Geographical Analysis of US Green Sector Industry Concentration

by

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Abstract

This paper analyzes the geographic distribution of "green energy" sector clustering in the lower 48 United States using recent developments in industry concentration analysis. Evidence suggests that the ten green energy subsectors and the aggregate of the firms comprising the green energy sector are regionally concentrated. Positive changes in industry concentration from 2002 to 2006 tended to be greatest in non-metropolitan counties, suggesting comparative advantage with respect to site location for the composite of firms making up these sectors.

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Problem Identification and Explanation

As world energy demand transitions away from fossil fuels to renewable energy sources, "green energy" has been considered a potential alternative that could provide a stable, long-term energy source (Chichilnisky and Eiseberger 2009). In 2009, 8% of the energy consumed in the United States came from renewable sources (US Department of Energy 2010). A new goal was announced during President Obama's January 2011 State of the Union Address —80% of the nation's energy would come from renewable energy sources by 2035. Now that targets have been set, supporting the transition process through research and learning is critical as the demand for a new set of skilled labor will grow and business will emerge and expand to meet this objective. But the development of the green energy sector will likely be volatile and highly competitive for investors (Chichilnisky and Eiseberger 2009). In addition to providing cleaner, more reliable, and environmentally neutral energy sources, the green sector is also considered as a key economic driver in the future of the nation, building on the 8.5 million jobs and $970 billion in revenue for 2006 (American Solar Energy Society 2009). Federal, state, and local policies continue to be implemented at all levels of governance to support emerging green energy industries. However, there is still a substantial amount of work that needs to be done to provide timely information to policy makers, investors, and consumers about how best to attract, support, and retain business establishments that will make up these so-called green industries.

Ensuring the continued growth of green sector businesses will be a daunting task. According to a report from the Pew Charitable Trusts, the United States now ranks second behind China in terms of clean energy investment dollars, and sixth in terms of the five-year growth rate in green energy investments (The Pew Charitable Trusts 2010). Favorable policies and low labor costs have contributed greatly to the expansion of green sector industries in China, Brazil, and the United Kingdom, making these countries the primary US competitors. In light of increased competitiveness between countries for green energy investment, reports have begun to surface detailing the departure of green energy firms abroad. For example, a Massachusetts-based solar panel manufacturer that received nearly $43 million in state aid recently closed its doors on its American plant, relocating operations to Beijing (Bradsher 2011).

To meet the desired goals set and to re-establish the United States as a leader in green energy expansion, policy makers require information to justify support for green sector industries. The focus for local policy makers will therefore be to determine which characteristics of their communities they can leverage to attract and retain green jobs and businesses. As the number of firms belonging to green industries grows, the decision to locate a business in a given region will be based on a variety of factors, including geographic concentration (Guimarães, Figueiredo, and Woodward 2007). The interactions between knowledge-spillovers, labor market pooling, and upstream/downstream linkages are important for policy makers in their pursuit of green sector investments and firms to sustain and expand growth. While bio-fuel jobs and establishments, such as ethanol producers, have been extensively researched, few studies have focused on the industry concentration patterns associated with other green sector technologies and the community factors associated with their geographic distribution.

The existing literature on geographic concentration and firm location determinants has covered a range of industries and sectors including manufacturing (Lambert, McNamara, and Garrett 2006; Holmes and Stevens 2002), high-tech firms (Ellison and Glaeser 1997; Feser et al. 2008), food processing (Lambert, McNamara and Beeler 2007), and ethanol production (Lambert, Wilcox, English, and Stewart 2008; Sarmiento and Wilson 2008). However, there is a lacuna of knowledge about the wider context of industries comprising the green sector. Little is known about what factors might encourage firms belonging to green sectors to concentrate in specific regions. This study explores eight sub-sectors belonging to the green energy production sector, including: (1) coal co-firing, (2) wood direct fire, (3) ethanol production from switchgrass, (4) wood ethanol, (5) landfill gas, (6) dairy methane, (7) solar energy, and (8) wind power. Each of these "industries" is, in reality, comprised of a variety of business involved in the extraction, production, and distribution of fuel products, as well as financing operations. To identify the levels of economic players analyzed, the green energy sector will be considered the broadest unit of analysis, comprised of each of the green sub-sectors. These sub-sectors, in turn, are made up of industries which are a collection of similar firms. Descriptions of the industries that make up each subsector can be seen in Appendix Tables 1 through 10.

This research provides information about which industries belonging to these sub-sectors demonstrate a relationship between firm location and the proximity to other similar or related industries. Information may be useful for state and local policy makers for targeting specific firms to locate within their communities, as well as by researchers pursuing more detailed studies in green sector location patterns. The use of this information will also be helpful to green sector entrepreneurs whose chance of success may be improved by the support they receive from policy makers and researchers, as well as more detailed knowledge about selecting an appropriate location for their businesses.

Research Objectives

The objectives of this research are to describe the degree of localization for each of the green energy sub-sectors and industries individually, and for the green sector as a whole using local and global indices of firm concentration.

