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Introduction

The Energy Policy Act of 2005 (EPA 2005) mandates to mix ethanol with gasoline sold in the United States (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.

Discussion

Of Energy Policy Act (EPA), passed by the U.S. Congress in 2005, the official rationale is to combat a growing problem of uncertainty in energy supplies as well as environmental issues (Farrell et al. 2006). It introduces a mandated blend of gasoline and ethanol with the end goal of at least 10% of ethanol being present in retail gasoline (Figure 1). The Act mandates 7.5 billion U.S. gallons of corn-based ethanol to be mixed with the gasoline sold by 2012. This policy has initiated Renewal Fuel Standards (RFS) program, and two years later the Energy Independence
and Security Act of 2007 (EISA 2007) that extends the previous corn based ethanol target to 15 billion U.S. gallons by 2022 (EPA 2013; De Gorter and Just 2009). Detailed description and timeline of other intricacies of biofuel related policies and mechanisms are reported by Carter et al. (2012).

Ethanol content in gasoline due to EPA 2005 and EISA 2007 has expanded from 2.9 percent in 2005 to 9.8 percent in 2011 (EIA 2013). As a result, corn prices have risen sharply (Roberts and Schlenker 2010, Hausman et al. 2012), and, in response to the high prices, plantings of corn have increased (USDA 2011) as can be seen in Figure 1.

Figure 1. Corn Acreage, Production Quantity, and Prices 1980-2012

![Corn Acreage, Production Quantity, and Prices (1980 - 2012)](image)

Source: NASS 2013

By 2006, the U. S. surpassed Brazil as the largest ethanol producer in the world (EIA 2013), producing 116 millions of barrels and comprising 45% of world ethanol production that year (Figure 4). Since 2006, U.S. production of ethanol has steadily increased. Diversion of corn stocks into ethanol production has increased significantly accounting for 20% of the corn crop in 2006 to on average 40% in the last three years (USDA-ERS, 2013).
The transformation the U.S. ethanol market into the world’s largest from 2006 onward has had a significant effect on the U.S. corn market. Corn acreage has expanded significantly after 2005 while the overall land in agricultural production remains relatively flat (Figure 7). In fact, total acreage in production trends downwards ever slightly after 2005 as demonstrated in Figure 2. As overall total acreage among the crops remains relatively flat, the expansion of corn acreage is at the expense of other crops’ acres.

Figure 2. Total Acreage in Agricultural Production and Corn Acreage

![Total Agricultural Acreage and Corn Acreage](image)

Source: NASS 2013

Figure 3 demonstrates the land shares of the five top crops produced in the U.S.: corn, cotton, hay, soybeans, and wheat. Of total agricultural land in production corn, cotton, hay, soybeans, and wheat are the top five crops grown in the U.S. and constitute 95% of the U.S. crops. Land share of these crops relative to total U.S agricultural land, 1960-2013, are plotted in
Figure 8. The land share of corn has increased after 2005 significantly while soybean’s land share gyrates around relatively the same level. Wheat, hay, and other crops category’s land shares have decreased significantly. Cotton’s land share fluctuates, but, on average, trends slightly downward.

Figure 3. Crops Land Shares as Percentage of Total Land in Agricultural Production 1960-2013

Source: NASS 2013

The motivation for the study comes from the fact that RFS policies initiated by the EPA 2005 may be affecting not just biofuel crops like corn, but they may be indirectly affecting acreages of other crops. Figures 3 and 4 suggest that acreages of other principle crops in the U.S may be negatively affected by these policies. Analysis of the state production data confirms these dynamics (Figure 4).

1 Other crops consist of 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.
Figure 4. Corn, Wheat, Soybean, and Cotton Production before and after EPA 2005
Using differential framework this study analyzes whether there is a statistically
significant structural change in land allocation dynamics among top five principle crops
produced in the U.S. 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 then
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. The study tests the overall hypothesis whether EPA 2005 introduces a
statistically significant structural change in agricultural production dynamics by testing for
statistical significance of the changes in acreage response to prices in the crop specific pairs.

Based on 1960-2012 price and production data for crops such as corn, cotton, hay,
soybeans, wheat, the analysis shows that the structural changes due to EPA 2005 are statistically
significant. 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.

The results in this study are valuable, especially in lieu of the recent findings of Carter et
al (2012) who estimates that corn prices are about 30 percent higher, on average, between 2006
and 2010 than they would have been if ethanol production had remained at 2005 levels (Carter et
al 2012). Coupling the estimated effect of the EPA 2005 on corn prices estimated by Carter et al
(2012) and the effect of corn price changes onto acreages of other crops estimated in this study,
we are able to link ethanol policy to changes in the acreages of other crops and finally interpret
the indirect effect of the ethanol mandate on the acreages of specific crops.

