



Article The Long-Run and Short-Run Effects of Ethanol Production on U.S. Beef Producers

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Abstract: Biofuel production has received considerable attention as a means of reducing greenhouse gas emissions and mitigating global energy problems. The expansion of biofuel production has benefited the environment, but rising feed prices have negatively affected the livelihood of livestock producers. This study examines the direct effects of corn-based ethanol expansion on beef producers' short-run resource transition and long-run productivity in the United States. Dynamic panel models are specified to measure farm productivity and to investigate the effects of ethanol expansion on input-use decisions and the productivity of individual beef producers. Analyses of farm-level panel data show that in the short run, ethanol expansion is associated with employment losses in the beef industry to compensate for increased costs of intermediate inputs used in the production process; however, in the long-run, it increases farm productivity. The productivity of surviving beef producers has improved because less efficient producers could not survive due to the drastic burden of rising feed prices. Given the interconnections between the agriculture and energy markets through the growth of biofuel production, our results provide important insights in developing sustainable energy policies that could harmonize both markets and reduce unintended negative effects of biofuel production.

Keywords: ethanol mandate; livestock producer; resource transition; sustainable energy policy; dynamic panel

1. Introduction

The global production of liquid biofuels (i.e., ethanol, biodiesel) has been rapidly increasing in the past decades. According to the International Energy Agency, the share of biofuels will increase by 27% in the transportation sector by 2050. The interest in using biofuels is mostly owing to their effectiveness in countering the increase in greenhouse gas emissions as well as the use of fossil fuels. One of the main problems with the growth of biofuel production is that it creates competition for feedstocks that have food-related uses. Currently, the main sources of biofuel production are corn, soybean, and wheat, among others; these feedstocks are also used as livestock feeds. The input supply changes in the feed markets directly affect livestock producers as they experience a rise in input costs. This partly indicates that the use of environmentally sustainable energy can directly pose a threat to rural communities where livestock is produced, and threaten a sustainable food

supply. Given the importance of global food security, the effects of biofuel expansion on agricultural markets have received substantial attention [1–7]. However, although maintaining sustainable farm production is important while pursuing biofuel expansion, there are no studies that examine the effect of ethanol expansion on individual farmers' decision-making behaviors and productivity. To fill this gap, we focused on the impact of ethanol expansion on beef producers in the United States since it is a major biofuel producer and also a leading global livestock market.

The United States is one of the world's major biofuel producers. It produced about 37 million metric tons of oil equivalent in 2017, which accounts for about 44% of global biofuel production. Given the Renewable Fuel Standard (RFS) in the United States' Energy Policy Act (EPA) of 2005 and 2007, the U.S. government mandated a minimum quantity of ethanol, the primary biofuel produced in the U.S., in gasoline. Under the RFS, U.S. ethanol production increased by more than 570%, from 2.14 billion gallons in 2002 to 14.34 billion gallons in 2014. Importantly, more than 90% of ethanol production came from corn. While U.S. corn-based ethanol production has yielded some benefits such as reduction in harmful emissions, mitigation of global warming concerns, and increase in energy security, among others, it also caused a conflict between the ethanol and livestock industries since corn used as livestock feed dropped from 75% in 2000 to 40% in 2012. In fact, the increase in corn-based biofuel production was one of the main factors that caused the rise in corn prices after 2006 [1–7].

Several studies have examined the impact of ethanol expansion on corn prices [8–13]. These studies have concluded that corn-based ethanol expansion contributes to the rise in corn prices that in turn causes hardship for livestock producers [14–16]. Specifically, production costs have increased due to the rise in feed costs. Feed is the largest cost item in livestock production. Given the stable market price for meat in the same period (i.e., the price for boxed beef cutout was \$140.74/cwt in 2004 and \$140.77/cwt in 2009), it is apparent that livestock producers have absorbed the financial loss related to the rise in feed costs, which then reduced farm profits. Surprisingly, despite the assertion that the growth in corn-based ethanol production has negatively affected the profitability of livestock producers and the sustainability of their livelihood, little attention has been directed toward the effects of ethanol expansion on livestock producers. Previous research has not explicitly examined the direct linkage between the livestock industry and ethanol production. Given the evolving interconnections between agriculture and the biofuel markets, examining the direct impact of energy market changes on the agriculture market is important to understand the dynamic changes occurring between these two markets. Thus, this study investigates the direct effect of ethanol expansion on livestock producers' short-run resource transition and long-run productivity.

