Capturing Dynamic Linkages Between Agriculture and Energy in Biofuel Assessment: The Case of Iowa

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This article is based on the study "Integration of agricultural and energy system models for biofuel assessment," by Elobeid, A., S. Tokgoz, R. Dodder, T. Johnson, O. Kaplan, L. Kurkalova, and S. Secchi published in Environmental Modeling and Software, Volume 48, October 2013, Pages 1-16.

THE EXPANSION of biofuel production brought about a significant change in the dynamics between agriculture and energy. In the past, energy prices influenced the agricultural sector primarily through agricultural commodity production and transportation costs. Now, because of biofuels, the energy sector impacts the agricultural sector through feedstock demand and prices; and conversely, the agricultural sector now impacts energy prices through its competition in the transportation energy sector. In the past, studies analyzed the impact of biofuel production on agricultural and energy markets separately without accounting for sector feedback. However, in analyzing the impact of biofuels, the interconnectedness between the agricultural and energy sectors should not be ignored.

We present a modeling framework to capture the dynamics of this 'new' linkage between agriculture and energy. Our framework incorporates agricultural and energy market interactions at the macro level, as well as the assessment of farmers' production practices at the micro (field) level in Iowa. This is achieved by linking two macro models: the Center for Agricultural and Rural Development's (CARD) US agricultural markets model and the US Environmental Protection Agency's (EPA) MARKet ALlocation (MARKAL) energy systems model.[1] The models vary in that CARD's model treats energy variables, such as crude oil and natural gas prices, as exogenous, and treats agricultural variables such as corn prices as endogenous. The MARKAL model, on the other hand, treats energy prices as endogenous and agricultural variables such as corn prices as exogenous. The two models are first run separately to establish an initial baseline for each model; once the models are linked, a joint baseline that projects supply, utilization, and prices in the agricultural and energy markets up to the year 2024 is established. The joint baseline allows for feedback between the agricultural and energy sectors in the model, and then the results from the initial baseline and the integrated baseline are used in a micro model to assess the shifts in farming practices resulting from biofuel production.

We use a field-level, GIS-based micro model to assess the land use implications of changes in the agricultural and energy markets in Iowa on a micro level. The micro-level model uses 30-square-meter grids based on USDA remote sensing crop cover maps and budget analysis to simulate the expected land use and management choices of Iowa farmers on each grid unit. The model assumes that Iowa famers choose between continuous corn, corn-soybeans, and corn-corn-soybeans rotations. There are also three alternative tillage systems: conventional, mulch, and no-till. Additionally, farmers can choose between collecting and not collecting corn stover without major erosion control problems. For each of the rotation-tillage-stover collection choices, the model estimates the yearly average expected net returns. The expected profit-maximizing rotation-tillage-stover collection choice is the one that maximizes the yearly average expected net returns.

Table 1 shows the initial baseline results for marketing year 2020/21 for the CARD agricultural model (Column A) and the baseline results after the integration with MARKAL (Column B) when feedback between the two models is endogenized.[2] Pre-linkage, when the energy sector is exogenous in the CARD model, supply demand and prices for corn and ethanol are higher—gasoline prices are 18 percent higher relative to post-linkage levels. Corn ethanol demand is above mandated levels, which leads to higher demand for corn as a feedstock for ethanol production. The higher corn price results in more land planted to corn. Post-linkage CARD baseline results (Column B) show lower ethanol production (by 22 percent) and disappearance (by 12 percent) when compared with the pre-linkage CARD baseline. Consequently, corn planted area and production are lower. Thus, with biofuel production, not accounting for feedback between the agricultural and energy sectors tends to overestimate corn and ethanol supply, demand, and prices.

Both pre- and post-linkage results for crop area and prices from the CARD model and regional energy prices from MARKAL are incorporated into the micro model to see how land use and management decisions change with and without feedback effects. Figure 1 shows the micro-level results for the

Pre- and post-linkage baseline results in the CARD agricultural model for marketing year 2020/21

	Column A			Column B		
	Initial (Pre-linkage) Baseline			Post-linkage (Converged) Baseline		
	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat
Planted area (million acres)	114	68	61	95	74	59
Production (million bushels)	18,916	3,164	2,358	15,818	3,349	2,417
Domestic use (million bushels)	16,259	2,441	1,356	13,164	2,416	1,327
Feed & residual[a]	6,155	2,247	214	5,389	2,234	168
Fuel alcohol	8,579			6,320		
HFCS	581			535		
Food & other	915		1,056	896		1,075
Seed	28	194	86	24	183	84
Exports (million bushels)	2,605	731	1,117	2,662	939	1,203
Ending stocks (million bushels)	1,212	221	332	1,493	250	631
Farm price ($/bushel)	4.37	10.81	5.86	4.28	9.96	6.37
Variable production expenses ($/acre)	301	140	126	320	141	134

	Initial Baseline	Post-linkage Baseline
	Ethanol	Ethanol
Production (million gallons)	37,153	28,900
From corn	24,618	18,357
From other feedstocks[b]	35	0
From cellulosic	12,500	10,543
Domestic disappearance (million gallons)	40,527	35,572
Conventional	24,500	12,775
Other advanced ethanol	3,526	12,255
Cellulosic	12,500	10,543
Net imports (million gallons)	3,500	6,741
Ending stocks (million gallons)	2,028	1,268
Unleaded gasoline price, FOB Omaha ($/gallon)	2.71	2.30
Unleaded gasoline price, retail ($/gallon)	3.33	3.06
Conventional ethanol price, rack Omaha ($/gallon)	1.69	1.60

[a] For soybeans, this refers to crush.
[b] This represents ethanol from non-corn feedstocks, which were not included in the integrated version.

pre- and post-linkage baselines for Iowa cropland. The pre-linkage baseline shows larger corn acreage under continuous corn with stover removal when compared to the post-linkage baseline, which has more corn-soybean rotation.