Data

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. In the U.S. the quantity of the crops produced in the category “other” is
significantly lower than that of the top five crops since they comprise only 5% of agricultural
output. This allows the aggregation of quantity, weighted prices and acreage for this category.
Thus, in our model, for the years from 1960 to 2012, the American agricultural sector is
described by the prices of six outputs, principle crops such as wheat; corn; cotton; soybeans;
hay; and “other,” and one quasi fixed input in production, land. The land variable for each crop
is quantified as a share of the acreage used in the production of that crop to the total farm land.

Methodology

In this paper, we employ the differential approach to production theory (Theil 1975;
Clements 1978; Laitinen and Theil 1978, Laitinen 1980; Theil 1980; Livanis 2004). In particular,
we follow the differential model developed by Vorotnikova, Asci, and Seale (2013) that
examines the multiproduct U.S. agricultural industry with a quasi-fixed input, land, as an input.
The model differentiates from the previous one by including the interaction dummy variable that
distinguishes the years leading up to the year of the EPA 2005 (1996-2004) policy from the years
after it (2005-2012). This allows us to test whether structural change occurs in U.S. land allocation dynamics due to EPA 2005. We use TSP 5.0 software to obtain the results.

The differential land allocation model for the multiproduct firm with land as an input is a variant of the Differential Land Allocation Model (DLAM) derived by Vorotnikova et. al. (2014). Since the observation numbers are not enough for analyzing two separate time periods before and after 2005, we incorporate dummy variables, \( D \), into the model to distinguish the years 1960-2004 (for which \( D=0 \)) from the years 2005-2012 (for which \( D=1 \)). Thus, we have

\[
(5) \quad \tilde{f}_j d(\ln L_i) = \theta_j d(\ln L) + \sum_{j=1}^{n} \pi_{ij} d(\ln P_{ij}) + \theta^k_i Dd(\ln L) + \sum_{j=1}^{n} \pi^{ij}_j Dd(\ln P_{ij}) + \varepsilon.
\]

\( d(\ln L) \) is a Divisia index for land: \( d(\ln L) = \sum f_j d \ln L_j \), where \( f_j \) is an average land share for the crop \( j \), and \( d \ln L_j \) is a log change in acreage for crop \( j \). \( d(\ln P_{ij}) \) is the log change of output price of crop \( j \), \( \theta_i \) and \( \pi_{ij} \). \( \tilde{f}_j = (f_{i,j}^t + f_{i,j,t-1})/2 \), and \( d(\ln X_i) = \ln X_i - \ln X_{i,t-1} \) where \( X \) represents \( L \) and \( P \), and \( \varepsilon \) be an error term.

Note that, the adding up conditions are: \( \sum \theta_i = 1 \), \( \sum \pi_{ij} = 0 \), \( \sum \theta_i^k = 0 \) and \( \sum \pi_{ij}^k = 0 \) the homogeneity condition is: \( \sum \pi_{ij} = 0 \) and \( \sum \pi_{ij}^k = 0 \), and the symmetry condition is: \( \pi_{ij} = \pi_{ji} \) and \( \pi_{ij}^k = \pi_{ji}^k \).

The parameters for the terms with dummy interaction give us the difference between the two time periods. For instance, the addition of two price coefficients results with the coefficient of the previous period. In other words, the dummy variable’s significance detects the significance of the structural changes that the year 2005 EPA policy introduces. The land volume elasticity and price elasticities (\( \eta_{ij} \)) after the EPA policy are calculated as:
These elasticities before the EPA policy can be calculated as:

\begin{align}
\eta_i &= \frac{\theta_i}{f_i} \\
\eta_{ij} &= \frac{\pi_{ij}}{f_i}
\end{align}

\begin{align}
\eta_i^k &= \frac{\theta_i + \theta_i^k}{f_i} \\
\eta_{ij}^k &= \frac{\pi_{ij} + \pi_{ij}^k}{f_i}
\end{align}

**Results**

We estimate the differential land allocation model Equation (5) with maximum likelihood through iterative seemingly unrelated regression using the LSQ command of TSP 5.0 version. The procedure requires one to drop one equation and estimate the remaining n-1 equations simultaneously, and the parameter results are invariant as to which equation is deleted (Barten 1964). The restriction of homogeneity and symmetry may be tested with a log-likelihood ratio test. To do so, the unrestricted, homogeneity restricted, and homogeneity and symmetry restricted models. The first test shows that homogeneity cannot be rejected at 5% significance level. Next, the log-likelihood-ratio test indicates that imposing symmetry after homogeneity also cannot be rejected at the 5% significance level. Thus, homogeneity and symmetry are not rejected.