Literature Review

Green Energy Location Decisions

The recent enthusiasm surrounding biofuels, specifically ethanol, has sparked a range of studies attempting to explain plant location decisions. Lambert et al. (2008) found that nonmetropolitan counties had a comparative advantage in attracting ethanol plants, largely due to access to feedstock in these locations, but counties that were very remote had little comparative advantage with respect to generating investment attention. Additionally, they found that subsidies directed toward ethanol production were a key component of ethanol plant location decisions. Stewart and Lambert (2011) and Sarmiento and Wilson (2008) found similar results regarding ethanol plant location decisions, additionally finding that the probability of selecting a site was reduced when an existing plant was located within 30 to 50 miles of that site. At distance of greater than 60 miles, there was virtually no impact on plant location decisions when other plants had already located in the area.

Geographic Clustering

Often times, certain location characteristics are expected to, all else equal, provide the impetus for more than one business within the same industry to locate in the same geographic region. Firms in similar industries have a tendency to agglomerate within a region (Marshall 1890; Hoover 1948; Krugman 1991). Agglomeration, localization, and concentration are all related to the geographic clustering over and above normal economic activity (Guimarães, Figureido, and Woodward 2009). The effects are increasing returns to scale for each industry resulting from the business relationships among the nearby firms, as labor search cost, innovative ideas, transport costs, and business transaction costs are reduced.

Numerous studies have also explored the dynamics of agglomeration economies across regions and industries. Holmes and Stevens (2002) and Guimarães, Figureido, and Woodward (2006) found that plant size tended to be larger when manufacturing firms concentrated in a region. Ellison and Glaeser (1999) found that a region's natural advantages could explain about 20 percent of the geographic concentration for the industries in that region. Strong evidence of agglomeration has also been found in high-tech industries, such as Silicon Valley (Ellison and Glaeser 1997), automobile manufacturing (Ellison and Glaeser 1997), carpet manufacturing (Krugman 1991), and dress manufacturing (Lichtenberg 1960; Holmes and Stevens 2002). This research has played an important role in the developing models for understanding why firms make location decisions, given the location decisions of other similar and related firms.

Measures of Industry Localization

Industry localization has been analyzed using a variety of methods, generally falling in two categories of measure: "global" and "local". Local measures focus on where industries tend to locate, whereas global measures describe the degree to which industries are concentrated in a region. The tools developed from both approaches have been useful for describing localization across regions and industries, while constantly being improved to provide more efficient measures.

Prominent global measures of concentration in economic activity have been used extensively, such as the Gini coefficient used by Krugman (1991) and Hoover's (1937) localization index. Another popular global measure of localization was developed by Ellison and

Glaeser (1997). Using a "dartboard" model, they decomposed the geographic concentration of U.S. manufacturing industries into (1) random effects and (2) the effects the agglomeration resulting from industry-specific spillovers and natural advantages. The index they proposed was based on a model explaining firm location in terms of a profit-maximization problem that was made with respect to the profitability of a location (which captures the natural advantages), the industry-specific spillovers resulting from agglomeration, and a set of idiosyncratic factors specific to firms. Additionally, their model controlled for lumpiness where industry production was taking place in only a few large plants. The model also had the desirable characteristic of allowing for comparisons across industries, regions, or time. The index derived from their model measured the degree to which an industry is localized over and above that which would be expected should the firms in the industry choose their location at random (similar to throwing darts at a dartboard). GFW (2007) increased the efficiency of the Ellison and Glaeser concentration index by including information about plant counts rather than only employment. The GFW model was also derived from a probabilistic framework, which provides a means by which hypotheses can be formulated about industry localization using a global, summary index.

Local measures are related to global concentration indices, but provide a method whereby the geographic patterns of location activity can be quantified. Florence (1939) pioneered the use of the location quotient as a measure of geographic concentration within a region. This metric compared the proportion of employment in a particular industry within a region with the proportion of employment in that industry within the nation, such that

$$L_{jk} = \frac{\frac{x_{jk}}{x_k}}{\frac{x_j}{x}},$$

where L_{jk} is the location quotient for industry j in location k, x_{jk} represents industry j employment in location k, x_k represents total employment in location k, x_j represents total employment in industry j and x represents total employment in the economy. It is generally assumed that when the location quotient is greater than one, industry j is concentrated in location k. In export base theory, the region is considered to be a net exporter of goods when location quotients exceed one.

The location quotient has been criticized as being without theoretical foundations (Guimarães, Figueiredo, and Woodward 2009). However, GFW (2009) bridged this gap, deriving a model of the location quotient based on the dartboard framework of Ellison and Glaeser (1997). Their derivation provides distinct advantages because it motivates hypothesis testing regarding the geographic location of economic activity, thus providing a theoretically-based foundation upon which to statistically quantify localization.