Examining the effects of external changes caused by a policy is difficult to characterize because they reflect complex decisions of individual decision makers. Individuals faced with an uncertain future can respond differently to external environmental changes in both the short run and long run. However, a bias can be introduced if we look only at either the long-run or short-run results (i.e., not both results) when evaluating or managing external shocks [17,18]. For example, those who look at the long-run efficiency gains from trade liberalization would favor free trade agreements [19–21] while those who only look at the short-run employment losses of trade liberalization would not support it [22–24]. For the ethanol mandate, one strand of research claimed that ethanol production has a long-run impact on corn prices [25,26] while another strand argued that ethanol production has a limited short-run impact on corn prices [27–29]. Given these conflicting results, it is important to consider individual producers' responses in both the short and long terms to better understand the effect of ethanol expansion and cope with a possible future uncertainty.

Specifically, this study deals with the impacts of corn-based ethanol expansion on U.S. livestock producers' short-run resource transition and long-run productivity. Given the rise in feed costs, livestock producers face higher production costs than in the past. Hence, individual producers might reallocate their resources to minimize total production costs in the short run. Examining how individual producers change their input decisions in response to ethanol expansion is important since it can help gauge the adjustment costs that are accrued due to changes in ethanol production in the short run. This

can also help in further developing effective government interventions between the two markets. In the long run, the growth in ethanol production can either positively or negatively affect farm productivity. Given a positive relationship between farm income and productivity, an immediate decrease in the expected farm income due to higher feed costs driven by an increase in ethanol expansion may decrease producer productivity in the long run. However, the sudden cost burden may cause farms with low productivity to exit from the industry and, in turn, increase the productivity of efficient farms that remain. The rise in cost may also provide an incentive for individual producers to manage farms more efficiently, and this change in farm management may positively influence producer productivity in the long run. Thus, the objective of this study is to examine the effects of ethanol expansion on individual livestock producers. This study focuses on the beef industry since it is the biggest livestock industry in terms of value of production in the United States. In addition, the United States is one of the leading beef exporters worldwide, indicating that U.S. supply changes can affect global food security. Specifically, we investigate the following: (1) How individual beef producers allocate their resources in the short run when facing changes in feed markets driven by the growth in ethanol production and (2) how ethanol expansion influences farm-level productivity in the long run. The results of this study would be important for both policymakers and the beef industry since it would lead to a better understanding of how external changes in the energy market affect the livestock industry. Particularly, given the linkage between food and energy markets and also the calls for reducing the use of agricultural feedstock for biofuel, the results from this study could be used as a guide in the development of energy policies that would balance the sustainable growth of the two markets.

To investigate the effects of ethanol expansion on individual beef producers, we used farm-level panel data from the Kansas Farm Management Association (KFMA). We specified a dynamic model to account for the dynamic structure of farm productivity and input choice decisions.

2. Empirical Methods

A two-step approach to modeling the impact of ethanol expansion on farms' long-run productivity is applied in this study. We first construct a farm-level productivity measure, total factor productivity (TFP), and then estimate the impact of ethanol expansion on farm productivity. To identify the effect of ethanol expansion on farm resource allocation in the short run, we directly regress farm resource (i.e., labor use and intermediate input use) usage on the quantity change in ethanol production.

2.1. Total Factor Productivity

Total factor productivity (TFP) is used to evaluate the impact of various policies [21,30–32]. Trefler [18] argued that it is best to use TFP as a performance measure of individual producers. TFP reflects both output performance and efficiency of input use. Farm-level TFP is obtained as the residual in the functional relationship between output and inputs. For the estimation of farm-level TFP in our study, farm production is assumed to follow the general form of a Cobb–Douglas production function as follows:

$$y_{it} = A_{it} + \beta_2 k_{it} + \beta_3 l_{it} + \beta_4 m_{it} \tag{1}$$

where y_{it} represents log of output of farm *i* in period *t*; k_{it} , l_{it} , and m_{it} are log inputs of capital, labor, and intermediate inputs of farm *i* in period *t*, respectively; A_{it} can be interpreted as the level of TFP.

