Effects of Relative Price Changes on the Land Allocation Dynamics among Top Staple Crops in the U.S. before and after the Energy Policy Act of 2005

Ekaterina Vorotnikova and James L. Seale Jr.
Graduate Student and Professor, respectivelly
Food and Resource Economics Department,
University of Florida

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Effects of Relative Price Changes on the Land Allocation among Top Staple Crops in the U.S. Before and After the Energy Policy Act of 2005

Ekaterina Vorotnikova and James Seale, Jr.
Authors are graduate student and professor, respectively. Food and Resource Economics Department, University of Florida

INTRODUCTION

The Energy Policy Act of 2005 (EPA 2005) mandates to mix ethanol with gasoline sold in the U.S., which increases the demand for corn and, as a consequence, corn prices rise. In response to high prices farmers allocate more land to growing corn (USDA 2011). However, since arable land is fairly fixed (Hertel 2011), there are reasons to believe that the expansion of corn production takes away land from other strategic staple crops. For instance, in the New York Times article "Crop Rotation in the Grain Belt," Barrionuevo (2006) points out that Kansas, traditionally known as the Wheat State, to the surprise of all produced 23% more corn than wheat.

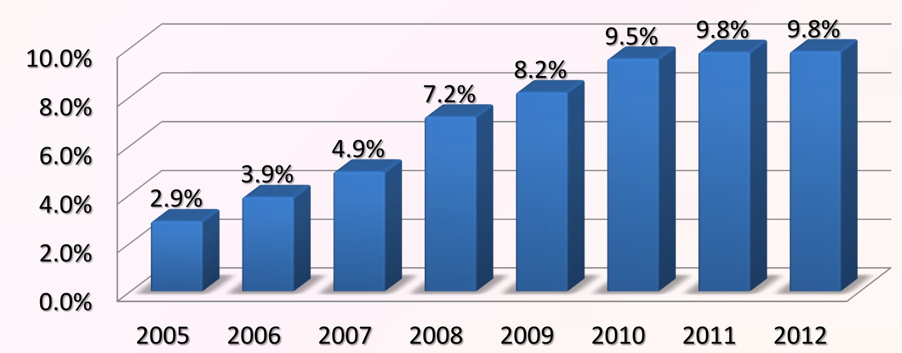
This paper tests if EPA 2005 introduces statistically significant structural changes to the U.S. farm land allocation dynamics. Specifically, it provides the effect of the relative price changes onto acreage in crop-specific pairs before and after the introduction of EPA 2005 policies.

DISSCUSSION

Energy Policy Act (EPA 2005) was passed by the U.S. Congress in 2005. It mandates blend of gasoline and ethanol with the end goal of at least 10% of ethanol being present in retail gasoline. The Act mandates 7.5 billion US gallons of corn based ethanol to be mixed with the gasoline sold by 2012. The following Energy Independence and Security Act of 2007 (EISA 2007) policy extends the target to 15 billion US gallons by 2022 (EPA 2013, De Gorter and Just 2009). Ethanol content in gasoline has expanded from 2.9 percent in 2005 to 9.8 percent in 2011 (Figure 2). Already by 2006 the United States has become the largest ethanol producer in the world ahead of Brazil producing 116 millions of barrels (Figure 3), comprising 45% of world ethanol production (EIA 2013) that year. Corn stocks diverted to ethanol production have increased significantly from around 20% in 2006 to on average 40% in the last three years (Figure 4). As a consequence, corn prices rise sharply, and in response to the high prices, plantings of corn have increased (Figures 5 and 6). However, additional agricultural land is scarce, there are reasons to believe that corn acreage expands at the expense of other crops. Figure 7 displays the dynamics of crop shares since 1950. Using differential framework this study analyzes whether there are a statistically significant structural changes in land allocation dynamics among top five principle crops produced in the U.S. such as corn, cotton, hay, soybeans, wheat after EPA 2005. The study identifies crops and intensity with which they compete for land with each other before and after the enactment of EPA 2005. The model allows to test whether the changes in the land competition dynamics in each crop-specific pair are significant. The model in this study provides crop-pair specific dynamics of competition for land, i.e. the effect of price changes of one crop onto another one's acreage, before and after the ethanol mandate of 2005.