This study applies the local and global measures to all levels of the green sector, thus shedding light on localization patterns of firms belonging to each of its sub-sectors. Global industry concentration indices will be analyzed using GFW's (2007) establishment-count localization index, while local industry concentration will be analyzed using the traditional location quotient, following GFW (2009).

Conceptual Framework

The theoretical model used to measure the degree of industry localization is based on a random profit maximization model introduced by GFW (2004) and follows McFadden's (1974) model of qualitative choice behavior. Firms are assumed to make location decisions to maximize profit. Locations decisions are modeled as probabilistic events conditioned on local factors. Assuming profit maximization, Ellison and Glaeser (1997) modeled location choice as a function of natural advantages, spillovers, and establishment-specific factors. Building on Ellison and Glaeser's and GFW's (2004) model, firm profits can be expressed by

$$\log \pi_{ijk} = \log \tilde{\pi}_j + \eta_{jk} + \varepsilon_{ijk} ,$$

where $\tilde{\pi}_j$ is the expected profitability (resulting from the natural advantages, as per Ellison and Glaeser (1997)) locating in location *j* for a firm in the industry, η_{jk} is a random component that captures the external economies and (or) natural advantages specific to location *j* for industry *k*, and ε_{ijk} is a disturbance that reflects the factors that are idiosyncratic to that plant.

Assuming that the disturbance term, ε_{ijk}, is identically and independently distributed as an Extreme Value Type 1 variable, the likelihood that a firm will select a particular location, conditional on the random effect, η_{jk}, is (GFW, 2009)

$$p_{j|\eta} = \frac{\exp(\log \tilde{\pi}_j + \eta_{jk})}{\sum_{j=1}^{J} \exp(\log \tilde{\pi}_j + \eta_j)} = \frac{\tilde{\pi}_j \exp(\eta_{jk})}{\sum_{j=1}^{J} \tilde{\pi}_j \exp(\eta_{jk})} .$$

Therefore, the likelihood a firm locates in a given area is a function of the profitability of selecting that location for a typical firm as well as the natural advantages of that location. Additionally, the expected probability of locating in region *j* is

$$E(p_j) = \frac{\tilde{\pi}_j}{\sum_j \tilde{\pi}_j} = x_j$$

with variance

$$V(p_j) = \gamma x_j (1 - x_j),$$

where x_j is area j's share of overall sector employment. Therefore, the greater the difference between x_j and p_j, the greater the influence location-specific effects have on firm location decisions. The difference is captured by γ, which can be interpreted as the degree to which an industry would locate beyond the level that would be expected from pure random selection (referred to as the "dartboard model" by Ellison and Glaeser (1997)). It is through γ that a *global index* of localization can be derived for a particular set of firms comprising an industry.

This framework is also a convenient starting point for motivating the theoretical derivation of the location quotient, as in GFW (2009). Assuming that the spatial distribution of establishments will be similar to the distribution of economic activity, GFW find that

$$E(p_{jk}) = \frac{x_j}{\sum_{j=1}^{J} x_j} = \frac{x_j}{x}.$$

Additionally, by requiring that the η_{jk}'s cancel out, GFW (2009) assume that

$$E(p_{jk}) = \frac{\tilde{\pi}_{jk}}{\sum_{j=1}^{J} \tilde{\pi}_{jk}}.$$

Therefore, the location probabilities can be rewritten in terms of the known employment levels, x_j as

$$p_{jk|\eta_k} = \frac{x_j \exp(\eta_{jk})}{\sum_{j=1}^{J} x_j \exp(\eta_{jk})}.$$

The likelihood of observing a particular spatial distribution of plants can be constructed as the product of all the probabilities weighted by a factor of w_{jk}, where $w_{jk} = \left(\frac{x_{jk}}{x_k}\right) \times n_k$, such that

$$l_k = \prod_{j=1}^{J} p_{j|\eta_k}^{w_{jk}} = \prod_{j=1}^{J} \left(\frac{x_j \exp(\eta_{jk})}{\sum_{j=1}^{J} x_j \exp(\eta_{jk})} \right)^{w_{jk}}.$$

By maximizing l_k and solving for the first order condition, it can be shown that $\hat{\eta}_{jk} = \ln L_{jk}$, where L_{jk} is a location quotient for industry k in region j

$$L_{jk} = \frac{\left(\frac{w_{jk}}{w_k}\right)}{\left(\frac{x_j}{x}\right)},$$

and w_k is the sum across regions of all w_{jk}'s. This derivation of the location quotient is identical to the conventional location quotient, yet now with a theoretical foundation for which to formulate and test hypotheses. GFW (2009) provide the background for constructing Wald statistics to test for geographic localization of firms specific to a given region of spatial unit.

This framework is the theoretical approach to modeling firm location decisions. A profit-maximizing firm will select the most profitable location for an establishment. Therefore, industry concentration can be analyzed such that "excessive" concentration existing within the green energy sub-sectors resulting from scale economies and (or) natural advantages can be identified, permitting conclusions to be drawn about which industries gravitate towards localized centers of economic activity.