Next, we test whether there is statistical evidence that EPA 2005 introduces structural changes, in U.S. land allocation. We start out by conducting Log-Likelihood test between the
restricted (Equation (4)) and unrestricted (Equation (5)) models. The test statistics are higher than the critical values for unrestricted, homogeneity imposed, and homogeneity and symmetry imposed cases. This indicates that there is a structural change.

Next, the specific structured changes are indicated by the parameter on the interactive terms of the dummy variable times the exogenous variables. If the parameter of the interaction of the coefficient and the dummy variable is significant, it indicates that the structural change occurs due to EPA 2005 in the price-land share dynamics for a pair of specific crops is significant. Negative sign of the dummy coefficient means that the coefficient is lower by magnitude before 2005, implying that it has increased significantly after 2005. On the other hand, positive dummy coefficient means that it is higher by magnitude before 2005 and thus, it has decreased after 2005.

Own Price Coefficients

The own-price coefficients for both 1960-2004 and 2005-2012 periods are all positive as production theory suggests (Tables 2 and 3). From the results of the dummy coefficients (Table 3) it can be seen that out of all own-price-dummy coefficients (i.e. for 1960-2004 period) only those of corn and soybeans are negative and statistically significant, both at the 0.01 level. The negative sign for those dummy coefficients means that the own price coefficients for corn and soybeans for 1960-2004 are lower by magnitude, specifically, by 0.09 and 0.12 units, respectively, than those of 2005-2012 period. This implies that after the year 2005, the own-price coefficients for corn and soybeans have increased by 4.58 and 3.64 times, respectively, compared to those of the 1960-2004 period. In other words, the acreage of corn and soybeans becomes 4.58 and 3.64 times more responsive to its own-price changes, respectively.
### Table 2. Coefficients of Rotterdam Model, 2005 – 2012

<table>
<thead>
<tr>
<th>Crops</th>
<th>Corn</th>
<th>Cotton</th>
<th>Hay</th>
<th>Soybeans</th>
<th>Wheat</th>
<th>Other Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Coefficients ($\beta_i$)</td>
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</tr>
<tr>
<td></td>
<td>0.255</td>
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<td>(0.185)</td>
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<td>-0.009</td>
<td>-0.105***</td>
<td>-0.031</td>
<td>0.036**</td>
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<td>(0.009)</td>
<td>(0.012)</td>
<td>(0.018)</td>
<td>(0.020)</td>
<td>(0.015)</td>
</tr>
<tr>
<td></td>
<td><strong>0.033</strong>*</td>
<td>-0.016**</td>
<td>-0.021</td>
<td>0.028*</td>
<td>-0.015*</td>
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</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.008)</td>
<td>(0.014)</td>
<td>(0.015)</td>
<td>(0.009)</td>
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</tr>
<tr>
<td></td>
<td>0.016</td>
<td>0.016</td>
<td>-0.033*</td>
<td>0.026**</td>
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<tr>
<td></td>
<td>(0.013)</td>
<td>(0.016)</td>
<td>(0.019)</td>
<td>(0.011)</td>
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<tr>
<td>Output Price Coefficients ($\pi_{ij}$)</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td><strong>Corn</strong></td>
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<td>0.006</td>
<td>0.019</td>
<td>0.086***</td>
<td>0.017</td>
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<td>(0.026)</td>
<td>(0.010)</td>
<td>(0.014)</td>
<td>(0.020)</td>
<td>(0.022)</td>
<td>(0.018)</td>
</tr>
<tr>
<td></td>
<td><strong>Cotton</strong></td>
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<td>0.018**</td>
<td>0.012</td>
<td>-0.033**</td>
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<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.015)</td>
<td>(0.015)</td>
<td>(0.010)</td>
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<tr>
<td></td>
<td><strong>Hay</strong></td>
<td>-0.014</td>
<td>-0.016</td>
<td>0.022</td>
<td>-0.029**</td>
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<td></td>
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<td>(0.017)</td>
<td>(0.019)</td>
<td>(0.013)</td>
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<tr>
<td></td>
<td><strong>Soybeans</strong></td>
<td>-0.119***</td>
<td>0.008</td>
<td>0.03</td>
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<tr>
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<td>(0.034)</td>
<td>(0.030)</td>
<td>(0.019)</td>
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<tr>
<td></td>
<td><strong>Wheat</strong></td>
<td>-0.028</td>
<td>0.015</td>
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<tr>
<td></td>
<td>(0.039)</td>
<td>(0.020)</td>
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<td></td>
<td><strong>Other Crops</strong></td>
<td>0.006</td>
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<td>(0.024)</td>
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</tbody>
</table>

Note: figures in parenthesis are standard deviations.

