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Powering America: The Impact of Ethanol Production in the Corn Belt States

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Abstract

This paper investigates the impact of ethanol production in the Corn Belt states (Iowa, Indiana, Illinois, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, Ohio, South Dakota, and Wisconsin). Employing data at the county level, from 2005 and 2006, we investigate the effect of ethanol production on employment and wages. Our empirical results show that ethanol production has a positive significant effect on employment and wages, but this effect is of insignificant magnitude. We also find that counties with high and medium levels of ethanol production capacity show higher levels of employment and wages than those counties that do not produce ethanol. Counties with low levels of ethanol production do not show any significant difference in employment and wages than non-producing ethanol counties.

JEL classification codes: Q10, R10, O13

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I. Introduction

The 2005 Energy Policy Act mandated the use of 7.5 billion gallons of renewable fuels in the United States by the year 2012. This modest goal was achieved relatively early, and as a result of this success, the Energy Independence and Security Act of 2007 increased the goal to 36 billion gallons of renewable fuels by 2022. The American Recovery and Reinvestment Act of 2009 provided additional funding to alternative fuel production and research. In fact, the Clean Air Act of 1963 was the original stimulus for ethanol, calling for greater use of the product as an oxygenate in gasoline to reduce carbon monoxide emissions. This legislation has led to a significant increase in the production of corn ethanol in the United States.[1]

Corn is used for ethanol generation in the United States because of its abundance and because cellulosic biomass development is only in the early stages of development globally and years away from economic viability. The increase of ethanol production and usage in the United States can be considered one of the factors explaining the rise in the price of corn, giving farmers in the Corn Belt a significant financial boost. While there are initial increases in corn prices due to ethanol production, high prices have leveled off somewhat as competitive markets have adjusted for the increasing demand for corn.[2] These initial price increases and the promise of continued ethanol demand have motivated congressmen from Corn Belt states to support and encourage initiatives to "go green" (Yacobucci, 2007). Unfortunately, environmentalists contend that corn-based ethanol is the least environmentally friendly of the conventional alternative fuels.

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[1] A brief review on legislation related to renewable fuels standard is provided by the Renewable Fuels Association at http://www.ethanolrfa.org/resource/standard/.

[2] Fortenbery's and Park (2008) analysis of the United States corn market shows that while corn prices are sensitive to ethanol production, ethanol production is not the sole factor explaining corn prices. They find that food, alcohol, and industrial demands have a greater impact on corn prices than ethanol production. Ferris and Joshi (2004) argue that the initial increase on the price of corn due to ethanol production is likely to diminish over time as corn acreage increases. It is expected that during the 2009-2010 year, corn supply in the United States will reach a record of 13.2 billion bushels, and prices will remain relatively strong at a range of 3.4-4.0 dollars per bushel (USDA, 2010).

Although it has been shown that the cost of producing corn ethanol is greater than the benefit, current legislation pushes for greater production and consumption of corn ethanol.[3]

In this paper, we look at the impact of ethanol production in the Corn Belt states on employment and wages to determine whether the push towards increasing ethanol production can be considered a tool for job creation. We contribute to the biofuels literature by looking at current data on ethanol production in the United States at the county level. This analysis determines whether the energy bills that promote greater ethanol production can be justified on the grounds that they lead to greater employment and greater income in the Corn Belt. The findings indicate that ethanol production in the years of 2005 and 2006 had a statistically significant positive effect on employment and wages in the Corn Belt, but the magnitude of the effect is insignificant. Interestingly, we find that counties with high and medium levels of ethanol production capacity show higher employment and wages than non-producing ethanol counties. Those counties with low levels of ethanol production show no significant difference in employment and wages from non-producing ethanol counties.

This paper is organized as follows: Section II presents a literature review on ethanol; Section III presents the methodology and data; Sections IV presents the empirical results; and Section IV provides a discussion of the policy implications of our findings.

II. Literature Review

Even though the amount of energy needed to grow corn and break it down into ethanol is much greater than the amount needed for sugar based or cellulosic ethanol, corn ethanol is currently the only biofuel produced in serious quantity in the United States (Montenegro, 2006;

[3] Hahn's and Cecot (2007) cost-benefit analysis of ethanol production shows that the costs of producing ethanol are greater than the benefits. More discussion on cost-benefit analyses of ethanol production is presented in the literature review.