Data

Establishment and employment data for this research will come from several sources. Establishment data will come from CBP datasets for 2002 and 2006, while employment is from WholeData.net's 2002 national dataset and IMPLAN's complete 2006 national database. Data will be used for all 3078 county divisions in the contiguous United States.

Methods

Geographic concentration patterns will first be described by a global concentration index constructed following GFW (2007). Second, location quotients will be estimated to hypothesize about the strength of the localization economies across the study region (Guimarães, Figueiredo, and Woodward 2009).

Global Concentration Index

Guimarães, Figueiredo, and Woodward's (2007) localization index can be estimated using establishment counts, which removes the influence of establishment size on the measure. This index is unbiased, like that of Ellison and Glaeser (1997), however there are some gains in efficiency because of the normalization by using establishments as a denominator. The use of this estimate for the localization index, γ_c is advantageous because, in addition to moderating the effects of establishment size on the index, it provides a measure of industry concentration that can be compared across industries or time. To illustrate, when $\hat{\gamma}_c = 0$, the concentration of establishments is not greater than what would be expected. When $\hat{\gamma}_c = 0$, any concentration that may be observed arises simply as a result of establishments locating in a manner similar to throwing darts at a dartboard. On the other hand, when $\hat{\gamma}_c = 1$, it is expected that all establishments for a particular industry would be found within a single region. Empirically, the values of $\hat{\gamma}_c$ rarely exceed 0.25 (Ellison and Glaeser 1997).

The plant-count index of GFW can be calculated as:

$$\hat{\gamma}_c = \frac{n_k G_{c_k} - \left(1 - \sum_{j=1}^{j} x_j^2\right)}{(n_k - 1)\left(1 - \sum_{j=1}^{j} x_j^2\right)},$$

where n_k is the number of establishments in sub-sector or industry k, x_j is the share of green sector employment in area j, and G_{c_k} can be calculated as:

$$G_{c_k} = \sum_{j=1}^{j} \left(\frac{n_j}{n} - x_j\right)^2 ,$$

where n_j is the number of establishments within area j, n is the total number of establishments in the observational region, and x_j is as described above.

To obtain the variance estimates of the localization index and their respective confidence intervals, a nonparametric bootstrap procedure is used. The bootstrap avoids assumptions about a particular distribution for the concentration measure, as the likelihood that each industry or sector would have the same distribution is very small. In other words, the technique provides a description of the distribution of the empirical estimators based on the data themselves (Greene 2000). To illustrate the bootstrap method, assume that $\hat{\gamma}_c$ is an estimate of vector γ_c based on establishment matrix n_{jk} and employment x_j. The bootstrap procedure will approximate $\hat{\gamma}_c$ by sampling m observations, with replacement from n_{jk} and x_j and recomputing $\hat{\gamma}_c$ with each sample. After B times, the desired sampling characteristics are computed from $\hat{\gamma}_c^* = [\hat{\gamma}_c(1)_m, \dots, \hat{\gamma}_c(B)_m]$. In this procedure, $B = 1000$. Thus, the localization estimate is calculated, yielding $\hat{\gamma}_c$ for each industry.

Local Concentration Index

Recall that, from GFW (2009), $\hat{\eta}_{jk} = \ln L_{jk}$, where L_{jk} is a location quotient for industry k in region j calculated as

$$L_{jk} = \frac{\left(\frac{w_{jk}}{w_k}\right)}{\left(\frac{x_j}{x}\right)},$$

where w_k is the sum across regions of all w_{jk}'s. The derivation of the location quotient from a probabilistic model allows for hypothesis testing about the strength and reliability of this measure. The first test to be completed is in regards to the localization within a region. Following GFW (2009), a Wald test is calculated as

$$W_{jk} = \frac{J[\ln L_{jk}]^2}{(J-2)w_{jk}^{-1} + \overline{\overline{w_k^{-1}}}},$$

and is distributed asymptotically as a χ^2 variate with one degree of freedom. The null hypothesis for this test, that η_{jk}= 0, is that the industry is non-localized in a region. Rejection of this test suggests that the industry analyzed is, in fact, concentrated within a given spatial unit. In addition to this test of regional non-localization, a useful hypothesis test is that of non-localization of an industry across a set of regions. The null hypothesis in this test is that all η_{jk}'s are equal to zero across the region. This amounts to a test of whether or not an industry is localized across a set of regions, which can be tested using GFW's (2009) t-test. Rejection of this hypothesis suggests that the industry is likely not localized across all regions.

The derivation of the location quotient from a probabilistic model, and the subsequent hypothesis tests allow for conclusions to be drawn about the degree to which industries are localized, over and above what would be expected to occur naturally. This improvement in the interpretation of location quotients provides richer information regarding where and which industries tend to concentrate as a result of external economies and (or) natural advantages. Applying the location quotient to the green energy sector will be useful in explaining the levels of localization across the US.

