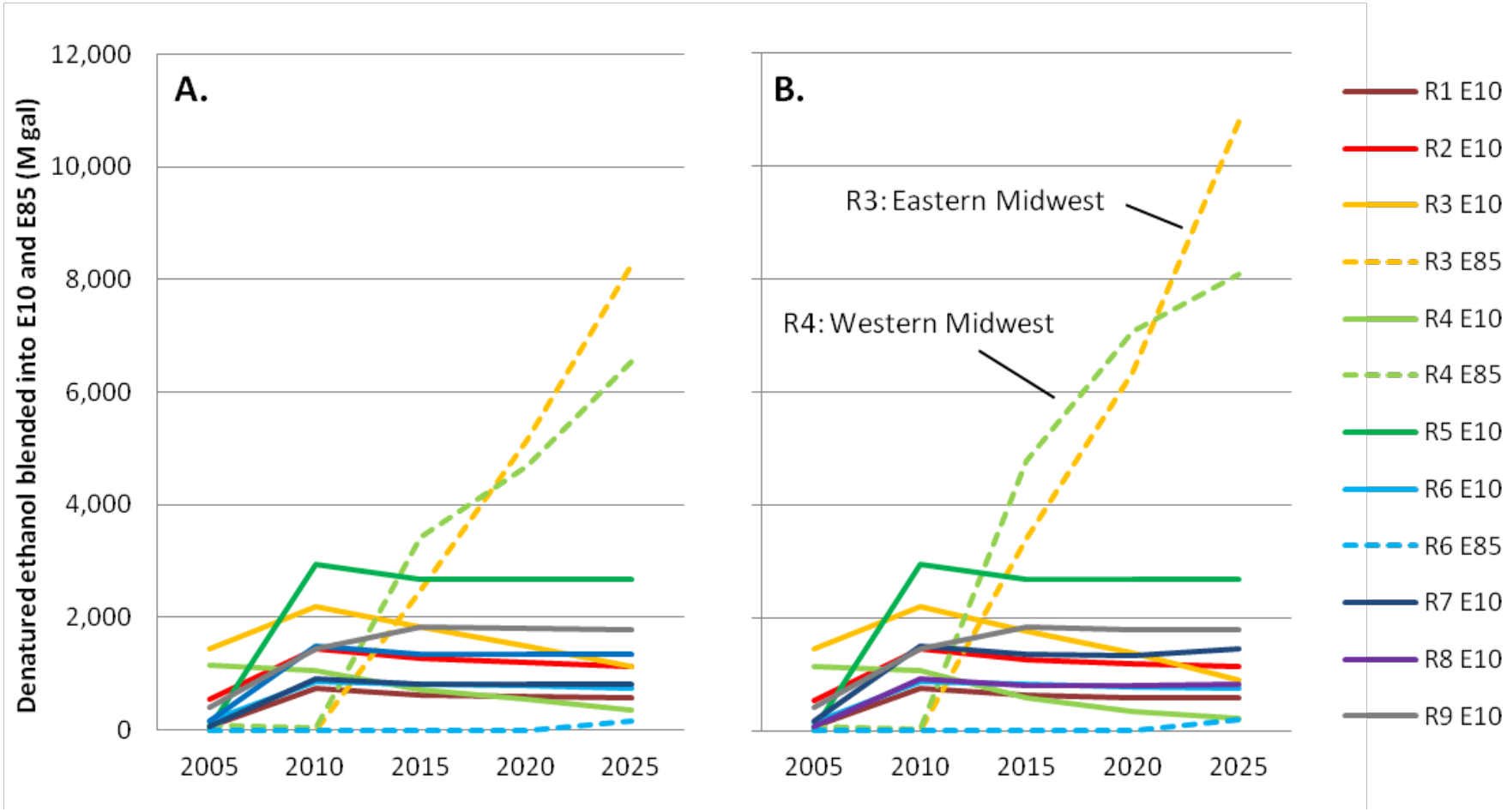
- Without the integrated framework both models overestimate the ethanol production under increased crude oil prices