Yacobucci and Schnepf, 2007).[4] Conventional and cellulosic ethanol yield approximately two-thirds the energy of gasoline, but cellulosic ethanol is three times more environmentally efficient (EIA 2007; USDA, 2007). For this reason, the Energy Security and Independence Act limits the amount of corn ethanol that can be utilized to reach energy goals. Nonetheless, the shift towards more efficient biofuels, such as cellulosic ethanol, is difficult. With the available technology, the production of cellulosic ethanol is not economically viable in the United States.[5] According to Sticklen (2008), the cost of producing cellulosic ethanol is three times the cost of producing corn ethanol.

The development of the ethanol market is distinct in several ways. Cascone (2007) notes "the development of biofuels is primarily driven by three fundamental policy considerations: rural development, energy independence, and a reduced carbon footprint" (p.95). He states that social and political interests seem to have motivated ethanol production in the United States and not market forces. When bringing together various sectors of society to artificially create a new market, there will be significant costs in the early stages of market creation. Import tariffs, tax credits, and consumption mandates are some of the policies that have been implemented with the purpose of protecting the domestic ethanol market.

There are several analyses on the welfare effect of the government policies related to the market for ethanol.[6] For example, Elobeid and Tokgoz (2006) find that the duties imposed on ethanol imports and the tax credit on domestic ethanol production have kept ethanol prices artificially high. De Gorter and Just (2007a,b,c and 2008) present a good theoretical framework

[4] The production of sugar based ethanol is unlikely in the United States due to geographic conditions.
[5] According to the United Nations Environment Programme (2009), investment in the development of cellulosic ethanol started in 2006 worldwide, and the first commercial cellulosic ethanol facility in the United States went into production in 2008. Thus, the production of cellulosic ethanol on an industrial scale is unlikely to be possible in the United States in the near future.
[6] Elobeid and Tokgoz (2006) and Kojima et al. (2007) present a good review of ethanol market policies in the United States.

to determine the welfare effects of major policies related to biofuels in the United States: excise-tax exemption, biofuels consumption mandate, and import tariff. For example, they find that the estimated deadweight cost of the tax credit is higher than the deadweight cost of farm subsidies (De Gorter and Just, 2007a). De Gorter and Just (2007b) also find that when the mandate for biofuels is non-binding, the removal of the tax credit leads to a decrease in the price of ethanol. On the other hand, when the mandate is binding, the removal of the tax credit has a very small impact on ethanol prices. Furthermore, Vedenov and Wetzstein (2009) estimate that the optimal ethanol subsidy for the United States is lower than the current subsidy. Thus, when designing future energy policy, it is important to look at the welfare effect of current government policies that affect the ethanol market. To better understand the implications of energy policy related to biofuels, we should consider whether the benefits of ethanol production and consumption offset internal and external costs and how these policies affect specific sectors in the economy.

Life cycle inventory analyses have been performed with the purpose of determining the resource cost and environmental implication of ethanol production. A review of the different life cycle analyses of the impact of biofuels presented by the United Nations Environment Programme (2009) shows that when comparing the impact assessment of biofuels to fossil fuels, results vary significantly. In the case of corn ethanol, greenhouse gas emission savings can go from 60 percent to negative 5 percent, depending on the feedstock and conversion technology used. According to Wang's et al. (2007) analysis, which looks at nine different types of ethanol plants in the United States, the greenhouse gas emissions savings can go from 3 percent (coal fueled plant) to 59 percent (wood chips fueled plant). They estimate that corn ethanol reduced greenhouse gas emissions on average by 19 percent in 2007, and forecast a reduction of 21 percent in 2010. One of the latest life cycle analyses on the production of corn ethanol in the

United States, provided by Liska et al. (2009), shows that corn ethanol reduces greenhouse gas emissions between 48 and 59 percent in comparison to gasoline. In addition, this analysis shows that net energy ratios of corn ethanol are higher than in previously estimated (1.5 to 1.8, instead of 1.2), and ethanol to petroleum ratios have reached between 10:1 to 13:1 as a result of the development of new technology.[7]

In contrast, the results from cost-benefit analyses on ethanol production are not positive. Hahn and Cecot (2007) perform a cost-benefit analysis of ethanol production in the United States, where they compare energy security and environmental benefits with the cost of producing and distributing ethanol, the deadweight loss of government programs, and the environmental costs associated with an increase in emissions. In their cost-benefit analysis, the costs are greater than the benefits by around 3 billion dollars annually. Furthermore, they estimate that tax credits and subsidies for corn ethanol are costing taxpayers more than 2 billion dollars annually. Bernard and Prieur (2007) do a similar cost-benefit analysis of ethanol production in France and also find that the cost of producing ethanol is greater than the benefit. When looking at the supply constraints related to corn production, Eaves and Eaves (2007) conclude that corn ethanol is not a reliable source of energy. They estimate that in order for corn ethanol to displace 15 percent of gasoline consumption, corn harvest must grow by 423 percent. They also state that if all current corn production is devoted to the production of ethanol, only a 3.5 percent of gasoline consumption will be displaced.