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

### Table 3. Dummy Variable Coefficients of Rotterdam Model, 1960-2004

<table>
<thead>
<tr>
<th>Crops</th>
<th>Corn</th>
<th>Cotton</th>
<th>Hay</th>
<th>Soybeans</th>
<th>Wheat</th>
<th>Other Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Coefficients ($\beta_i$)</td>
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<tr>
<td></td>
<td>0.202</td>
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<td>(0.188)</td>
<td>(0.087)</td>
<td>(0.111)</td>
<td>(0.173)</td>
<td>(0.224)</td>
<td>(0.089)</td>
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<td><strong>-0.093</strong>*</td>
<td>0.006</td>
<td>0.019</td>
<td>0.086***</td>
<td>0.017</td>
<td>-0.034**</td>
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<td>(0.026)</td>
<td>(0.010)</td>
<td>(0.014)</td>
<td>(0.020)</td>
<td>(0.022)</td>
<td>(0.018)</td>
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<td></td>
<td><strong>-0.014</strong></td>
<td>0.018**</td>
<td>0.012</td>
<td>-0.033**</td>
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<td>(0.015)</td>
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<td>-0.016</td>
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<td>0.008</td>
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</table>

Note: figures in parenthesis are standard deviations.

* - significant at 10% level; ** - significant at 5% level; *** - significant at 1% level.
From Table 2 it can be seen that during 2005-2012 period soybeans have the highest own price coefficient by magnitude (0.16), followed by corn (0.12), and then wheat (0.08), and cotton (0.03). Corn, cotton, and soybeans are significant at 0.01 level while wheat is significant at 0.05 level. Hay and other crops category’s own price dummy coefficients are not significant.

Elasticities

In this section price and land elasticities for both periods, 1960-2004 and 2005-2012, are found and presented in Tables 4 and 5, respectively. We then test whether the difference between two periods output price-land elasticities is significant for each pair of crops (Table 6). Methodological choice of dummy variable that distinguishes coefficients between the two periods makes it convenient to test such hypothesis. Assessing Tables 3 and 6, it can be noticed that the crop pair significance of the elasticity differences (Table 6) coincides perfectly with those of dummy coefficients (Table 3).

Own Price Elasticity

The most significant change in own-price elasticities shows up in two crops, soybeans and corn. Out of all differences in own-price elasticities before and after 2005, only those of corn and soybeans are significant at 1% level and are 0.338 and 0.508, respectively (Table 6). Specifically, for the 2005-2012 period corn’s own price elasticity has increased by a factor of 4.67 compared to 1960-2004 while the significance level has increased from 0.05 before 2005 to 0.01 after 2005 (Table 4). This means that 1 percent corn price increase (decrease) is associated with an increase (decrease) of corn’s acreage by 0.092 percent before 2005 and by 0.43 percent after 2005. Soybeans own price elasticity has increased by a higher magnitude than that of corn, 9.4, while remaining at the same 0.01 significance level after 2005 as that before 2005 (Table 4).
Table 4. Output Price and Land Elasticities of the Estimated Rotterdam Model, 2005-2012

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

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

Table 5. Output Price and Land Elasticities of the Estimated Rotterdam Model, 1960-2004

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

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

This means that 1 percent soybean price increase (decrease) is associated with an expansion (contraction) of soybean’s land share by 0.19 percent before 2005 and by 0.70 percent after 2005. Cotton’s, hay’s, wheat’s, and other category’s own-price elasticities’ differences are...
not significant, which suggests that the changes for those crops are not significant between the two periods. It is important to note that even though cotton’s difference is not significant, assessing cotton’s point estimates, it can be seen that the own price elasticity increases from 0.507 before 2005 to 0.859 after 2005 (significant at 0.01 level for both periods), which is an increase by 69 percent (Table 5). This means that 1% cotton price change is associated with an expansion/contraction in cotton’s land share by 0.51 percent before 2005 and 0.86 percent after 2005. Next, wheat’s own price elasticity increases by a 64 percent in magnitude, but loses significance from 0.01 before 2005 to 0.05 level after 2005. Thus, 1 percent in wheat’s upward (downward) price change is associated with an increase (decrease) of wheat’s land share by 0.26 percent before 2005 and by 0.41 percent after 2005. Hay’s and other crops category’s own price elasticities are not significant either before or after 2005.