Moving from the pre- to post-linkage baseline, over 2.3 million acres of cropland (less than 11 percent of Iowa's cropland) switches from continuous corn to corn-soybeans and from conventional to conservation tillage. This result has important implications for the environmental outcomes of biomass production—continuous corn rotation requires higher levels of nitrogen fertilizer and is associated with higher rates of conventional tillage as opposed to more environmentally benign conservation tillage. Figure 1 shows that, in the pre-linkage baseline, more intensified corn production is concentrated on Iowa's most productive land in the north-central part of the state. This result indicates that without the linkage between agriculture and energy, models may overestimate the extent

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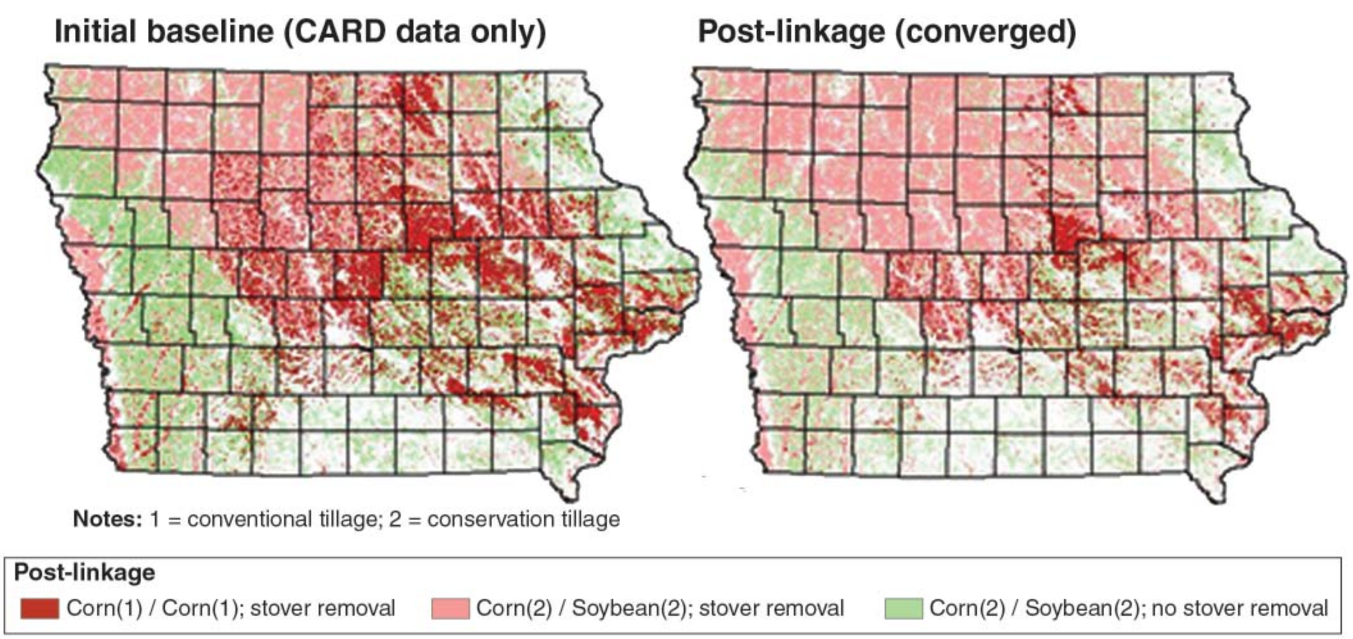

Figure 1. Crop rotations and management practices in Iowa pre-and post-linkages

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of continuous corn and the associated environmental impacts.

Our results show that, given the expansion of biomass feedstock production, the interplay between agriculture and energy affects land use and management decisions. As biofuel production continues to rely on land-based feedstocks, it becomes increasingly important to accurately assess the agricultural and environmental effects of these changes. Iowa is likely to experience significant intensification and extensification of production in terms of expanding land for biofuel production. Analyzing the impact of biofuels with limited attention to the linkages between agricultural and energy sectors, and how those coupled markets affect decisions at the field level, provides an inaccurate assessment. Thus, an integrated agricultural-energy market framework is necessary for accurate analysis and understanding the full ramifications of biofuel expansion. ■

Footnotes

[1]For the full description of the two models and how they are linked, see Elobeid et al. (2013).

[2] Comparison between the pre- and post-linkage results for the MARKAL model are available in Elobeid et al. (2013).

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