Employment in the agricultural sector has been considered one of the driving forces behind policies that promote biofuels production. According to Charles et al. (2007) the production of biofuels has created a security net for specific rural areas, which has led to more

[7] See Lavigne and Powers (2007) and Rajagopal and Zilberman (2007) for a good literature review on analyses that look at the net energy value of ethanol.

support for this sector in the United States and the European Union. Charles et al. (2007) also argue that strong farming lobbies, existing distribution infrastructure, and supply chains are the reasons behind strong government support for biofuels. Some analyses have tried to predict the economic impacts of ethanol production in the agricultural sector in the United States. For example, De La Torre et al. (2007) estimate the economic impact of ethanol production on the agricultural sector by integrating a dynamic agricultural sector model with an economy input-output model. They assume ethanol production reaches 10, 30, and 60 billion gallons annually by 2010, 2020, and 2030, respectively. They also assume that cellulosic ethanol technology becomes commercially available in 2012, thereby making corn the main source for ethanol production through 2012 but keeping the use of corn at near capacity (the growth of the use of corn is reduced after 2012 and it becomes flat after 2020). Under this scenario, De La Torre et al. (2007) estimate that a gradual increase of ethanol production will lead to a cumulative gain in net farm income of 210 billion dollars between 2007-2030.

The Environmental Protection Agency (EPA, 2007) projections of the economic impact of ethanol production on the agricultural sector coincide with De la Torre's et al. (2007) estimates of a positive effect of significant magnitude on farm income. The EPA uses the Forest and Agricultural Sector Optimization Model and assumes an increase in the volume of renewable fuels to 7.5 billion gallons per year by 2012. The EPA (2007) calculates an increase in farm income of 2.65 billion dollars in 2012 due to the increase in ethanol production. This increase in farm income will be concentrated in rural areas and it will represent an increase of 5 percent on farm income. Under this analysis, a minimal increase in agricultural employment will be observed since the current production process is not labor intensive, and the increase in employment due to ethanol plant construction and operation is likely to be small (between 30 to 50 people are employed per ethanol plant).

Based on this literature review, it is evident that there is some disagreement on what is the true impact of the increase in ethanol production and consumption resulting from current energy policy in the United States. It is important to note that most of the analyses on the ethanol market are based on projections and assumptions and, although they can be considered as best estimates, there is a high level of uncertainty surrounding them. For this reason, we are interested in looking at current data to analyze the economic impact of ethanol production on employment and wages in the Corn Belt. Through this analysis, we intend to determine whether the push toward greater ethanol production can be justified on the grounds of being a tool for job creation and wage increase.

III. Methodology and Data

We analyze the impact of ethanol production on employment and wages at the county level using Hanson's (2001) methodology. Hanson (2001) assumes a competitive labor market in the United States and derives the reduced form equations for equilibrium employment and wages.[8] Due to the nature of the industry in this analysis, we make three main modifications to Hanson's (2001) methodology. First, we use information at the county level instead of information at the city level. Second, we consider total employment and wages at the county level instead of employment and wages by industry. Third, the ethanol production variable is

[8] Reduced form equations express an endogenous variable in terms of the error term and predetermined (exogenous) variables. The coefficients in a reduced form equation represent the impact of an increase in an exogenous variable on the endogenous variable. See Cameron and Trivedi (2005, p.20) for further explanation on reduced form equations.

incorporated in the model specification as an independent variable.[9] Using a modified version of Hanson's (2001) model specification, we estimate the following equations separately:

$$Ln(N_{ijt}) = \beta_0 + \beta_1 Ln(ALT\_W_{ijt}) + \beta_2 Ln(ALT\_Y_{ij}) + \beta_3 Ln(ALT\_N_{ijt}) + B_4 Ethanol_{ijt} + \varepsilon_{ijt} \quad (1)$$

$$Ln(W_{ijt}) = \alpha_0 + \alpha_1 Ln(ALT\_W_{ijt}) + \alpha_2 Ln(ALT\_Y_{ij}) + \alpha_3 Ln(ALT\_N_{ijt}) + \alpha_4 Ethanol_{ijt} + \eta_{ijt} \quad (2)$$