Results and Discussion

Global Measure of Concentration

Calculating the plant-count index for each of the green energy subsectors yields a range of information regarding their degree of concentration within the nation. First, it is observed from the bootstrapped confidence intervals that $\hat{\gamma}_c$ for each subsector is significant at a 5% level. Tables 1 and 2 show the point estimates for $\hat{\gamma}_c$ along with their respective confidence intervals for 2002 and 2006 respectively. Table 3 provides a depiction of the change in concentration over the period for each of the subsectors. All subsectors showed an increase in geographic concentration, with the exception of the commercial solar production network. These changes in concentration should not be considered "growth" or "decline" of the sectors, per se, but rather a tightening of the geographic dispersion of these firms.

While difficult, objectively interpreting the magnitude of the indices is important to understanding *how* concentrated these green energy subsectors are. If an estimate of zero is to be interpreted as pure random site selection, any value greater than that should indicate the presence of positive effects from agglomeration. Ellison and Glaeser (1997) observed a skewed distribution of their γ for US manufacturing industries with the mean being 0.051 and the median being 0.026. Thus interpretation relative to their results may provide some insight on the degree of concentration relative to established industries (i.e. manufacturing). Ellison and Glaeser describe industries with $\gamma > 0.02$ as "not very concentrated". From Tables 1 and 2, the green energy subsectors, therefore, are not very concentrated. However, these smaller levels of concentration should not be considered abnormal. In fact, Ellison and Glaeser's results indicated that:

> *"…slight concentration is remarkably widespread, while the more extreme concentration that has attracted attention existing in a smaller subset of industries."*

Thus, it does not seem remarkably surprising green sector firms to not exhibit a strong tendency to concentrate, especially when considering the relative infancy of the industry relative to more mature industries for which time and learning has led to more efficient location decisions.

Local Measure of Concentration

Of the 10 subsectors explored by this research, all have shown a tendency to concentrate within the nation. The next step is to describe where these firms tend to localize. In analyzing the location quotients, concentration is evidenced when $L_{jk} > 1$ and when the respective Wald statistic is greater than 3.84 (for $\alpha = 0.05$). Figures 1 and 2 provide maps of where statistically significant concentration was found for the entire green sector. Note that three different levels of significance are specified.

While a detailed discussion of the precise locations in which they localize is beyond the scope of this text, each sector can be broken down in its tendency to localize in metropolitan, micropolitan, and non-core counties. Furthermore, the change in those locations over time can be described as well. Table 4 provides a look at the number of counties in each subsector and for the entire green sector as well. Table 5 describes the percentage change from 2002 to 2006 for each. The first thing that should stand out from Table 5 is that, for any subsector that experienced the number of counties with significant concentration increase, the strongest growth was in either micropolitan or non-core counties. For the entire green sector, the strongest growth in counties with significant concentration was in non-core counties. Among the various subsectors, five experienced the strongest increases in concentration among micropolitan counties (ethanol from switchgrass, ethanol from wood, landfill gas, dairy methane, and wind energy), while biodiesel and residential solar experienced their strongest increase in concentrated counties among non-core counties. Commercial solar was the only network for which metropolitan counties accounted for the greatest increase. There seems to be a clear indication that concentration among green subsectors is generally shifting away from metropolitan counties to micropolitan and non-core counties. Additionally the number of counties exhibiting concentration in the biodiesel, coal co-firing, and wood direct fire subsectors decreased over the period.

Additional results from the use of the location quotient can be found by the calculation of GFW's (2009) t-test. While this result does not provide a value indicating the global degree of concentration, it does indicate whether significant concentration of this type is present. Results were consistent with those from the $\hat{\gamma}_c$ estimates and confidence intervals. Evidence of concentration exists in all green energy subsectors and within the entire sector as well.

Conclusion and Implications

Using the recent developments in geographic analysis, it is possible to develop a description of geographic concentration within the green energy production sector. Applying various measures demonstrates evidence of small, but significant levels of concentration within each of these sectors. Furthermore, evidence at a local level indicates that non-core and micropolitan counties experienced most of the growth in geographic concentration from 2002 to 2006. The greater tendency of concentration to move toward nonmetropolitan counties, however, should not be construed as an indication of increased profitability by locating in those counties. Instead, it suggests that those counties have a stronger concentration of supporting firms.

Clearly these micropolitan and non-core counties exhibit factors that support industries engaged in the green energy supply chain. As federal, state, and local policy makers continue exploring how best to support the developing green energy sectors, they will undoubtedly be focusing on where best to target their efforts. They may find that fostering growth of these subsectors' networks in non-metropolitan counties will further promote the growth of the green sector. On the other hand, investors can look upon these counties as alternatives to the more expensive and competitive metropolitan locations.

Having established non-metropolitan counties as a key location for increased concentration of green energy subsectors, future research should focus on determining the factors underlying this trend. Additionally, expanding the analysis period to the most recent for which data are available will demonstrate whether this trend has continued. Finally, incorporating neighboring effects into the measures will provide a more detailed description of concentration, capturing not just natural advantages, but spillovers across county lines as well.