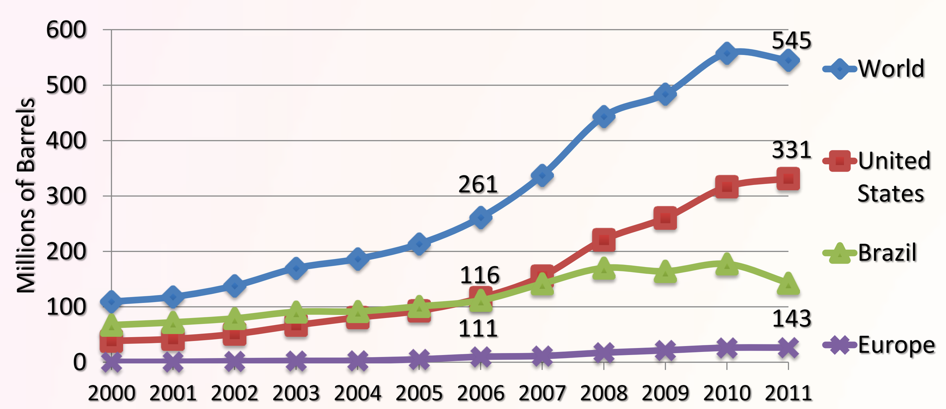
Based on 1960-2012 price and production data for crops, the study identifies specific crops whose acreages respond statistically different to its own and other crops price changes before and after 2005. The effect of prices on acreages is expressed as an elasticity measure. The magnitude of changes between two periods is also calculated.

Figure 2. Percentage of Ethanol in Gasoline 2005-2012



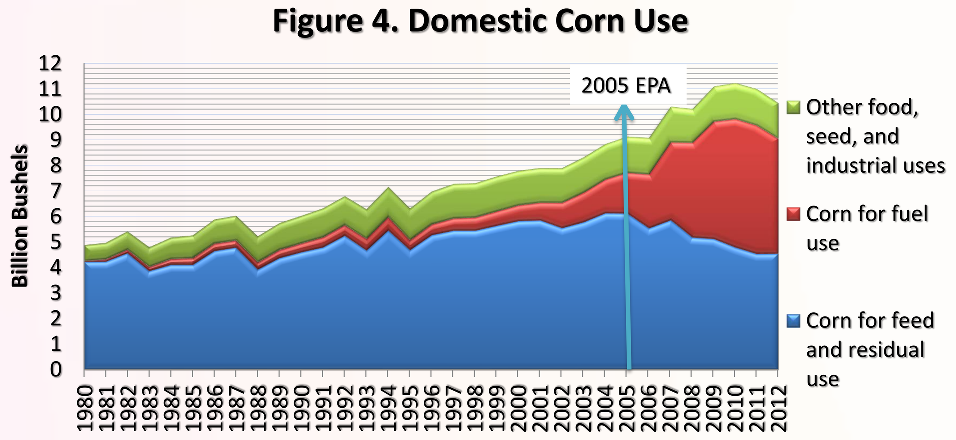
Source: Calculated based on data from U.S. Energy Information Administration (EIA) 2013 and U.S. Department of Energy (USDOE) 2013

Figure 3. U.S. Ethanol Production Relative to the World 2000-2011



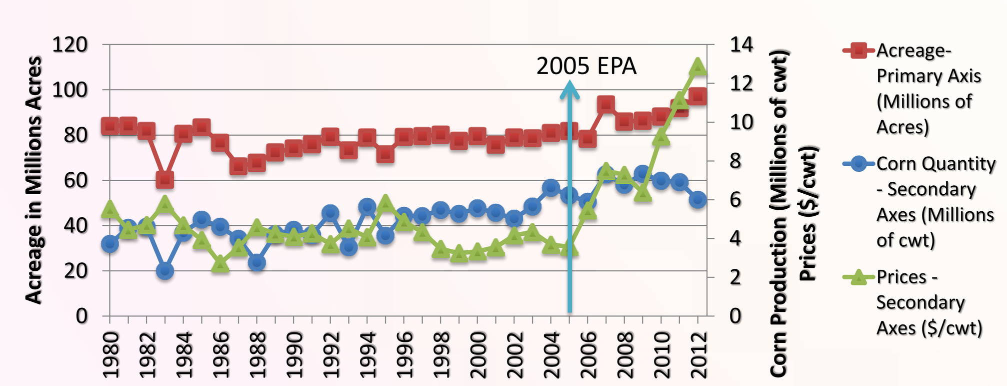
Source: U.S. Energy Information Administration (EIA) 2013