The traditional estimation method, that is, applying ordinary least squares (OLS) to a balanced panel of farms, has several methodological issues. OLS may not account for a potential endogeneity problem since productivity and input choices may be correlated [30,33,34]. Moreover, using a balanced panel does not allow free entry and exit of farms and causes a selection bias [33,35]. The fixed effects model can be an alternative method to account for these issues, but the fixed effects model would not perform well in practice given that it would not be able to account for time-varying factors [36]. As such, the fixed effects model has been relaxed by allowing productivity to be decomposed into a

fixed effect and an autoregressive component [37]. Thus, A_{it} of Equation (1) can be decomposed into three error components:

$$A_{it} = c_i + c_t + u_{it} \tag{2}$$

where c_i captures individual specific productivity that is fixed over time, c_t denotes other common shocks in productivity, and u_{it} is an idiosyncratic productivity shock that can adopt an autoregressive form: $u_{it} = \rho u_{it-1} + \epsilon_{it}$ with $|\rho| < 1$ and an idiosyncratic error term, ϵ_{it} . Given these assumptions, Equation (1) becomes a dynamic structure as follows:

$$y_{it} = \delta_1 y_{it-1} + \delta_2 k_{it} + \delta_3 k_{it-1} + \delta_4 l_{it} + \delta_5 l_{it-1} + \delta_6 m_{it} + \delta_7 m_{it-1} + \delta_8 (c_i + c_t) + \epsilon_{it}$$
(3)

The estimation of Equation (3) permits the measurement of farm-level TFP. The estimated TFP explains total output growth relative to growth of inputs (i.e., capital, labor, and intermediate inputs). With all inputs accounted for, this measure represents the efficiency of production and the long-term increases in output.

2.2. Effect of Ethanol Expansion on Beef Producers

Farm productivity in the previous period can directly influence the current productivity level [38]. In addition, individual farms' input choice decisions can be affected by their previous decisions [37]. To account for the dynamic structure of individual productivity and input-use decisions and also to investigate the effect of ethanol production on individual producers, we specify the following dynamic model:

$$Y_{it} = \alpha + \beta_1 Y_{i,t-1} + \beta_2 Eth_t + \beta_3 GP_{it} + \gamma_1 Size1_{it} + \gamma_2 Size2_{it} + \gamma_3 Age_{it} + \gamma_4 DCrop_{it} + \gamma_5 Noninc_{it} + \gamma_6 DOrgan_{it} + \sum_{2003}^{2013} \alpha_t + \varepsilon_{it}$$

$$(4)$$

where Y_{it} denotes total factor productivity, labor employment, or intermediate input use of farm *i* in period *t*; *Eth*_t denotes U.S. ethanol production in period *t*; *GP*_{it} denotes government payment to farm *i* in period *t*; *Size*1_{it} denotes beef farm size; *Size*2_{it} denotes crop acres. Some beef farms in our data produce both beef and crops. Thus, crop acres are included in the model to partly control for the effects of farm heterogeneity. *Age*_{it} denotes the age of the farm operator, *DCrop*_{it} denotes a dummy variable for farms that produce both beef and crop, *Noninc*_{it} denotes nonfarm income of farm *i* in period *t*, *DOrgan*_{it} denotes a dummy variable for a farm's organization type (0 for sole proprietor and 1 for partnership and corporations), α_t denotes year dummies, and ε_{it} denotes a random disturbance that is composed of farm-specific effect δ_i and an i.i.d. component v_{it} . In this model, we assume that capital use is quasi-fixed in the short run following economic theory; therefore, we do not consider it in this analysis.

The external shock (i.e., ethanol production expansion caused by the policy change) is included to identify farms' responses in both the long run and the short run. Farm production costs increase with the rise in ethanol production [15,39]. In response to an increase in production costs, individual farms may reallocate their current resources to reduce the total production cost based on economic theory. Additionally, a policy variable (i.e., government payments) is included in the model since it can influence farms' input choices by liquidating farm credit in input markets, and that, in turn, positively affects farms' productivity.

To control for the effects of farm size, both the number of cattle and crop acres are included in the models. These two size variables may cause an increase in labor input use, but they may have different effects on intermediate input use since beef farms with larger crop sizes may be more resistant to negative external environmental changes. There may also be an inverse relationship between farm size and productivity as suggested by other studies [40–43]. A dummy variable for farms that produced both beef and crop is included to control for the effect of multi-product production in farms. Farms

with multiple outputs may use more labor, but they may reduce cost burden on the feed purchase. Moreover, dual production can give risk-management benefits when farms face uncertainty, and it can result in productivity gains in the long run [44]. Non-farm income is also included in the model since it may influence input decisions and farm productivity by liquidating farm credits in input markets [45].