Our dependent variables in equations (1) and (2) are: the natural logarithm of average employment (N) and the natural logarithm of average real wage (W) for county i, in state j, at period t. The control variables in both equations are: the natural logarithm of alternative real wage (ALT_W), the natural logarithm of alternative real income (ALT_Y), and the natural logarithm of alternative employment (ALT_N).[10] The alternative real wage variable represents the average real wage at the state level, excluding the county in which the observation was taken. Alternative real income is equal to total income in the state, excluding the county in which the observation is taken. Alternative employment is total employment at the national level minus employment in the state in which the county is located. These control variables are used to account for observable state and national conditions. Our estimation of equations 1 and 2 include state and time dummy variables to control for unobserved state and time specific factors.[11]

In order to estimate how ethanol production affects employment and wages at the county level, we look at the variable Ethanol, which is the ethanol production capacity in a county (in

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[9] In Hanson's (2001) analysis, the focus is on determining the impact of the maquiladora sector in Mexico on employment and wages in the United States border cities. In our analysis, the industry of interest is ethanol, and therefore, we introduce a variable that accounts for activity in that industry (instead of the maquiladora value added included by Hanson (2001)). We provide further discussion on why we consider Hanson's (2001) approach adequate for our analysis in this section.

[10] We use the consumer price index to deflate nominal wages and income to obtain the real values.

[11] Specifically, there are other minor differences from Hanson's (2001) equations 1 and 2. While Hanson (2001) excludes the city value from which the observation is taken when he estimates the alternative wage and income, we exclude the county value. Hanson (2001) includes fixed effects that account for time and city industry variation, while we include fixed effects that account for time and state variation.

billions of gallons). For robustness, we also evaluate the impact of actual ethanol production on employment and wages, perform estimations including only the major ethanol producing states, and account for endogeneity.[12] Furthermore, we estimate whether there is a significant difference in average employment and wages between ethanol producing counties and those counties that do not produce ethanol. For this part of the analysis, we construct three dummies that account for different production capacity levels: high (Ethanol_H), medium (Ethanol_M), and low (Ethanol_L). Ethanol_H is equal to one if a county has an ethanol production capacity greater than the mean plus one half the standard deviation (0.081 billion gallons), zero otherwise. The Ethanol_M dummy is equal to one if a county has an ethanol production capacity below or equal to the mean plus one half the standard deviation but greater or equal to the mean minus one half the standard deviation (values between 0.081 and 0.028 million gallons), zero otherwise. Ethanol_L is equal to one if the county has an ethanol production capacity lower than the mean minus one half the standard deviation, zero otherwise. We include these three dummies, making non-producing ethanol counties the comparison group.[13]

Hanson (2001) uses the equation shown above to analyze the impact on economic activity in the United States-Mexico border region as a result of the North American Free Trade Agreement (NAFTA). NAFTA led to a significant increase in the trade of manufacturing products between the United States and Mexico. Our analysis is similar to Hanson's (2001) analysis in the sense that we intend to quantify the regional impact of an increase on ethanol production in the Corn Belt. We consider Hanson's (2001) methodology appropriate for this analysis because we focus on the regional impact of an increase on production in a specific industry, which is similar to Hanson's (2001) work. In our framework, it is expected that ethanol

[12] The correlation between ethanol production capacity and actual production is equal to 0.83.
[13] To create these dummy variables, we use the mean and standard deviation estimated for ethanol producing counties.

operations have an incentive to concentrate in the Corn Belt due to lower costs of corn transportation.[14] Thus, we intend to evaluate whether the development of the ethanol industry has a real effect on wages and employment in the region. Since there is no current research evaluating the impact of the ethanol industry at the regional level, we draw our methodology from another industry as it relates to regional impacts.

We also consider Hanson's (2001) methodology appropriate for our analysis because the reduced form equations allow controlling for other factors at the county, state, and national level that affect employment and wages. Hanson's (2001) approach has been mainly used at the city-industry level, which differs from the county set up we use in this analysis. However, we consider a county level analysis reasonable and applicable when focusing on the impact of ethanol production in the Corn Belt states. Ethanol can be considered an important industry for this region, and it is unlikely to be concentrated in the cities or metropolitan areas due to its dependence on agricultural inputs.