Figure 4. Domestic Corn Use



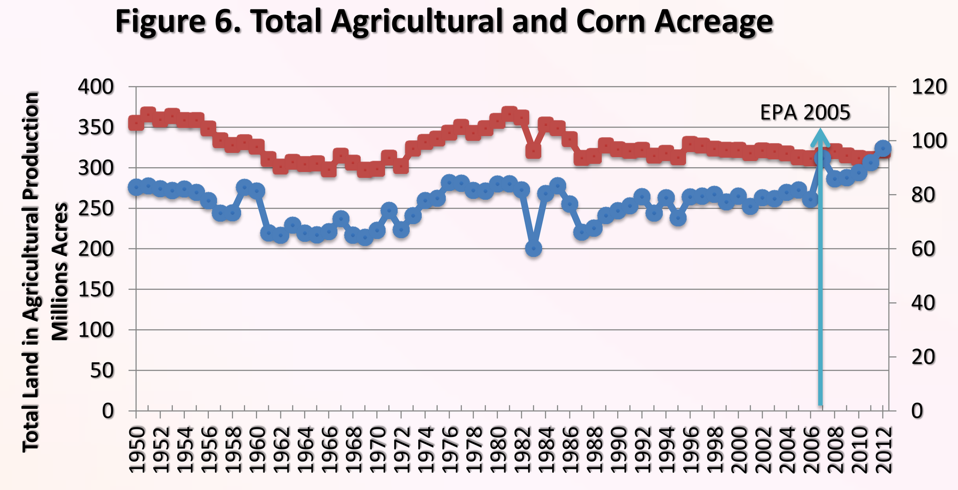
Source: USDA, Economic Research Service 2013 (Market year September-August).

Figure 5. Corn Acreage, Production, and Prices 1980-2012



Source: NASS 2013

Figure 6. Total Agricultural and Corn Acreage



Source: NASS 2013

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Barrionuevo, A. 2006. "Crop Rotation in the Grain Belt." *The New York Times – Business*, September 16.
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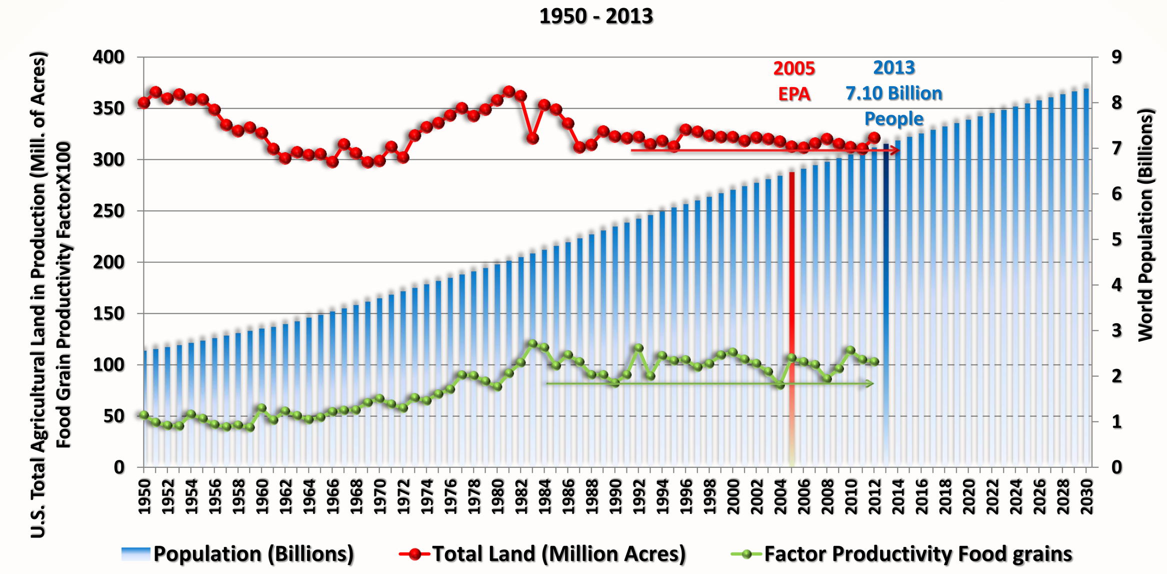
EPA 2005 in the Broader Paradigm in the U.S. Agricultural Production

Thomas Hertel, a distinguished professor and past president of Agricultural and Applied Economics Association (AAEA), in his presidential address to the AAEA in 2010 points out that, as a consequence of population growth (7.10 Billion people in 2013), the farming industry faces significant pressure to expand agricultural production, especially for the staple grains sector (Hertel 2011). In the U.S., however, arable land is fairly fixed and yield is almost at the maximum for many staple crops (Hertel 2011). U.S. total land in agricultural production has remained relatively flat for the years 1950 to 2013 (Figure 1) while Food Grain Productivity has also remained relatively flat approximately since 1985 (NASS 2013).