To control for the effects of different organization types (i.e., sole proprietor, partnership, and corporation), an indicator for the organization type of farms is included in the models. Partnerships and corporations can be an external source of capital resources; therefore, it may reduce the need for additional resources from external shocks. However, partnerships and corporations may also reduce managerial effort and cause a decrease in farm performance [38]. The farm operator's age is included to control for the effects of experience. Farm productivity can increase with the operator's experience. The producers may invest and expand their farms at the earlier stage of the life cycle, and that in turn could increase productivity at the later stage. Year dummies are included to capture the potential time and other market effects. The dynamic structure of the model allows productivity and input use in the previous period to impact those of the current period [37,46,47].

2.3. Estimation Strategy

The dynamic panel models include the lagged dependent variable as explanatory variables and unobserved panel-level effects. The unobserved panel-level effects are correlated with the lagged dependent variables by construction, and this can cause inconsistent estimators in linear regression models. Arellano and Bond [48] developed the difference generalized method of moments (GMM) estimator for estimating parameters under these conditions. The difference GMM estimator removes the panel-level effects by first-differencing and using all valid historical values of the lagged level variables as instruments to construct the moment conditions.

However, the lagged level variables in the difference GMM estimator become weak (weakly correlated with endogenous variable) as instruments in the model when the data get close to being nonstationary or when the relative variation of individual heterogeneity becomes too large (see the discussion in [49]). Weak instruments could cause large finite sample bias and poor precision in simulation studies. To account for this problem in the difference GMM estimator, Blundell and Bond [49] proposed a system GMM estimator. This estimator uses two moment conditions as follows. The lagged levels of variables in Equation (4) are used as instruments for the differenced equation, implying the following moment conditions: $E[Y_{i,t-2}\Delta v_{it}]$ where $\Delta v_{it} = v_{it} - v_{i,t-1}$, and the lagged differences of variables in Equation (4) are used for the level equation: $E[\Delta Y_{i,t-1}(\delta_i + v_{it})]$ where $\Delta Y_{i,t-1} = Y_{i,t-1} - Y_{i,t-2}$. All the instruments are thus available to the differenced equation and the level equation.

The system GMM is necessary in our study since the unobserved farm-specific effects are correlated with the lagged dependent variable; therefore, the estimation should use an instrument to account for an endogeneity problem in the model. However, the dependent variables (i.e., total factor productivity, labor, and intermediate use) are nonstationary in levels. Based on Fisher-type panel unit-root test, the null hypothesis that the variables contain unit roots (*p*-values for three variables are close to 0.99) is failed to be rejected. Non-stationarity of the variables could cause a weak instrument problem and cause finite sample biases in the traditional difference GMM [49].

The moment conditions in the system GMM are valid only when there is no serial correlation in the level disturbances. Serial correlation at order one in the first-differenced disturbances does not imply that the model is mis-specified since the first difference of i.i.d. errors will be autocorrelated by construction. However, rejecting no autocorrelation at the second order provides evidence of misspecification of the model. Serial correlation in the errors is tested using the Arellano–Bond test [48]. To test whether the instruments used in the system GMM estimation are valid, we also conduct the Sargan test of overidentifying restrictions [50].

3. Data and Empirical Results

3.1. Data

Data used in this study are from farms enrolled in the Kansas Farm Management Association (KFMA) programs. Kansas is the third largest producer of cattle in the United States, and about half of all agricultural revenues come from this industry. The beef industry in Kansas significantly contributes to the state's economy by providing revenues for the state, employing citizens, and supplying high animal protein to people. The farm-level panel data cover the period from 1973–2013 with details on farm characteristics, crop production, livestock production, farm income, farm expenses, and other farm characteristics. The dataset is an unbalanced panel. Since beef farms in different production phases (i.e., cow/calf, backgrounding, and finishing) experienced higher production costs during the periods of ethanol expansion, we include all farms related to beef production and 766 farms for both beef and crop production) are included. Given that higher feed costs could mainly affect farms in the finishing phase, we provide the results for farms that are involved in this phase in the Appendix A (see Tables A2 and A3).