In order to determine the impact of current energy policies in the Corn Belt, this analysis focuses on the twelve Corn Belt states of Iowa, Indiana, Illinois, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, Ohio, South Dakota, and Wisconsin. Our period of analysis includes the years 2005 and 2006, and there are 1122 counties in the sample (with a total of 2244 observations).[15] Data on wages, income, and employment at the county, state, and national level was obtained from the Bureau of Economic Analysis (BEA). The Consumer Price Index (CPI) used to convert nominal values into real values was obtained from the Bureau of Labor Statistics (BLS). Data for ethanol production at the county level was obtained from the Official Nebraska

[14] In fact, as stated by Hettinga et al. (2009, p.191) "ethanol plants generally require feedstock sourcing within a 80 km radius to keep transportation costs low."
[15] We were able to get consistent data at the county level only for 2005 and 2006 at the time this study was undertaken.

Government Website on Ethanol Production Capacity by Plant archive and is measured in millions of gallons. Table 1 presents a description of the variables used and their sources, and Table 2 shows the summary statistics of these variables.

IV. Results

The results in Table 3 show the estimates obtained when we use average employment as dependent variable (equation 1). In column 1 of Table 3, estimates for the full sample show that the alternative employment, real wage, and real income have a significant negative effect at the 5 and 1 percent level. Based on Hanson's (2001) discussion of the control variables, the negative values of alternative employment and real income are unexpected. Since it is argued that greater income and greater national employment should be reflected in greater employment across counties in that region, we expected that these variables would have a positive sign. The negative sign for alternative wages is similar to Hanson's (2001) finding and fits with the idea that workers will move to places with higher wages, which will lead to a decrease in employment in a specific county. Ethanol production capacity has a significant positive effect on employment at the 1 percent level.

Estimates in Table 3, column 1, indicate that an increase of one standard deviation of the ethanol production capacity variable (0.025 billion gallons) leads to an increase in average employment by 3.83 percent. While this estimate indicates that the effect of ethanol production in employment is of significant magnitude, it is important to note that there is a very large standard deviation in the ethanol production capacity variable (standard deviation is almost four times the mean value). Thus, a more realistic evaluation is to focus on the mean value to determine the magnitude of the effect of ethanol production capacity on employment. A one percent increase in ethanol production capacity for the average county (using the mean value), leads to an increase in employment by 0.01 percent. This estimate shows that the impact of ethanol production capacity on employment is very small, where the sensitivity of employment to ethanol production can be considered inelastic. For robustness, we use the actual amount of ethanol produced by the county, and these estimates are shown in column 2 of Table 3. From this estimation, we find actual ethanol production has a significant positive effect on average employment at the 1 percent level. A one percent increase in actual ethanol production leads to an increase in employment by 0.007 percent for the average county.

In this analysis, we also estimate the employment model for the states that are major producers of ethanol (Iowa, Illinois, Indiana, Nebraska, Ohio, and South Dakota). These states account for 73 percent of total ethanol production in the Corn Belt. In Table 3, columns 4 and 5 present the estimates for this subsample using the ethanol production capacity and actual ethanol production, respectively. For this subsample we find similar results, where ethanol production capacity has a positive significant effect on employment, and the magnitude of the effect is also similar to the one found for the full sample. When looking at the average county (using the mean value for this subsample), a one percent increase on ethanol production capacity and actual ethanol production is associated with an increase in employment of 0.02 and 0.01 percent, respectively. Results are robust to using actual ethanol production for the major ethanol producer subsample (Table 3, column 5)

Table 4 presents the estimates when we use average real wage as the dependent variable (equation 2). Column 1 of Table 4 shows the estimates obtained when we include all the states and use ethanol production capacity. In this estimation, alternative wages and alternative income are statistically significant at the 1 percent level and the sign of their coefficients is as expected (positive and negative, respectively). Ethanol production capacity is positively significant at the 1 percent level and has an effect of insignificant magnitude. Using the estimates in column 1 (Table 4), an increase of one percent in ethanol production capacity leads to an increase in average real wage of 0.005 percent for the average county. When we use the actual amount of ethanol produced, we find a similar effect on real wages (Table 4, column 2). For the average county, a one percent increase in ethanol production leads to an increase in average real wage of 0.004 percent. Results are robust when we include only the major ethanol producing states (Table 4, Columns 4 and 5).