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Table 1 - $\hat{\gamma}_c$'s and Confidence Interval for US Green Energy Subsectors - 2002

Industry	Establishments	Employment	$\hat{\gamma}_c$	Lower 5%	Upper 95%
Biodiesel	2,061,911	12,944,391	0.00062	0.00042	0.00085
Cofire	782,710	9,015,782	0.00055	0.00041	0.00071
Wood Direct Fire	777,306	9,206,047	0.00055	0.00040	0.00076
Ethanol - Switchgrass	1,122,755	10,552,367	0.00041	0.00023	0.00065
Ethanol - Wood	1,904,160	20,513,715	0.00047	0.00030	0.00065
Landfill Gas	763,581	9,714,170	0.00086	0.00053	0.00115
Dairy Methane	757,450	7,558,072	0.00051	0.00031	0.00077
Commercial Solar	146,060	5,142,390	0.00082	0.00053	0.00127
Residential Solar	1,098	42,911	0.00688	0.00385	0.00958
Wind Energy	1,045,790	13,778,125	0.00098	0.00058	0.00139

Source: 2002 WholeData.net and CBP datasets

Table 2 - $\hat{\gamma}_c$'s and Confidence Interval for US Green Energy Subsectors - 2006

Industry	Establishments	Employment	$\hat{\gamma}_c$	Lower 5%	Upper 95%
Biodiesel	1,569,774	17,275,533	0.00111	0.00077	0.00149
Cofire	1,042,672	5,417,057	0.00130	0.00076	0.00192
Wood Direct Fire	981,447	5,586,650	0.00112	0.00082	0.00150
Ethanol - Switchgrass	1,028,278	6,674,635	0.00103	0.00067	0.00144
Ethanol - Wood	2,225,963	24,810,395	0.00066	0.00046	0.00087
Landfill Gas	878,564	3,702,716	0.00109	0.00066	0.00154
Dairy Methane	947,920	4,648,078	0.00132	0.00058	0.00243
Commercial Solar	336,135	6,888,514	0.00078	0.00055	0.00103
Residential Solar	25,528	549,916	0.00884	0.00343	0.01270
Wind Energy	1,396,584	10,234,347	0.00106	0.00062	0.00151

Source: 2006 IMPLAN and CBP datasets

Table 3 - Percent change in $\hat{\gamma}_c$ from 2002 to 2006

Industry	Establishments	Employment	$\hat{\gamma}_c$
Biodiesel	-23.87%	33.46%	77.09%
Cofire	33.21%	-39.92%	138.24%
Wood Direct Fire	26.26%	-39.32%	102.09%
Ethanol - Switchgrass	-8.41%	-36.75%	150.55%
Ethanol - Wood	16.90%	20.95%	40.93%
Landfill Gas	15.06%	-61.88%	33.05%
Dairy Methane	25.15%	-38.50%	158.73%
Commercial Solar	130.13%	33.96%	-5.46%
Residential Solar	2224.95%	1181.53%	28.53%
Wind Energy	33.54%	-25.72%	7.73%

Table 4 - Number of US counties with significant concentration

	2002				2006			
Subsector	Metro	Micro	Non-Core	Total	Metro	Micro	Non-Core	Total
Biodiesel	324	64	102	490	200	56	141	397
Cofire	267	150	278	695	187	121	187	495
Wood Direct Fire	287	154	289	730	195	120	202	517
Ethanol - Switchgrass	301	166	313	780	312	203	369	884
Ethanol - Wood	164	70	142	376	175	106	192	473
Landfill Gas	233	114	225	572	319	223	335	877
Dairy Methane	351	184	352	887	289	200	324	813
Solar Commercial	102	51	88	241	108	52	91	251
Solar Residential	115	69	110	294	301	220	402	923
Wind Energy	162	76	155	393	234	149	235	618
Entire Green Sector	235	38	60	337	194	50	128	372

Source: CBP 2002 & 2006, WholeData.net 2002, IMPLAN 2006

Table 5 - %Δ – number of counties with significant concentration

Subsector	Metro	Micro	Non-Core	Total
Biodiesel	-38%	-13%	38%	-19%
Cofire	-30%	-19%	-33%	-29%
Wood Direct Fire	-32%	-22%	-30%	-29%
Ethanol - Switchgrass	4%	22%	18%	13%
Ethanol - Wood	7%	51%	35%	26%
Landfill Gas	37%	96%	49%	53%
Dairy Methane	-18%	9%	-8%	-8%
Solar Commercial	6%	2%	3%	4%
Solar Residential	162%	219%	265%	214%
Wind Energy	44%	96%	52%	57%
Entire Green Sector	-17%	32%	113%	10%