Integrated results: changes in the energy system



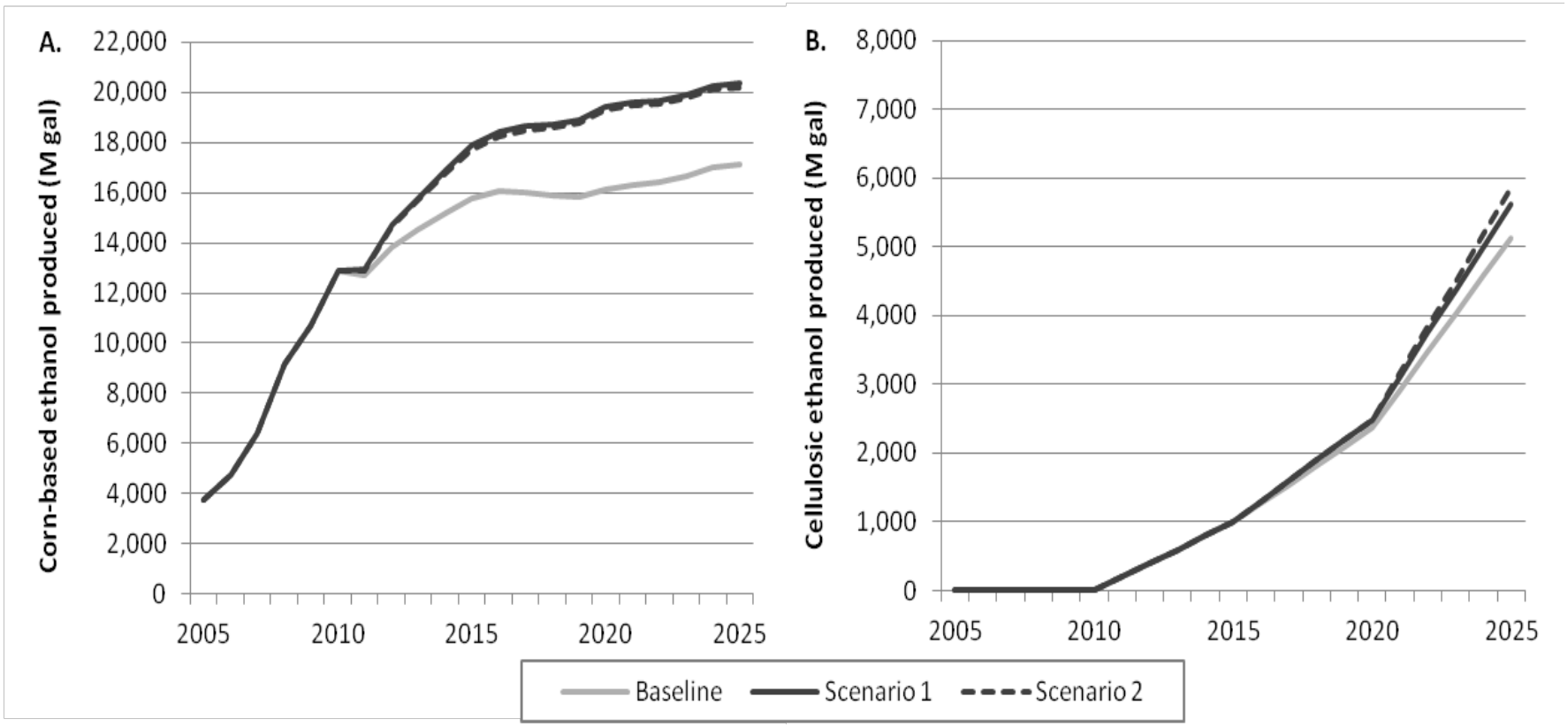
Energy prices and fuel consumed: Percent change from the baseline for both scenarios.

Integrated results: changes in the energy system



Regional changes in volumes of denatured ethanol blended in E10 (solid lines) and E85 (dashed lines) for (A) Baseline and (B) Scenario 2.

Integrated results: changes in the energy system



Denatured ethanol volumes for the baseline and two scenarios from (A) corn-based ethanol production, and (B) cellulosic ethanol production.

Conclusions

- The impact of crude oil prices on the demand for biofuels and their feedstocks is much greater than the impact of natural gas prices on the cost of production of corn and biofuels.
  - The main driver is the interaction between crude oil-based fuels and biofuels.
- In terms of total ethanol demand, the question of coupled versus non-coupled natural gas and crude oil markets appears to be secondary to the trends in the crude oil markets alone.
- The major shift in scenarios occurs in the increased penetration of FFVs, geographically concentrated in the ethanol-producing states.
  - As the use of E85 increases across scenarios, there are substantial differences in how that demand for additional ethanol is met via a mix of corn-based ethanol and cellulosic ethanol.

Conclusions

- Higher natural gas prices, coupled with high crude oil prices, provide the largest impetus to the cellulosic ethanol markets due to the disadvantages placed on corn ethanol via increased fertilizer prices, and the cost of natural gas as a fuel for dry mill facilities
- Modeling the energy and agricultural markets separately shows greater impacts of the crude oil and natural gas price increases, whereas the integrated modeling framework has more moderated impacts on crop prices and biofuel volumes.

Thank You

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