# *ENERGY INPUTS IN CROP PRODUCTION: ESTIMATION OF DERIVED DEMAND*

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## Overview

Crop production is profoundly affected by the changes in energy prices as it requires a number of energy inputs: diesel fuel to power planting and harvesting machinery, LP gas to dry harvested crops, and nitrogen fertilizer (which is derived from natural gas) to supply crop nutrients. The changes in energy prices change the costs of operation and alter the net returns to farming for energy and/or fertilizer intensive crops. Most of previous assessments of the derived demand for energy inputs in crop production have been conducted before the significant structural changes in energy consumption in the U.S. agriculture such as the shift from gasoline to diesel use from the 1970s to the early 1990s (Miranowski, 2005).While recent discussions suggest that the increase in fuel prices is likely to widen the use of conservation tillage and lower fertilizer application rates, little is known about the magnitude of these responses. Complicating the assessment is the multitude of the potential farmers' choices - notably, the possibilities for not only changing the levels of energy inputs, but also for substituting between various inputs and/or between various outputs (which crops to grow and in what rotation).

In addition to the need to capture both input and output substitution effects, the evaluation of the aggregate, region-total response to the changes in energy prices is further complicated by the inherent within-region heterogeneity of production conditions. Because of the heterogeneity of land, the changes in energy prices may cause a significant compositional change in the use of land in a given region.

The purpose of this paper is to estimate the elasticities of derived demand for energy inputs for the state of Iowa. In modelling the impact of energy prices, we focus on three components of energy use in crop production: diesel fuel, nitrogen fertilizer, and LP gas. Diesel and fertilizer are the two largest components of the total energy consumption on US farms with fertilizer accounting for 498 Trillion Btu and diesel – for 469 Trillion Btu in the total of 1718 Trillion Btu consumed on US farms in 2002 (Miranowski, 2005). Corn Belt, of which Iowa is a significant part, used the most fuel among U.S. farm production regions in 2003 (Miranowski, 2005). Nitrogen accounted for about 56% of all chemical fertilizer used in the U.S. agriculture in 2005, and the largest share of nitrogen use, 42% of the total, has been attributed to corn (Huang, 2007). Nitrogen fertilizer constitutes the largest component of operating costs for corn producers: on average, some 18% of the total operating cost in 2005 (Huang, 2007). LP gas used for drying crops accounted for 79 Trillion Btu consumed on US farms in 2002 (Miranowski, 2005).

One motivation for the study comes from the recent changes in energy prices. This study is also motivated by the understanding that cropping, tillage and fertilizer use patterns significantly affect the environmental footprint of agricultural production. Many current conservation programs specifically target the most environmentally sensitive land such as the land classified by the U.S. Department of Agriculture (USDA) as Highly Erodible Land (HEL). Some 29 percent of Iowa cropped land is HEL. HEL is subject to conservation compliance which requires farmers to implement soil conservation practices to maintain eligibility for government programs, thus restricting farmers' choices. Our study provides the crucially needed assessment of the impact of conservation compliance on the responsiveness of the derived demand for energy inputs. This information could help policy-makers in identifying the geographic areas that might need strengthened conservation compliance enforcement efforts and/or alternative conservation incentives.

## Methods

To study the effect of a change in energy prices we use a simulation model of Iowa crop production operating on a 56 square meter grid coming from the USDA National Agricultural Statistical Service (NASS) GIS-based remote-sensing crop-cover maps for the year 2009 (USDA/NASS, 2009; Elobeid et al., 2013). For each grid unit, we use the measures of soil productivity and environmental vulnerability that come from the Iowa Soil Properties and Interpretations Database GIS soil data layer. Soil productivity is measured by the Corn Suitability Rating (CSR), an index from 0 to 100 with the higher CSR values corresponding to the higher land's productivity in corn production. Environmental vulnerability of cropland is measured by the HEL code. USDA Natural Resource Conservation Service classifies cropland as HEL if the potential of a soil to erode, considering the physical and chemical properties of the soil and climatic conditions where it is located, is eight times or more the rate at which the soil can sustain productivity. While most of Iowa cropland is of high productivity, most of the presently cropped HEL is of medium productivity.

In this study, we use the data on all the land that has been cropped in 2009 and has positive CSR and HEL map code values. Out of the total of 21,771,106 acres in the 2009 GIS-based crop-cover data, we are missing CSR and/or HEL indicators for only 0.22% and/or 0.42% of the total area, respectively. Overall, the study data covers approximately 95% of the state's cropped land. Under the assumption of expected profit maximization, the model we develop takes on the crop and production input prices as exogenous and predicts the farmers' choices of cropping rotation, fertilizer use, and tillage system choice, all by the varying soil quality, as represented by the CSR. We estimate the response to the changing energy prices by assessing the changes in the model's endogenous variables as the energy prices are exogenously varied.

## Results

We find that as diesel prices increase, (1) the changes towards fewer years of corn in rotations and less intensive tillage progress gradually from the lower- to the higher-quality land and the environmentally vulnerable land is affected by these changes to a greater extent than the erosion-free land, (2) the majority of the decrease in diesel use is attributable to the crop rotation changes rather than to the reduced tillage. The average elasticity of diesel use with respect to the price of corn has been estimated to be 0.406.The estimates of the own-price elasticities of the demand for diesel fuel range between -0.231 and -0.066, with an average of -0.135.

Total fertilizer use decreases as energy prices increase for three reasons, the two most important of which are related to changes in crop rotation. As the rotations shift towards fewer years of corn, there are fewer total acres of corn requiring nitrogen. Also, the acres of corn that remain have a greater percentage of corn following soy, which requires less average nitrogen per acre than corn following corn. The third reason is the gradual decrease in the profit-maximizing level of nitrogen use for any given rotation due to this production input becoming more expensive. The own-price elasticity of demand for nitrogen fertilizer has been estimated to be -0.783 on average.

## Conclusions

Our paper's contribution to the literature is both empirical and methodological. On the empirical side, we estimate the responsiveness of the derived demand for energy inputs for a major crop production region of the U.S. In contrast with previous work, we go beyond measuring the responsiveness as the expected change in the region-aggregate quantities such as the area under alternative crops and rotations, the amount of diesel fuel used, and the amount of fertilizer applied. Rather, we take the assessment of the impact of energy prices to a fundamentally richer level by evaluating the expected change in the *spatial distribution* of the rotations, fuel use, and fertilizer rates.

The methodological contribution of the study is in developing of an integrated economic and geographic modelling system that combines the newly available, field-level, GIS-based soil and cropping history data with the latest advances in soil and crop sciences' understanding of the response of crop yields to rotation, tillage, and nitrogen applications. The presented modelling system could be used for subsequent analyses of Iowa's crop production response to changing economic conditions and/or agricultural, energy, and conservation policies, as well as a prototype for other large-region crop production modelling systems. We estimate the marginal effects that are needed to improve the accuracy of existing, large-scale models of the U.S. energy and agricultural sectors (Elobeid et al., 2013). Due to unavailability of reliable estimates, most of these models do not presently explicitly account for the impact that the changing economic conditions may have on farmers' tillage choices, or on the total per-acre energy use in crop production in general (Whistance and Thompson, 2010).

## References

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