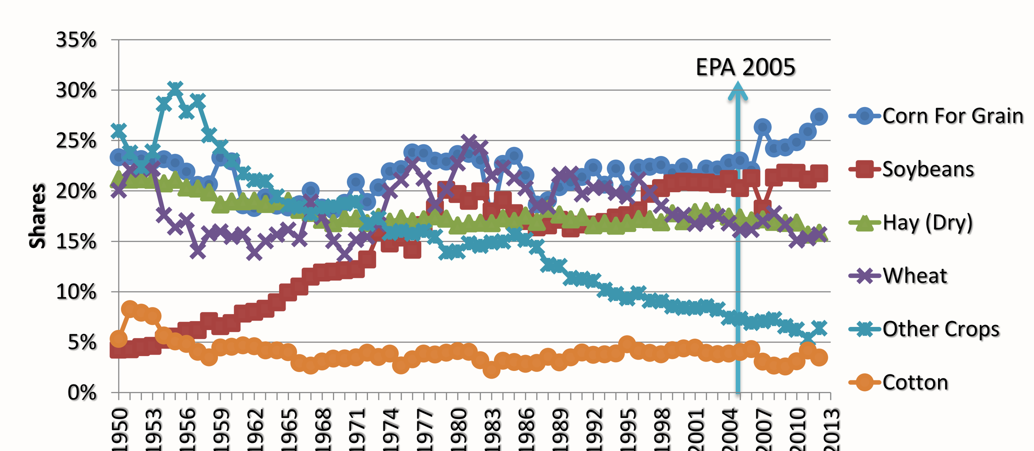
When Energy Policy Act is enacted in 2005 (EPA 2005), which mandates ratio of ethanol in gasoline, it creates additional demand for corn in the environment of already scarce arable land. As farmers allocate more land to corn production (USDA 2011), there are reasons to believe that corn's acreage expands at the expense of acreages of other crops (Figure 6).

Figure 1. U.S. Total Land in Production, World Population, and Food Grains Total Productivity 1950 - 2013



Sources: United States Census Bureau (USCB) 2013; National Agricultural Statistical Services (NASS) 2013;

Figure 6. Crop Shares of Total Land in Production 1950-2013



Source: NASS 2013

DATA AND METHODOLOGY

The data span years 1960 to 2012 and are collected from National Agricultural Statistical Service (NASS). The data includes annual quantity of produced crops, prices, and acreages for the following crops: corn, cotton, hay, wheat, and soy plus 12 other crops whose quantities are summed to the category "other." This category contains: 1) rice; 2) potatoes; 3) beans; 4) peas; 5) rye; 6) oats; 7) barley; 8) tobacco; 9) flaxseed; 10) peanuts; 11) sweet potatoes; and 12) sorghum wheat – comprising 5% of U.S. agricultural output.

Rotterdam parameterization model is used to examine the multiproduct U.S. agricultural industry with a quasi-fixed input, land, as developed by Vorotnikova et al. (2013).

$$\bar{f}_{it} d(\ln L_i) = \theta_i d(\ln L)_t + \sum_{j=1}^{n} \pi_{ij} d(\ln P_{ij})_t + \varepsilon_t$$

The model differentiates from the previous one by including the interaction dummy variable that distinguishes the years leading up to the year of the policy from the years after it, 1960-2004 and 2005-2012.

$$\bar{f}_i d(\ln L_i) = \theta_i d(\ln L) + \theta_i^k Yd(\ln L) + \sum_{j=1}^{n} \pi_{ij} d(\ln P_{ij}) + \sum_{j=1}^{n} \pi_{ij}^k Yd(\ln P_{ij}) + \varepsilon$$

θ_i^k and π_{ij}^k parameters allow us to test whether the structural changes in the land allocation dynamics due to EPA 2005 are statistically significant. TSP 5.0 software is used to obtain the results.