For robustness purposes, we also evaluate the possibility of endogeneity of ethanol production. Endogeneity in this analysis does not seem to be a major issue since ethanol production does not have to be determined by local wages and employment due to the fact that ethanol is consumed at the national level and its production has been determined by policy. However, it could be argued that more employment and higher wages might lead to greater consumption of fuels and, consequently, to greater demand for ethanol. Finding an adequate instrument that accounts for ethanol capacity at the county level is difficult. Thus, we took advantage of the time variation in our analysis and perform a two stage least square estimation (2SLS) using the lag of ethanol production capacity as an instrument for ethanol production. The drawbacks of this approach are that it reduces our sample to only one observation per county (only for 2006) and we are unable to test for over-identification to corroborate the validity of the instrument. We find that previous results are robust to addressing for endogeneity, where the impact of ethanol production capacity and actual ethanol production on employment and wages is significantly positive but of insignificant magnitude.[16]

[16] 2SLS results are not included for purpose of space, but are available upon request.

Due to the large variation in ethanol production capacity across counties, we evaluate whether there is a difference in employment and wages for ethanol producing counties at different levels of production capacity from non-producing ethanol counties. We include in equations 1 and 2 the three dummies that account for different production capacity levels mentioned before: Ethanol_H, Ethanol_M, and Ethanol_L. Because we include these three dummies in the estimations of equations 1 and 2, non-producing ethanol counties are the comparison group.

The estimates obtained when we include the ethanol production capacity dummies in the employment equation are shown in Table 3, columns 3 and 6. Estimates in column 3 are for the full sample and estimates in column 6 are for the major ethanol producing states subsample. Interestingly, column 3 shows that ethanol producing counties with high and medium levels of ethanol production capacity have higher levels of employment than those counties that do not produce ethanol by 16 and 12 percent, respectively (statistical significance at the 1 percent level). Counties that have low levels of ethanol production capacity do not show any statistically significant difference. This result is robust to considering only major ethanol producing states (Table 3, column 6). Estimates for the wage equation when we include the ethanol production capacity dummies are shown in Table 4, columns 3 and 6. When looking at the full sample, (Table 4, column 3) counties with high and medium ethanol production capacity show higher levels of average real wage by 8 and 5 percent than the control group, respectively (statistical significance at the 1 percent level). These estimates are robust to the major ethanol producing states subsample (Table 4, column 6).

In summary, we find ethanol production has a positive significant effect on employment and wages, but the magnitude of the effect is very small. From this part of the analysis, we conclude that employment and wages at the county level are insensitive to changes in ethanol production. All these results are robust to using an alternative measure of ethanol production, restricting our sample to major ethanol producing states, and addressing for endogeneity. When we compare ethanol producing counties to those that do not produce ethanol, there is an interesting result. Our estimates indicate that ethanol producing counties with high and medium levels of ethanol production capacity have higher levels of employment and wages than non-producing ethanol counties. We also find that counties with low levels of ethanol production capacity show no statistical difference from non-producing ethanol counties.

V. Discussion

The results obtained showing the small effect of increases in ethanol production on employment and wages might be related to the fact that the ethanol industry is not labor intensive. While increases in ethanol production might push for a greater demand in corn, the production process of ethanol (and even the production of the agricultural input) is likely to be capital intensive and not labor intensive in the United States. Thus, an increase in the level of ethanol production does not lead to significant increases in average employment and wages since there is not a significant increase in labor demand. In this case, the push towards greater ethanol production might not imply significant increases in employment and wages across the board as it has been previously suggested.

When comparing ethanol producing counties with non-producing ethanol counties, the results obtained in this analysis relate to the nature of the industry. It is interesting to note that those counties with low levels of ethanol production are not statistically different than those counties that do not produce ethanol. This finding implies there is a certain scale that ethanol production must reach in order to observe higher levels of employment and wages. This finding shows that the scale of production matters, and that increases in ethanol production per se are not as relevant as expected.

Empirical analyses on the effects of ethanol production in the United States that take into consideration current data at the local level are currently nonexistent. Part of the reason for this is the lack of data at the county level for ethanol production. In order to have a better understanding of the impact of ethanol production in the economy, future research on this topic should look at accumulating data for greater periods of time. Future research should also focus on looking at specific ethanol plant data on employment and wages. By gathering data on employment and wages in the ethanol industry, a comparative analysis of different industries will be valuable for future energy policy.