Table 6. Difference between Output Price and Land Elasticities before and after 2005 EPA

<table>
<thead>
<tr>
<th>Crops</th>
<th>Corn Prices</th>
<th>Cotton</th>
<th>Hay</th>
<th>Soybeans</th>
<th>Wheat</th>
<th>Other Crops</th>
<th>Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>0.338***</td>
<td>-0.020</td>
<td>-0.070</td>
<td>-0.312***</td>
<td>-0.060</td>
<td>0.123**</td>
<td>-0.73258</td>
</tr>
<tr>
<td></td>
<td>(0.094)</td>
<td>(0.037)</td>
<td>(0.049)</td>
<td>(0.072)</td>
<td>(0.080)</td>
<td>(0.065)</td>
<td>(0.68)</td>
</tr>
<tr>
<td>Cotton</td>
<td>-0.142</td>
<td>0.352</td>
<td>-0.463**</td>
<td>-0.300</td>
<td>0.856**</td>
<td>-0.303</td>
<td>-8.548***</td>
</tr>
<tr>
<td></td>
<td>(0.261)</td>
<td>(0.241)</td>
<td>(0.224)</td>
<td>(0.386)</td>
<td>(0.389)</td>
<td>(0.257)</td>
<td>(2.25)</td>
</tr>
<tr>
<td>Hay</td>
<td>-0.101</td>
<td>-0.095**</td>
<td>0.074</td>
<td>0.086</td>
<td>-0.115</td>
<td>0.151**</td>
<td>0.562158</td>
</tr>
<tr>
<td></td>
<td>(0.071)</td>
<td>(0.046)</td>
<td>(0.076)</td>
<td>(0.087)</td>
<td>(0.101)</td>
<td>(0.066)</td>
<td>(0.59)</td>
</tr>
<tr>
<td>Soybeans</td>
<td>-0.365***</td>
<td>-0.049</td>
<td>0.069</td>
<td>0.506***</td>
<td>-0.034</td>
<td>-0.126</td>
<td>0.553948</td>
</tr>
<tr>
<td></td>
<td>(0.084)</td>
<td>(0.063)</td>
<td>(0.070)</td>
<td>(0.143)</td>
<td>(0.126)</td>
<td>(0.079)</td>
<td>(0.73)</td>
</tr>
<tr>
<td>Wheat</td>
<td>-0.090</td>
<td>0.181**</td>
<td>-0.119</td>
<td>-0.044</td>
<td>0.153</td>
<td>-0.082</td>
<td>0.533211</td>
</tr>
<tr>
<td></td>
<td>(0.120)</td>
<td>(0.082)</td>
<td>(0.105)</td>
<td>(0.162)</td>
<td>(0.213)</td>
<td>(0.109)</td>
<td>(1.22)</td>
</tr>
<tr>
<td>Other Crops</td>
<td>0.451**</td>
<td>-0.156</td>
<td>0.624**</td>
<td>-0.222</td>
<td>-0.199</td>
<td>-0.081</td>
<td>2.712***</td>
</tr>
<tr>
<td></td>
<td>(0.238)</td>
<td>(0.132)</td>
<td>(0.264)</td>
<td>(0.278)</td>
<td>(0.265)</td>
<td>(0.315)</td>
<td>(0.637)</td>
</tr>
</tbody>
</table>

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

Out of all the marginal land elasticities’ differences between two periods, only those of cotton and other crops category are significant. Cotton’s land elasticity remains significant at the same 0.01 level throughout the two periods. For the period 1960-2004 cotton’s marginal land elasticity is 1.74, but it becomes negative for 2005-2012, -6.80, meaning that 1% additional land is associated with an increase by 1.74 percent before 2005 and a decrease of cotton’s land by 6.80 percent after 2005, which is a fundamental change. Other crops category is an aggregation of many crops, so it is difficult to interpret the changes in the marginal land elasticity.

Assessing point estimates for other crops, it can be seen that for 1960-2004 period for every 1 percent additional land available for agricultural production, wheat’s, corn’s, and soybeans land increased by 1.70 percent, 1.66 percent, and 0.40 percent, respectively, all significant at 0.01 level (Table 5). However, after 2005 marginal land elasticities of corn and soybeans lost their significance, while land elasticity for wheat decreases it significance to 0.10 level increasing in magnitude slightly to 2.235 (Table 4).