Summary statistics of data used in this study are presented in Table 1. One aggregated output and nine inputs are used for the total factor productivity estimation. The output measured is farm revenue. Inputs include labor; capital including machine hire, equipment expenses, machine repairs, and building repairs, and intermediate inputs including fuel, fertilizer, herbicide, feed purchased, and other utilities. Money-value variables are deflated with the appropriate price index provided by the United States Department of Agriculture (USDA) Economic Research Service (ERS). Beef producers in Kansas hire about 1.3 people and spend about 153.24 and 35.45 USD (in thousand dollars) for intermediate and capital inputs, respectively. On average, the United States produced about 7.59 billion gallons of ethanol during the same period with about 2.80 billion gallons in 2003 and about 13.29 billion gallons in 2013.

Variables	Unit	Mean	Std. Dev.
Output	1000 dollars	606.49	1189.05
Labor	Persons	1.29	1.07
Capital	1000 dollars	35.45	44.30
Intermediate	1000 dollars	153.24	331.42
Total Factor Productivity	_	1.22	1.07
Ethanol production	billion gallons	7.59	4.49
Government payment	1000 dollars	13.91	18.93
Beef size	Animals	236.47	513.41
Crop size	1000 acres	0.73	0.82
Âge	Years	57.43	45.88
Nonfarm income	1000 dollars	34.61	158.86
Dual production	Dummy	0.77	0.42
Organization type	Dummy	0.15	0.36

Table 1. Summary Statistics (2002-2013).

Note: Ethanol production data are from the United States Department of Agriculture Economic Research Services.

On average, Kansas beef farms raised about 236 animals during the same period. The average beef size was 237 animals in 2005, but it decreased to 218 animals in 2007, suggesting that beef farms may have reduced their herd's size after the rise in corn prices. Approximately 75% of Kansas beef farms also produced other crops like corn, wheat, and soybean, and they had on average 0.73 thousand acres for crop production. The average farm operator's age was about 57 years, and they earned about 35,000 USD from nonfarm activity, which is about 9.4% of gross farm income. On average, Kansas beef farms also received 14,000 USD of payment from the government from 2002–2013. Their organization type was mostly sole proprietor.

The average farm-level total factor productivity was calculated from the estimation of Equation (3). The estimation results of Equation (3) are presented in Table A1 in the Appendix A. The estimated average TFP in Kansas is 1.22, which is higher than the average U.S. national agricultural TFP (1.01) for livestock and crops in the same period. This result suggests that Kansas beef farms are more productive than general beef producers in the United States. Kansas is one of the biggest states in terms of cattle inventory in the United States. This size differential may be substantial in terms of production and input stock and use, and may cause the productivity difference from the national level.

3.2. Short Run Resource Allocation

Table 2 reports estimation results from the system GMM for the cases where the dependent variables are labor use and intermediate input use. The Sargan tests fail to reject the hypothesis that over-identifying moment conditions are valid in the models. This means that the instruments used in the models are valid. The Arellano–Bond test for zero autocorrelation in first-differenced errors fails to reject the null hypothesis of no autocorrelation at the second order, indicating that there is no serial correlation in the level disturbance. The test results suggest that the moment conditions are valid in both models.

Variables	Labor Use		Intermediate	Input Use
	Coefficient	Std. Err.	Coefficient	Std. Err.
Lagged Input Use	0.387 **	0.162	0.962 ***	0.057
Ethanol Production	-0.016 **	0.006	6.105 ***	2.201
Government Payment	0.002	0.002	0.218	0.634
Dual Production	-0.035	0.029	-61.185 ***	18.906
Organization Type	-0.048	0.275	-44.008	51.953
Beef Size	0.000	0.000	-0.033	0.032
Crop Size	0.612 ***	0.230	62.871 **	30.054
Operator Age	0.005	0.005	0.999	1.096
Nonfarm Income	0.000	0.000	-0.064	0.122
Constant	0.191	0.439	57.674	112.825
Observations (Farms)	2425 (618)		2425 (618)	
Sargan test (H0: over-identifying restrictions are valid)				
0	Chi2-statistic:		Chi2-statistic:	
	73.35	p-value > 0.19	74.85	p-value > 0.16
Arellano–Bond test (H0: no autocorrelation)				
Order 1	z-statistic: -2.60	<i>p</i> -value < 0.05	z-statistic: -2.37	<i>p</i> -value < 0.05
Order 2	z-statistic: 0.59	<i>p</i> -value > 0.56	z-statistic: -0.50	<i>p</i> -value > 0.61

Table 2. Effect of Ethanol Expansion on Resource Allocation.