It is important to investigate the distributional effects of current energy policies. The push towards greater ethanol production has come with consumption mandates, tax credits, and import tariffs that led to higher prices of ethanol, which affects all consumers. The benefits of these energy policies are regionally concentrated, while the costs are shared at the national level. Because the push towards ethanol consumption has led to significant distributional effects, where there is a transfer of wealth from one region to another, policymakers should estimate this transfer of wealth and evaluate whether it can be justified.

With the increasing emphasis on ethanol production in the United Sates and the continuing quest to make ethanol a large portion of the renewable energy in the country, it is important to perform analyses on the impact of ethanol production. At this stage in our analysis, it seems that moving forward with ethanol production in the United States is inevitable and our findings are relevant for future policy-making. Many congressmen maintain that ethanol provides a great benefit to the communities where it is produced. Our analysis shows that greater ethanol production has a positive effect on wage and employment, but of insignificant magnitude. Differences in employment and wages are only observed when ethanol production capacity reaches medium and high levels. While ethanol is still being produced in relatively small amounts in one concentrated area, this industry has shown a significant increase in the 2000s and it was expected that it would lead to a significant increase in employment. Our findings are relevant because they illustrate that we cannot justify the movement towards increasing consumption of biofuels as a way to create jobs and increase wages all across the board. Our results show that scale matters, where ethanol production capacity must reach certain levels in order to experience higher employment and wages.

Our findings might apply to other industries related to renewable energy. For example, our findings on the impact of ethanol production on wages and employment might closely apply to the expected effects of increases in the production of cellulosic ethanol. Cellulosic ethanol is also expected to be capital intensive and not labor intensive, where cellulosic ethanol production is likely to result in small increases in employment and wages. Our analysis is also relevant when looking at the current push towards promoting green jobs with the American and Recovery Reinvestment Act of 2009. Supporters claim that the energy provisions from this legislation will create a significant amount of jobs in the renewable energy industry. From our analysis, it is suggested that policymakers should be more cautious when making this claim. As more data on renewable fuels becomes available, we will be able to develop a better understanding on how this industry affects overall economic activity.

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Table 1. Variable Definition and Data Sources

Variable	Definition
N	Average employment (number of jobs divided by population). Source: BEA, CA34
W	Average wage per job (in dollars) deflated by the US CPI. Source: BEA, CA34
ALT_N	Total national employment, excluding the state in which the county is located. Source: BEA, CA34
ALT_W	Average wage and salary disbursement for the state in which the county is located, excluding the county in which the observation is taken, deflated by the CPI. Source: BEA, CA34
ALT_Y	Total personal income (thousands of dollars) for the state in which the county is located, excluding the county in which the observation is taken. Total personal income was deflated by the CPI. Source: BEA, CA1
Ethanol capacity	Ethanol production capacity (billions of gallons) Source: Official Nebraska Government Website Ethanol Production Capacity by Plant Archive
Ethanol production	Ethanol actual production (billions of gallons) Source: Official Nebraska Government Website Ethanol Production Capacity by Plant Archive
Ethanol_H	Dummy equal to one if a county has an ethanol production capacity greater than the mean plus one half the standard deviation (0.081 billion gallons), zero otherwise.
Ethanol_M	Dummy equal to one if a county has an ethanol production capacity below or equal to the mean plus one half standard deviation but greater or equal to the mean minus one half the standard deviation (less of equal 0.081 billion gallons but more or equal to 0.028 billion gallons), zero otherwise.
Ethanol_L	Dummy equal to one if a county has an ethanol production capacity less than the mean minus one half the standard deviation (0.028 billion gallons), zero otherwise.
CPI	Consumer price index for the United States. Source: BLS

Table 2. Summary Statistics*

	Mean	Max.	Min.	Std. Dev.
Ethanol capacity	0.007	0.305	0.000	0.025
Ethanol production	0.004	0.274	0.000	0.020
Ethanol_H	0.026	1.000	0.000	0.159
Ethanol_M	0.061	1.000	0.000	0.239
Ethanol_L	0.019	1.000	0.000	0.136
Ln(N)	-0.979	0.021	-2.108	0.329
Ln(W)	4.952	5.558	4.443	0.178
Ln(ALT_N)	18.751	18.777	18.719	0.015
Ln(ALT_W)	4.517	4.752	4.190	0.100
Ln(ALT_Y)	13.551	14.705	11.453	0.750

*All variables have 2244 observations. Ethanol_H is equal to 1 for 58 observations, Ethanol_M is equal to 1 for 137 observations, and Ethanol_L is equal to 1 for 42 observations.