Cross Price Elasticities

The differences between cross-price elasticities before and after 2005 are significant for corn-soybeans, corn-other crops, cotton-hay, cotton-wheat, and hay-other crops as well as their reverse combinations (since elasticities are not symmetric). Corn-soybeans price-land elasticity difference is significant at 0.01, and all the rest are significant at 0.05 level. Furthermore, the model allows for assessment of point estimates before and after 2005, which is done in the following section. However, final conclusions are drawn upon coordination of these results with the test of differences in cross output price-land elasticities in Table 6.
Corn

For 1960-2005 period 1 percent corn price changes most negatively affect the land share of cotton (-0.52 percent), then soybeans (-0.08 percent), and then wheat (-0.08 percent). They are significant at 0.05, 0.05, and 0.10 levels, respectively. In reverse combinations, for the same time period, soybeans-corn and wheat-corn price elasticities are lower by magnitudes than the other way around (-0.07 and -0.05, significant at 0.05 and 0.10 levels, respectively) while cotton-corn cross-price elasticity is not significant at all (Table 5). This means that before 2005 corn price changes affected most negatively cotton’s land, then that of soybeans, and then that of wheat more significantly then the other way around.

After 2005 corn price changes affect negatively only soybeans (-0.45 percent), confirming the results obtained by assessing the significance of differences of two period elasticities (Table 6). As can be seen in Table 4, the magnitude of corn-soybean cross-price elasticity increases by a factor of 5.54 compared to that before 2005 (Table 5). Also corn-soybeans cross price elasticity’s level of significance have increased from 0.05 before 2005 to 0.01 after 2005 (Table 4). The corn-cotton and corn-wheat cross-price elasticities have lost their significance after 2005. In reverse combination, soybean-corn elasticity after 2005 is -0.38 (significant at 0.01 level), which is less by magnitude than that of corn-soybean elasticity for the same time period confirming that in aftermath of 2005, corn price changes affect land of soybeans more significantly than the other way around, whereas before 2005 the elasticities of both combinations were practically the same by magnitude. Also corn-other crops elasticity becomes significant at 0.05 level, indicating a structural change in the dynamics between these two crops. Positive cross-price elasticity of 0.13 indicates that corn and other crops behave as compliments when it comes to acreage allocation.
Taking significance and magnitude changes of cross output price-land elasticities between the two periods into account, the results for corn can be summarized as follows: before 2005 land shares of the following crops were most sensitive to the corn price changes (in descending order): cotton, soybeans, wheat. After 2005 only soybeans land share remains sensitive to corn price changes and other crops become significantly sensitive to the corn price changes. While corn-soybeans cross-price elasticity increases in magnitude significantly indicating increase of competition for land between these crops, corn and other crops category behave as compliments when it come to land allocation dynamics. Using state-wide corn planting acreage data Figure 5 was compiled using ArcGIS software.
Figure 5. Corn Plantings Expansion after 2005 EPA
Soybeans

For 1960-2004 soybeans compete for land most significantly with cotton, then corn, and then wheat, the cross-price elasticities are -0.25, -0.07, -0.06, respectively. Therefore, 1 percent soybean price upward (downward) movement is associated with decrease (increase) the land share of cotton, corn, and wheat by 0.25, 0.07, and 0.06 percent, respectively (Table 5). Each of the elasticities is significant at 0.05, 0.05, and 0.10 levels, respectively. Furthermore, the reverse combinations, cotton-soybean and wheat-soybeans cross-price elasticities are lower by magnitude (-0.041 and -0.043 significant at 0.05 and 0.10 levels, respectively) while corn-soybeans cross price elasticity is higher by magnitude, -0.08, than the other way around. This means that before 2005 soybeans competes for land with cotton and wheat more significantly than the other way around. In the meantime, corn competes with soybeans more significantly then the other way around. The land share of cotton and wheat is more sensitive to soybean’s price changes than the other way around while soybean’s land share is more sensitive to corn’s price changes than corn’s land share to soybean’s price changes.

After 2005, soybeans-other crops elasticity has become significant at 0.05 level and of highest magnitude compared to other combinations, -0.47. Such result is interesting in lieu of the fact that the test for significance of differences in cross-price elasticities between two periods for this combination does not show that there is a significant change. Nevertheless, as a point estimat the result means that 1 percent soybean upward (downward) price changes is associated with decrease (increase) of other crops land by 0.47 percent. Other-crops-soybean combination is significant, but lower in magnitude (-0.15, significant at 0.05 level) than that of reverse combination, which means that soybean prices affect other crops land more significantly than the other way around. Soybean-corn cross-price elasticity has increased 5.54 times from -0.07 before
2005 to -0.38 after 2005, each significant at 0.05 and 0.01 levels, respectively (Table 4).