Note: ** and *** denote statistical significance at the 5% and 1% levels, respectively. A set of year dummies is included in the models.

In both the employment and intermediate inputs models, the lagged dependent variables are positive and statistically significant at the 5% level, which is consistent with Hansen and Sargent [46]. They concluded that optimal input decisions by rational producers are intertemporally correlated, and the decision processes are based on the autoregressive model. Our results indicate that beef farms consider both current and previous periods when they decide on labor use and intermediate input use. Specifically, a higher input use in the previous period correlates to more demand for both inputs in the current period. This suggests that failing to consider the dynamic structure of input-use decisions could cause model misspecification.

The coefficient of ethanol production is positive and statistically significant in the intermediate input-use model. Previous studies have found a positive relationship between ethanol expansion and corn prices [8,10–12]. This finding indicates that beef producers needed to pay more for feed purchases when corn prices spike after ethanol production increased. On average, beef producers spent

about \$61,033 USD in 2005, and this increased by 45% in 2007 in our data. However, the coefficient of ethanol production is negative and statistically significant in the labor-use model. This suggests that with an increase in costs of intermediate inputs, beef producers choose to decrease labor use in beef production to minimize total production cost. The effects of ethanol expansion on input use are bigger when we only include farms involved in the finishing phase since large amounts of feed grains are required in this production phase (see Table A2). Labor is a variable input in the production process with quasi-fixed capital in the short run. Thus, individual beef producers compensate increased total production cost by reducing labor employment in the production process. The average labor employment was about 1.29 in 2005, and it decreased to about 1.20 in 2007 in our data.

Focusing on other variables, government payments increase both the labor and intermediate input uses as we expected, but they are not statistically significant. The coefficients of crop size are positive and statistically significant in both models, indicating that farms need more labor and intermediate inputs with an increase in crop acres. The dummy variable for dual production farms is negative and statistically significant in the intermediate input model. This may indicate that farms that produce both beef and crops reduce cost burden on feed resources by integrating their beef and crop production. Moreover, dual production may have benefits of improved soil physical, biological, and chemical fertility and weed management such that farms minimize costs of intermediate inputs like fertilizer and herbicide [44]. The coefficients of organization type are negative in both models. This suggests that farms that are partnership or corporations reduce their demand for both labor and intermediate inputs as expected. However, the results are not statistically significant.

3.3. Long-Run Productivity

Table 3 presents estimates for the case where the dependent variable is the farm-level total factor productivity. Both the Sargan and Arellano–Bond tests suggest that the moment conditions are valid in the model. The lagged farm productivity is positive and statistically significant, indicating that productivity in the previous period has a direct impact on productivity in the current period. This suggests that farms with higher productivity in the previous period have more potential to further improve their productivity. This result also suggests that the inherent dynamic structure of farm productivity should be considered to avoid misspecification of the model.

Variables	Coefficient	Std. Err.		
Lagged Productivity	0.125 **	0.061		
Ethanol Production	0.011 **	0.005		
Government Payment	0.001 **	0.0005		
Dual Production	-0.050	0.044		
Organization Type	-0.027	0.067		
Beef Size	-0.000 **	0.000		
Crop Size	-0.002	0.067		
Operator Age	0.002	0.002		
Nonfarm Income	-0.000	0.000		
Constant	-0.153	0.178		
Observations (Farms)	2425 (618)			
Sargan test (H0: over-identifying restrictions are valid)				
	Chi2-statistic: 63.53	<i>p</i> -value > 0.49		
Arellano–Bond test (H0: no autocorrelation)				
Order 1	z-statistic: -7.00	<i>p</i> -value < 0.01		
Order 2	z-statistic: 1.15	<i>p</i> -value > 0.25		

Table 3. Effect of Ethanol Expansion on Farm Productivity.

Note: ** denotes statistical significance at the 5% level. A set of year dummies is included in the models.