Source: CBP 2002 & 2006, WholeData.net 2002, IMPLAN 2006

Appendix

Table 1 - Biodiesel Subsector Industries

NAICS Code	IMPLAN Code	Sector Description
2211	30	Power Generation & Supply
2213	32	Water, Sewage & Other Systems
23	37	Manufacturing & Industrial Bldgs.
32512	148	Industrial Gas Manufacturing
32518	150	Other Basic Inorganic Chemical Manufacturing
32519	151	Other Basic Organic Chemical Manufacturing
33242	239	Metal Tank, Heavy Gauge, Manufacturing
333298	269	All Other Industrial Machinery Manufacturing
333922	292	Conveyor & Conveying Equipment Manufacturing
5222	425	Banking (Contingency (10%))
5241	427	Insurance Carriers
531	431	Real Estate (Land)
5412	438	Accounting
5413	439	Architectural & Engineering Services
55	451	Management of Companies & Enterprises
8113	485	Commercial Machinery Repair & Maintenance

Table 2 - Coal Co-firing Subsector Industries

NAICS Code	IMPLAN Code	Sector Description
23	41	Other New Construction
332311	232	Prefabricated Metal Buildings and Components
333922	292	Conveyor & Conveying Equipment Manufacturing
333994	298	Industrial Process Furnace & Oven Manufacturing
334513	316	Industrial Process Variable Instruments
336211	346	Motor Vehicle Body Manufacturing
5222	425	Banking (Contingency (30%))
5413	439	Architectural & Engineering Services
8113	485	Commercial Machinery Repair & Maintenance

Table 3 - Wood Direct Fire Subsector Industries

NAICS Code	IMPLAN Code	Sector Description
23	37	Manufacturing & Industrial Buildings
32551	161	Paint & Coating Manufacturing
331111	203	Iron & Steel Mills
33243	240	Metal can, box, & Other Container Manufacturing
33312	259	Construction Machinery Manufacturing
333319	273	Other Commercial & Service Industry Machinery Manufacturing
333414	277	Heating Equipment, except Warm Air Furnaces
333415	278	AC, Refrigeration, & Forced Air Heating
333611	285	Turbine & Turbine Generator Set Units Manufacturing
333922	292	Conveyor & Conveying Equipment Manufacturing
334512	315	Automatic Environmental Control Manufacturing
334513	316	Industrial Process Variable Instruments
336211	346	Motor Vehicle Body Manufacturing
5222	425	Banking
55	451	Management of Companies & Enterprises
8113	485	Commercial Machinery Repair & Maintenance

Table 4 - Coal Co-firing Subsector Industries

NAICS Code	IMPLAN Code	Sector Description
5413	439	Architectural & Engineering Services
8113	485	Commercial Machinery Repair & Maintenance
335311	333	Electric Power & Specialty Transformer Manufacturing
333414	277	Heating Equipment, except Warm Air Furnaces
33242	239	Metal Tank, Heavy Gauge, Manufacturing
23	41	Other New Construction
32411	142	Petroleum Refineries
2211	30	Power Generation & Supply
333911	288	Pump & Pumping Equipment Manufacturing
31491	101	Textile Bag & Canvas Mills

Table 5 - Ethanol from Switchgrass Subsector Industries

NAICS Code	IMPLAN Code	Sector Description
2211	30	Power Generation & Supply
2213	32	Water, Sewage, & Other Systems
23	37	Manufacturing & Industrial Buildings
32518	150	Other Basic Inorganic Chemical Manufacturing
32519	151	Other Basic Organic Chemical Manufacturing
325312	157	Phosphatic Fertilizer Manufacturing
325998	171	Other Miscellaneous Chemical Product Manufacturing
32741	196	Lime Manufacturing
33241	238	Power Boiler & Heat Exchanger Manufacturing
33242	239	Metal Tank, Heavy Gauge, Manufacturing
33243	240	Metal Can, Box, & Other Container Manufacturing
332999	255	Miscellaneous Fabricated Metal Product Manufacturing
333111	257	Farm Machinery & Equipment Manufacturing
333298	269	Other Industrial Machinery Manufacturing
333319	273	Other Commercial & Service Industry Machinery Manufacturing
333411	275	Air Purification Equipment Manufacturing
333412	276	Industrial & Commercial Fan & Blower Manufacturing
333414	277	Heating Equipment except Warm Air Furnaces
333415	278	AC Refrigeration & Forced Air Heating
333611	285	Turbine & Turbine Generator Set Units Manufacturing
333911	288	Pump & Pumping Equipment Manufacturing
333912	289	Air & Gas Compressor Manufacturing
333922	292	Conveyor & Conveying Equipment Manufacturing
333924	294	Industrial Truck, Trailer, & Stacker Manufacturing
333997	301	Scales, Balances, & Miscellaneous General Purpose Machinery
334513	316	Industrial Process Variable Instruments
5241	427	Insurance Carriers
5412	438	Accounting Bookkeeping Services
562	460	Waste Management & Remediation Services
8113	485	Commercial Machinery Repair & Maintenance