Soybeans-wheat cross price elasticity has lost its significance after 2005. Therefore, in the aftermath of 2005 soybeans competes for land most intensely with other crops, while corn completes most intensely with soybeans.

In summary, before 2005 soybeans most severely compete for land with corn, cotton and wheat, whose land shares are most sensitive to the soybean price changes during this time, but after 2005 only corn and other crops land shares are negatively and significantly affected by the soybean price changes. The difference of elastities test for significance shows that only corn-soybeans combination shows significant structural changes, and corn competes for land with soybeans more intensely than the other way around. Figure 6 depicts state-wide soybeans planting acreage data before and after the year 2005.
Figure 6. Soybeans Plantings before and after 2005 EPA
Other Crops

The difference test for significance between elasticities of two periods shows significance only for corn-other crops and hay-other crops combinations (Table 6), indicating that only these two combinations experience a structural change due to EPA 2005. Assessing point estimates before 2005 shows that none of the cross price elasticities related to other crops category were significant; however, after 2005, other crops-cotton and other crops-soybeans cross price elasticities have became significant, -0.37 and -0.15, respectively, at 0.10 and 0.05 levels behaving as compliments. Other crops-hay elasticity also becomes significant at 0.05 level and is 0.14, indicating that these two cross are compliments. Furthermore, the reverse combinations, cotton-other crop cross price elasticity is lower by magnitude (-0.19) while soybean-other crop elasticity is higher by magnitude (-0.47), each significant at 0.10 and 0.05 levels, respectively (Table 4). This means that soybeans price changes affect negatively the land share of other crops more significantly than the other way around while other crops price changes affect cotton more significantly than in the reverse combination.

In summary, before 2005 all cross-price elasticities that have other crops in the combination are not significant, but after 2005 the statistically significant structural change is detected in corn-other crops and hay-other crops combinations behaving as compliments when it come to land allocation dynamics during this period. Although soybeans prices negatively and significantly affect other crops land share after 2005, the test for significance in elasticity differences between two periods does not indicate a structural change due to EPA 2005.

Cotton and Hay
The test for significance in differences of cross-price elasticities between the two periods detects a structural change only in cotton-hay combination at 0.05 statistical significant level. Before 2005 cotton is competing for land only with soybeans: 1 percent cotton price changes affect negatively only the land share of soybeans (-0.04 percent) out of all crops, significant at 0.05 level. However, during the same period soybeans-cotton cross output price-land elasticity is -0.245, which is a lot higher in magnitude than the reverse combination, significant also at 0.05 level (Table 5). This means that before 2005 soybean price changes have more negative impact on cotton’s land share than the other way around. After 2005 this combination elasticity becomes insignificant and no structural change is detected for this combination. Before 2005 hay competes for land only with wheat, meaning that 1 percent hay price change negatively affect land share of wheat by 0.06 percent and in reverse combination, wheat-hay cross-price elasticity is almost of the same magnitude, -0.058 percent, both significant at 0.05 level (Table 5). After 2005 wheat hay cross-price elasticity is -0.17, which is slightly lower by magnitude than that of the reverse combination (Table 4). This means that after 2005 hay has slightly more significant impact on wheat’s land share. There is no statistically significant structural change due to EPA 2005 detected for this combination.

After 2005 cotton price changes affect most negatively other crops land share (-0.19 percent), then hay’s land share (-0.08 percent), each significant 0.10 and 0.05 level. In reverse combination, after 2005 other crops-cotton cross-price elasticity after 2005 is -0.374, which is a higher by magnitude than that of cotton-other crops cross-price elasticity for the same time period (Table 4). This confirms that in after 2005, other crops price changes affect land of cotton more negatively and significantly than the other way around, however, structural changes in land allocation dynamics due to EPA 2005 is not detected for this combination. Furthermore, hay-
cotton cross price elasticity is higher by magnitude (-0.40) than that of cotton-hay signifying that after 2005 hay price changes affect land of cotton more negatively and significantly than the other way around. Before 2005 the cross output price-land elasticities of cotton-other crops, cotton-hay and their reverse combinations are not significant.