The expansion of ethanol production has a positive and significant impact on farm productivity. This result may suggest that an increase in ethanol production caused by the policy change was a permanent shock in the beef industry. Corn supply in the feed market was constrained by the increase in ethanol production from 2006, and this shortage of corn used for animal feed changed the feed market by sharply elevating feed price. For example, the average corn price paid for by farms was about \$2.00 USD per bushel in 2005, but increased to about \$7.00 USD per bushel in 2012. The feed price spikes resulted in a cost burden for beef producers in the short run, but could also have provided an incentive to manage farm inputs more efficiently. This change in farm management might then increase productivity in the long run. Another possible interpretation of our result is that farm productivity rose due to the exit of farms with low productivity from the industry. The increase in production cost after the feed price spikes may have caused farms with low productivity to exit the industry. In our data, there were 383 farms with an average of 201 animals per farm in 2002, and the number of farms decreased to 223 with an average of 239 animals in 2013. This suggests that only efficient farms were left in the industry, and they would garner the productivity gains in the long run. Our results are partly consistent with other studies on the impact of external environmental changes on productivity. For example, Trefler [18] examined the effects of free trade agreements on both short-run resource transition and long-run productivity. The study found that trade liberalization causes resource transition costs (i.e., displacement of labor) in the short run, while it increases the long-run productivity of efficient producers. The study claimed that productivity gain is mainly owing to the exit of producers with low productivity from the industry.

Focusing on policy variable, the coefficient of government payment is positive and statistically significant. Government payments can provide farms liquidity in input markets, and that in turn could influence farm output. This could also cause productivity gains in the long run. Two farm-size variables (i.e., beef size and crop size) have negative impact on farm productivity. Smaller farms may intensively use their inputs, and it could potentially result in productivity gains in the long run. The inverse relationship between farm size and productivity has also been observed in previous studies [40–43]. Crop size and all the other farm characteristics are not statistically significant in the model. The coefficient of age is positive as we expected, but it is not statistically significant. A farm being a partnership or a corporation would reduce farm productivity as expected, but this is also not statistically significant.

4. Conclusions and Discussion

The interconnections of the agriculture and energy markets have evolved with the rise in biofuel production. The increase in biofuel production has produced some intended benefits such as a reduction in greenhouse gas emissions and an increase in fuel security, but it also had other unintended effects. Biofuel production is heavily dependent on feed grains that are used for food and livestock feed; therefore, the rapid growth of biofuel production has raised global food security concerns. Specifically, livestock producers faced higher feed costs and decreased net farm incomes because of the expansion of biofuel production costs, the production of animal protein could decrease and rural communities where livestock are produced could experience loss of economic activity. This indicates that environmentally sustainable energy use could directly pose a threat to rural communities and future food security. Additionally, given the growth in global population and increasing incomes in some developing countries, consumption of meat and other dairy products has sharply increased in the last decades. Hence, to meet global food demand, having a sustainable food supply is extremely important.

Despite the argument that the rise in biofuel production has had a negative impact on the livelihood of livestock producers, previous studies have not explicitly investigated the direct effect of the growth of biofuel production on individual livestock producers. As an initial attempt to examine the direct effect of biofuel expansion on livestock producers, this study investigated beef producers' short-run resource transition and long-run productivity change in response to the rise in corn-based ethanol production in the United States. Examining both the short-run and long-run effects of ethanol production on individual agricultural producers gives us important insights on how to develop policies that can reduce the conflict between agriculture and biofuel industries and also enhance the sustainability of livestock producers' livelihood to counter any unintended effects of previously established energy policies.

Given the dynamic nature of farm productivity and input-use decisions, the dynamic panel models were specified to measure farm productivity and to examine the effects of ethanol expansion on farm resource transition and productivity. Using farm-level panel data from the Kansas Farm Management Association covering 2002–2013, our results first showed that traditional static models of farm productivity and input-use decisions are mis-specified given that both productivity and input-use decisions are intertemporally correlated. Consequently, we used the system GMM estimator to account for both endogeneity and serial correlation problems in the dynamic models.

Our results showed that with the rise in corn prices after the expansion of ethanol production, beef producers spent far more for intermediate inputs. To compensate for increased total production costs driven by the increase in corn demand for ethanol production, producers reduced labor use in the production process. This finding suggests that the sudden expansion of ethanol production is associated with employment losses in the beef industry. Our empirical results also showed that ethanol expansion increased average farm productivity due partly to significant reduction in the number of farms over the years. The sudden cost burden from higher feed costs might have caused the exit of farms with low productivity, which in turn increased the productivity of the efficient farms that remained in the industry.