Table 6 - Ethanol from Switchgrass Subsector Industries

NAICS Code	IMPLAN Code	Sector Description
2211	30	Power Generation & Supply
2213	32	Water, Sewage & Other Systems
23	37	Manufacturing & Industrial Buildings
32512	148	Industrial Gas Manufacturing
32518	150	Other Basic Inorganic Chemical Manufacturing
32519	151	Other Basic Organic Chemical Manufacturing
333922	292	Conveyor & Conveying Equipment Manufacturing
3365	356	Railroad Rolling Stock Manufacturing
42	390	Wholesale Trade
453	411	Miscellaneous Store Retailers
5222	425	Banking
531	431	Real Estate
5411	437	Legal Services
55	451	Management of Companies & Enterprises
5615	456	Travel Arrangement & Reservation Services
5617	458	Services to Buildings & Dwellings
562	460	Waste Management & Remediation Services

Table 7 - Landfill Gas Subsector Industries

NAICS Code	IMPLAN Code	Sector Description
23	41	Other New Construction
33121	205	Iron, Steel Pipe & Tube from Purchased Steel
33242	239	Metal Tank, Heavy Gauge, Manufacturing
333132	261	Oil & Gas Field Machinery & Equipment
333411	275	Air Purification Equipment Manufacturing
333412	276	Industrial & Commercial Fan and Blower Manufacturing
333414	277	Heating Equipment, except Warm Air Furnaces
333912	289	Air & Gas Compressor Manufacturing
333994	298	Industrial Process Furnace & Oven Manufacturing
334513	316	Industrial Process Variable Instruments
335311	333	Electric Power & Specialty Transformer Manufacturing
335314	336	Relay & Industrial Control Manufacturing
33593	341	Wiring Device Manufacturing
3363	350	Motor Vehicle Parts Manufacturing
541512	442	Computer Systems Design Services
8113	485	Commercial Machinery Repair & Maintenance

Table 8 - Commercial Solar Subsector Industries

NAICS Code	IMPLAN Code	Sector Description
334413	311	Semiconductors & Related Device Manufacturing
5222	425	Banking
5413	439	Architectural & Engineering Services
541512	442	Computer System Design Services
55	451	Management of Companies & Enterprises
8113	485	Commercial Machinery Repair & Maintenance

Table 9 - Residential Solar Subsector Industries

NAICS Code	IMPLAN Code	Sector Description
8113	485	Commercial Machinery Repair & Maintenance
334413	311	Semiconductors & Related Device Manufacturing

Table 10 - Wind Subsector Industries

NAICS Code	IMPLAN Code	Sector Description
23	41	Other New Construction
333611	285	Turbine & Turbine Generator Set Units Manufacturing
334513	316	Industrial Process Variable Instruments
335312	334	Motor & Generator Manufacturing
484	394	Truck Transportation
5222	425	Banking
5411	437	Legal Services
5413	439	Architectural & Engineering Services
541512	442	Computer Systems Design Services
8113	485	Commercial Machinery Repair & Maintenance

Figure 1: Map of 2002 L_{jk} P-Values

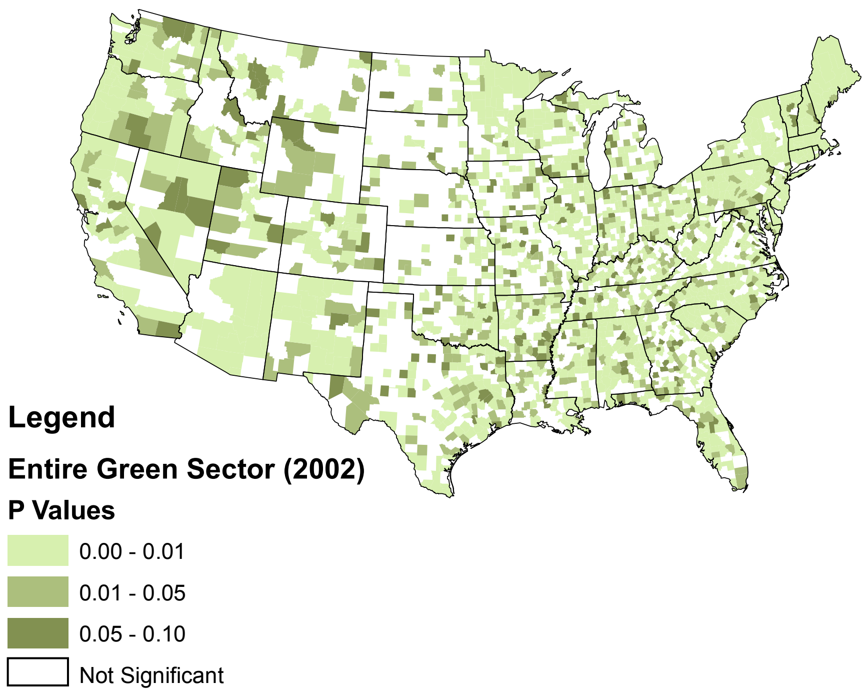

Figure 2: Map of 2006 L_{jk} P-Values