Table 1. Output Price and Land Elasticities of the Estimated Rotterdam Model, 2005-2012

		Crop Prices						
	Crops	Corn	Cotton	Hay	Soybeans	Wheat	Other Crops	Land
Crop Land Shares	Corn	0.430***	-0.035	-0.033	-0.381***	-0.111	0.130**	0.923
		(0.081)	(0.032)	(0.043)	(0.066)	(0.074)	(0.055)	(0.67)
	Cotton	-0.248	0.859***	-0.401**	-0.547	0.711***	-0.374*	-6.808***
		(0.230)	(0.222)	(0.208)	(0.372)	(0.378)	(0.221)	(2.20)
	Hay	-0.048	-0.082**	0.083	0.083	-0.173*	0.137**	0.687
		(0.063)	(0.043)	(0.069)	(0.083)	(0.099)	(0.057)	(0.57)
	Soybeans	-0.446***	-0.090	0.067	0.697***	-0.077	-0.151**	0.953
		(0.077)	(0.061)	(0.067)	(0.138)	(0.123)	(0.072)	(0.72)
	Wheat	-0.167	0.150***	-0.179*	-0.099	0.411**	-0.116	2.235*
		(0.111)	(0.080)	(0.102)	(0.158)	(0.205)	(0.101)	(1.19)
	Other Crops	0.475**	-0.192*	0.343**	-0.472**	-0.282	0.128	3.221
		(0.202)	(0.114)	(0.144)	(0.224)	(0.245)	(0.268)	(2.44)

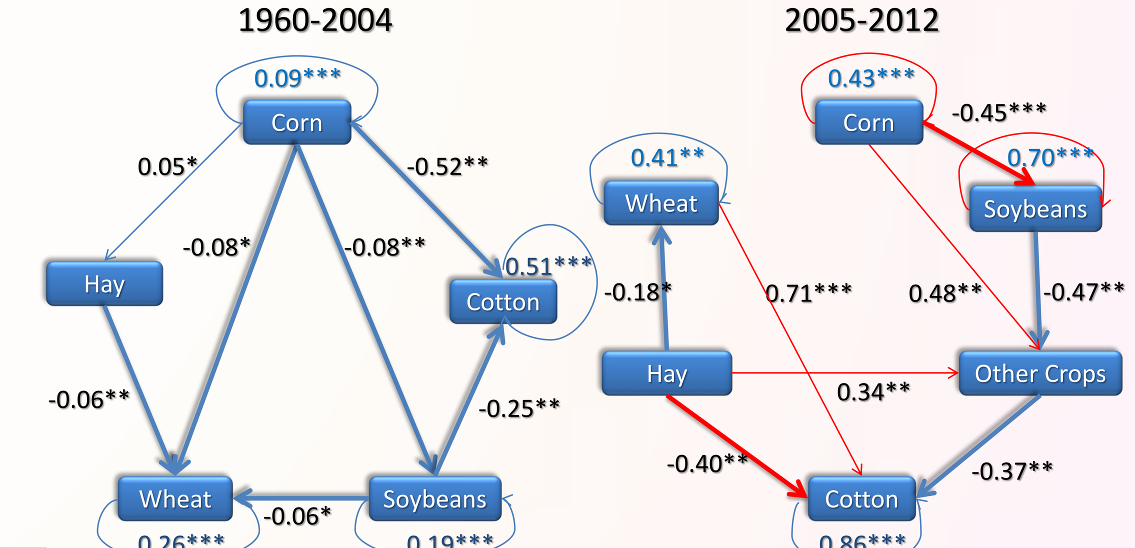
Note: figures in parenthesis are standard deviations.
*** - significant at 1% level; ** - significant at 5% level; * - significant at 10% level.

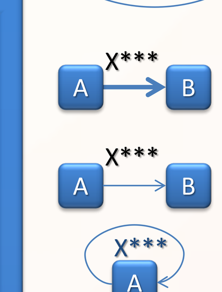
Table 2. Output Price and Land Elasticities of the Estimated Rotterdam Model, 1960-2004

		Crop Prices						
	Crops	Corn	Cotton	Hay	Soybeans	Wheat	Other Crops	Land
Crop Land Shares	Corn	0.092**	-0.015	0.037*	-0.069**	-0.052***	0.007	1.656***
		(0.048)	(0.018)	(0.023)	(0.029)	(0.030)	(0.034)	(0.141)
	Cotton	-0.519**	0.507***	0.063	-0.247**	-0.146	-0.071	1.740***
		(0.230)	(0.093)	(0.084)	(0.103)	(0.095)	(0.130)	(0.470)
	Hay	0.053*	0.013	0.009	-0.003	-0.058**	-0.014	0.125
		(0.034)	(0.017)	(0.031)	(0.027)	(0.024)	(0.033)	(0.121)
	Soybeans	-0.080**	-0.041**	-0.002	0.192***	-0.043*	-0.025	0.399***
		(0.034)	(0.017)	(0.021)	(0.037)	(0.028)	(0.033)	(0.146)
	Wheat	-0.077*	-0.031	-0.060**	-0.055*	0.258***	-0.034	1.702***
		(0.044)	(0.020)	(0.025)	(0.035)	(0.054)	(0.042)	(0.235)
	Other Crops	0.024	-0.037	-0.035	-0.079	-0.083	0.209	0.591
		(0.126)	(0.067)	(0.083)	(0.103)	(0.101)	(0.166)	(0.509)

Note: figures in parenthesis are standard deviations.
*** - significant at 1% level; ** - significant at 5% level; * - significant at 10% level.