Overall, the results generally suggest that to better assess the impact of external changes and cope with uncertainty, it is important to consider individual decision makers' responses in both the short run and the long run. This study also suggests that given the evolving linkage between agriculture and energy markets, policymakers should consider the potential unintended effects of new energy policies from both short and long-term perspectives. Given our findings, energy policies that promote corn-based ethanol expansion should focus on short-term assistance for employment losses in the livestock industry and profit losses of producers who exit the industry. This study provides important information on how livestock producers respond to an external change in the energy market (i.e., corn-based ethanol expansion) in the short term and the long term. Our results indirectly suggest that for a more sustainable food supply, policymakers should consider reducing the unintended impact of threats to food security when promoting biofuel production as an alternative energy policy.

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Appendix A

Variables	Coefficient	Std. Err.		
Lagged Output	0.287 ***	0.071		
Labor	0.122 *	0.069		
Lagged Labor	0.022	0.058		
Capital	0.079 **	0.037		
Lagged Capital	-0.069 **	0.031		
Intermediate	0.263 ***	0.052		
Lagged Intermediate	0.006	0.049		
Constant	5.197 ***	0.731		
Observations (Farms)	2425 (618)			
Sargan test (H0: c	Sargan test (H0: over-identifying restrictions are valid)			
Ç .	Chi2-statistic: 68.48	<i>p</i> -value > 0.30		
Arellano-Bo	Arellano-Bond test (H0: no autocorrelation)			
Order 1	z-statistic: -6.76	<i>p</i> -value < 0.01		
Order 2	z-statistic: -0.03	<i>p</i> -value > 0.95		

Table A1. Estimation Result of Production Function.

Note: *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. A set of year dummies is included in the models.

Table A2. Effect of Ethanol Expansion on Resource Allocation (Farms involved in Finishing Phase	e).
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Variables	Labor Use		Variables Labor Use		Intermediate	Input Use
	Coefficient	Std. Err.	Coefficient	Std. Err.		
Lagged Input Use	0.323 **	0.131	0.843 ***	0.087		
Ethanol Production	-0.058 **	0.029	23.164 **	9.500		
Government Payment	0.001	0.004	0.978	1.350		
Dual Production	0.006	0.232	-223.601 ***	85.271		
Organization Type	-0.500	0.700	-207.846	218.805		
Beef Size	-0.000	0.000	-0.075	0.134		
Crop Size	1.061 **	0.415	106.385	96.329		
Operator Age	0.013	0.011	1.356	1.612		
Nonfarm Income	0.001	0.002	0.048	1.027		
Constant	0.188	1.135	177.601	256.895		
Observations (Farms)	413 (174)		413 (174)			
Sargan test (H0: over-identifying restrictions are valid)						
	Chi2-statistic: 61.50	<i>p</i> -value > 0.56	Chi2-statistic: 81.22	<i>p</i> -value < 0.09		
Arellano-Bond test (H0: no autocorrelation)						
Order 1	z-statistic: -1.75	<i>p</i> -value < 0.09	z-statistic: -2.475	<i>p</i> -value < 0.05		
Order 2	z-statistic: -1.16	<i>p</i> -value > 0.24	z-statistic: -0.709	<i>p</i> -value > 0.47		

Note: ** and *** denote statistical significance at the 5% and 1% levels, respectively. A set of year dummies is included in the models.

Table A3. Effect of Ethanol Expansion on Farm Productivity (Farms involved in Finishing Phase).

Variables	Coefficient	Std. Err.
Lagged Productivity	0.448 ***	0.098
Ethanol Production	0.041 ***	0.010
Government Payment	0.003 ***	0.001
Dual Production	0.097	0.084
Organization Type	0.283 **	0.128
Beef Size	-0.000	0.000
Crop Size	0.037	0.125
Operator Age	-0.004	0.003
Nonfarm Income	0.000	0.001

Variables	Coefficient	Std. Err.		
Constant	-0.400	0.297		
Observations (Farms)	413 (174)			
Sargan test (H0: over-identifying restrictions are valid)				
Chi2-statistic: 69.03 <i>p</i> -value >		<i>p</i> -value > 0.31		
Arellano-Bond test (H0: no autocorrelation)				
Order 1	z-statistic: -3.97 <i>p</i> -value < 0			
Order 2	z-statistic: 0.31 p -value > 0 .			

Table A3. Cont.

Note: ** and *** denote statistical significance at the 5% and 1% levels, respectively. A set of year dummies is included in the models.

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