Summing up, cotton’s land share is negatively and significantly affected by soybean price changes before 2005 and by hay’s and other crops price changes after 2005. However, no structural changes are detected for any of the combinations except for that of hay-cotton. Hay and wheat are substitutes when it comes to land allocation dynamics before and after 2005, and no structural change is detected for this combination due to EPA 2005. Figure 7 is based on the state-wide cotton planting acreage data before and after the year 2005.
Figure 7. Cotton Plantings

Cotton Plantings before and after 2005 EPA

2004 Cotton Production

2012 Cotton Production

Cotton Plantings (thousand acres)
- 47 - 85
- 86 - 220
- 221 - 500
- 501 - 550
- 551 - 775
- 776 - 1110
- 1111 - 5871
- 5872 - 6558

Sources: USDA-NASS 2013
Date: 08-09-2013
Created by: Ekaterina Vorotnikova
Project
Wheat

The test for significance in differences of cross-price elasticities between the two periods detects a structural change only in wheat-cotton combination at 0.05 statistical significant level. The crops behave as compliments after 2005 whereas their cross-price elasticity is not significant before 2005.

Before 2005 wheat competes for land with hay, corn, and soybeans. Their respective cross price elasticities are -0.06, -0.05, and -0.04, each at 0.05, 0.01, and 0.10 significance level, respectively. Reverse combinations, hay-wheat, corn-wheat, and soybeans-wheat cross price elasticities are slightly higher by magnitude, meaning that 1 percent price change of hay, corn, and soybeans decreases the land share of wheat by 0.060, 0.08, and 0.06 percent, respectively (Table 5). This means that hay, corn, and soybean price changes have a slightly more negative effect on wheat’s land share than the other way around.

After 2005 wheat competes for land most significantly with hay, wheat-hay cross output price-land elasticity is -0.17 (Table 4), which is an increase by a factor of 2.98 compared to that before 2005. Reverse combination, hay-wheat cross price elasticity is slightly higher by magnitude, -0.18, thus, after 2005 hay continues to affect the land share of wheat more significantly then the other way around. However, despite the difference in these point estimates between the two periods, the test for significance in difference of the two period cross price elasticities does not detect a structural change for this combination. Crops like corn and soybeans have lost significant effect on wheat’s land share after 2005, and no structural change was detected for wheat in combination with corn and soybeans.
Figure 8. Wheat Plantings

Wheat Plantings before and after 2005 EPA

Wheat Plantings (Thousand Acres)

- 8 - 50
- 51 - 190
- 191 - 330
- 331 - 530
- 531 - 680
- 681 - 1250
- 1251 - 9500
- 9501 - 10000

Sources: USDA-NASS 2013
Date: 08-09-2013
Created by: Ekaterina Vorotnikova
Project
Summarizing, before 2005 wheat’s land share is most sensitive to and negatively affected by the price changes of the following crops in descending order of cross-price elasticity magnitudes: hay, corn, and soybeans whereas after 2005 only hay remains a significant competitor when it comes to land. However, the test for significance of differences in two-period elasticities shows no structural changes for these combinations, except for a compliment combination of wheat-cotton, which becomes significant after 2005 at 0.01 level. Figure 8 is complied based on the state-wide wheat planting acreage data before and after the year 2005.

Even though own output price-land elasticities of crops like corn, wheat, soybeans, and cotton increase in magnitude after 2005 compared to those before 2005, only those of corn and soybeans show a statistically significant structural change due to EPA 2005.

Next, cross output price-land elasticities are discussed. Before 2005 corn price changes affect negatively cotton, soybeans, and wheat acreage whereas after 2005 only soybeans land share remains sensitive to the corn’s price changes while the intensity of corn’s completion for land increases by a factor of 5.6. Soybeans’ price changes negatively affect the land share of wheat in addition to that of cotton before 2005, but after 2005, its price changes negatively affect only the land share of other crops. Corn-hay combination behave as compliments, but elasticity loses is significance after 2005. However, out of all these combinations only that of corn-soybeans (competitors) and corn-other crops (compliments) show a significant structural change due to EPA 2005, so their arrows on the right diagram are red.

For 1960-2004 cotton’s land share is sensitive to and negatively affected by soybeans price changes in addition to those of corn whereas after 2005 it is hay and other crops price changes that negatively affect cotton’s land share. Before 2005 in addition to corn’s and
soybeans’ price changes, wheat’s land share is also sensitive to the price changes of hay, whereas after 2005 it remains sensitive only to hay, and the intensity of the hay’s effect increases by a factor of 2.98. After 2005 hay’s price changes also negatively affect the land share of cotton. Wheat-cotton and hay-other crops behave as compliments after 2005. Out of all crop pairs discussed only hay-cotton (competitors), wheat-cotton (compliments), and hay-other crops (compliments) combinations show statistically significant structural changes due to EPA 2005.

References


June 2013.