Figure 7. The Dynamics of Competition for Land before and after 2005





Notation:
X indicates elasticity. Denote own-price-land elasticity by a circular arrow and cross-price-land elasticity by a straight arrow. Thick arrow is used for the crops displaying competing dynamics and thin arrow – for those with complimentary dynamics. Since elasticities are not symmetric, for convenience only the highest by magnitude elasticity of the two possible combinations, A-B and B-A, is displayed. In other words, the direction of the arrow indicates which crop's price changes affect the land share of the other more significantly than the other way around.

Red color marks elasticities that are determined to be significantly different between the two periods before and after 2005 according to the results of the test for significant of differences in elasticities between the two periods.

*** - significant at 1% level;
** - significant at 5% level;
* - significant at 10%;

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U.S. Environmental Agency (EPA). 2013. "Renewable Fuel Standard Program." Available at http://www.epa.gov/otaq/fuels/renewablefuels/index.htm (accessed March 16, 2013).

RESULTS

The results confirm that after the enactment of EPA 2005 policy there are statistically significant structural changes in the allocation dynamics of the U.S. farm land, especially it is the case for corn and soybeans as well as hay and cotton. In Figure 7 the diagram on the left schematically represents the dynamics of land allocation among crops for 1960-2004 period, and the diagram on the right – for 2005-2012 period. The digram is a schematic representation of output price-land elasticities displayed in Tables 1 and 2, further referred to as price elasticity. It measures how 1% price change in one crop affects the land that's being allocated to that smae crop (own-price elasticity) or another crop (cross-price elasticity). The significance in own-price elasticities differences shows up in two crops, soybeans and corn. For the 2005-2012 period corn's own price elasticity has increased by a factor of 4.67 compared to that of 1960-2004. Soybeans own price elasticity has increased by a higher magnitude than that of corn, 9.4 (Tables 1 and 2).

Next, crop-pairs such as corn-soybeans, hay-cotton, wheat-cotton, corn-other crops, and hay-other crops have experienced a statistically significant structural change due to EPA 2005. Corn-soybeans completion for acreage has intensified by a factor of 5.6 as a result of EPA 2005. Hay's price change effect on cotton's acreage is not significant before 2005, but after 2005 for every 1% price change in hay cotton's acreage is negatively affected by 0.40 percent.

Wheat-cotton, corn-other crops, and hay-other crops display statistically significant complimentary behavior in respect to acreage after 2005 whereas their relationships are not significant before 2005.

Out of all the marginal land elasticities' differences between two periods, only those of cotton and other crops category are significant. Marginal land elasticity measures how responsive is the acreage of a crop to new land made available for agricultural production. For the period 1960-2004 1% additional land is associated with an increase in cotton's land by 1.74 percent and a decrease of cotton's land by 6.80 percent after 2005, which is a fundamental change.

CONCLUSION

As a result of Energy Policy Act enacted in 2005 (EPA 2005) that mandates ratio of ethanol in gasoline, farmers allocate more land to corn. Since additional arable land is scarce (Hertel 2011), there are reasons to believe that corn's acreage expands at the expense of acreages of other crops. By using differential framework we test the hypothesis whether EPA 2005 introduces statistically significant structural changes to the U.S. farm land allocation dynamics. The results confirm that after the enactment of EPA 2005 policy there are statistically significant structural changes in the allocation dynamics of the U.S. farm land, especially it is the case for corn and soybeans as well as hay and cotton.

After the year 2005, corn and soybeans have become more sensitive to their own price changes by 378 and 268 percent, respectively, compared to those of 1960-2004 period. The intensity of corn's negative effect onto soybean's acreage has increased by 462 percent. After 2005 1% of land made available for agricultural production is associated with a loss of acreage for cotton.

Wheat-cotton, corn-other crops, and hay-other crops combinations display statistically significant complimentary behavior in respect to acreage after 2005.