Table 3. Effect of Ethanol Production on Employment

	(1)	(2)	(3)	(4)	(5)	(6)
Ethanol	1.504***	1.775***		1.533***	1.864***	
	(0.174)	(0.206)		(0.181)	(0.207)	
Ethanol_H			0.160***			0.165***
			(0.031)			(0.033)
Ethanol_M			0.119***			0.156***
			(0.024)			(0.030)
Ethanol_L			0.037			0.001
			(0.034)			(0.060)
Ln(ALT_N)	-111.927**	-114.115**	-110.912**	-37.952	-49.161	-37.454
	(50.097)	(50.161)	(50.057)	(89.877)	(89.924)	(89.942)
Ln(ALT_W)	-1.745**	-1.785**	-1.686*	-1.622	-1.768	-1.531
	(0.892)	(0.895)	(0.886)	(1.135)	(1.146)	(1.144)
Ln(ALT_Y)	-1.822***	-1.799***	-1.845***	-1.563**	-1.500**	-1.607**
	(0.579)	(0.578)	(0.584)	(0.765)	(0.759)	(0.778)
Constant	2131.829	2172.727	2112.821	738.588	948.880	729.367
	(939.016)	(940.225)	(938.224)	(939.016)	(1687.296)	1687.515
R-sq	0.206	0.204	0.205	0.151	0.149	0.150
Obs.	2244	2244	2244	1080	1080	1080

Robust standard errors in parentheses. *, **, and *** indicate significance at 10, 5 and 1 percent level, respectively. Coefficients for state and time dummies not included for purpose of space. Columns 1, 2, and 3 include observations from all Corn Belt states (IA, IL, IN, KS, KY, MI, MN, MO, NE, OH, SD, and WI). Columns 4, 5, and 6 include observations from the major ethanol producing states (IA, IL, IN, NE, OH, and SD). Columns 1 and 4 use ethanol capacity, columns 2 and 5 use actual ethanol production, and columns 3 and 6 use ethanol dummies based on ethanol production capacity.

Table 4. Effect of Ethanol Production on Wages

	(1)	(2)	(3)	(4)	(5)	(6)
Ethanol	0.737***	0.993***		0.799***	1.088***	
	(0.100)	(0.111)		(0.103)	(0.109)	
Ethanol_H			0.076***			0.085***
			(0.019)			(0.020)
Ethanol_M			0.046***			0.062***
			(0.010)			(0.011)
Ethanol_L			0.025			0.052*
			(0.016)			(0.029)
Ln(ALT_N)	11.080	10.115	11.195	20.556	14.829	18.260
	(24.572)	(24.600)	(24.620)	(40.809)	(40.582)	(40.820)
Ln(ALT_W)	1.950***	1.922***	1.972***	1.374**	1.280*	1.369**
	(0.585)	(0.584)	(0.588)	(0.696)	(0.703)	(0.688)
Ln(ALT_Y)	-2.823***	-2.805***	-2.832***	-2.109***	-2.066***	-2.116***
	(0.452)	(0.450)	(0.455)	(0.464)	(0.459)	(0.469)
Constant	-172.919	-154.940	-175.061	-360.728	-253.322	-317.517
	(459.723)	(460.274)	(460.605)	(765.367)	(761.137)	(765.528)
R-sq	0.409	0.411	0.406	0.426	0.430	0.420
Obs.	2244	2244	2244	1080	1080	1080

Robust standard errors in parentheses. *, **, and *** indicate significance at 10, 5 and 1 percent level, respectively. Coefficients for state and time dummies not included for purpose of space. Columns 1, 2, and 3 include observations from all Corn Belt states (IA, IL, IN, KS, KY, MI, MN, MO, NE, OH, SD, and WI). Columns 4, 5, and 6 include observations from the major ethanol producing states (IA, IL, IN, NE, OH, and SD). Columns 1 and 4 use ethanol capacity, columns 2 and 5 use actual ethanol production, and columns 3 and 6 use ethanol dummies based on ethanol production capacity.