Spatial Analysis of the Gender Wage Gap in Architecture, Civil Engineering and Construction Occupations in the United States

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Abstract

Over the past recent decades, the economic status of women has been changed significantly. Gender segregation levels have decreased, and women have started participating in male-dominated occupations like construction occupations. Nevertheless, the gender wage gap in construction occupations persists which is one of the issues related to attracting more females to the construction industry. So far, no comprehensive study has been conducted on the gender wage gap in the construction occupation. Therefore, the purpose of this study is to portray the gender wage gap in construction occupations. Additionally, the spatial analysis of the gender wage gap is of paramount importance not only for its academic interest but also for its major role in the area-based public policies which are targeted to eliminating inequalities. The researchers used recent American Community Survey data and GeoDa software for spatial analysis. Analyses were performed at global (Moran's I) and local (Local Indicators of Spatial Association (LISA)) levels to test for the presence of spatial patterns. The results of the LISA analysis have shown spatial autocorrelation at local levels, which highlights the status of gender wage gaps in construction-related occupations in various states. This study will contribute to the existing body of knowledge in the area of Labor and Personnel Issues, specifically Workplace Diversity and Discrimination, and help the construction industry to better understand the wage gap, further investigate the problem, and make an effort to decrease it, which will help the industry attract more females.

Keywords: Construction, Civil Engineering, Women, Gender Wage Gap, Spatial Analysis

1. INTRODUCTION

The construction industry, one of the largest job providing sectors in the U.S., is having problems with a labor shortage, as well as a severely unbalanced composition of employment between males and females (Choi et al. 2018). Possible negative impacts of labor cliff on the construction industry include cost overruns, scheduling issues, labor costs (CII, 2015; Kim, Chang, & Castro-Lacouture, 2019), and worker's safety (Choi et al. 2017; Lin et al. 2017). Increasing gender and racial diversity in the construction industry will help the industry to solve the labor shortage problem. However, attracting more females to the industry is not easy, as there are complex issues, and past efforts have often failed. Previous studies have addressed strategies for retention and recruitment of women to construction education and workforce by investigating types of problems women face and motivation factors to increase women's retention from a long time ago. (Amaratunga, Haigh, Shanmugam, Lee, & Elvitigala, 2006; Bigelow, Bilbo, Ritter, Mathew, & Elliott, 2016; Lee Shoemaker & Elton, 1989; Lopez, Puerto, Guggemos, & Shane, 2011; Morello, Issa, & Franz, 2018). Nevertheless, these efforts have not been proved to be successful. The indication of such failure and women underrepresentation is evident by their share is construction occupations equal to 2.6%, which has not changed from 1983 to 2016 (Bigelow et al., 2016). To increase racial and gender diversity in the construction industry, both the industry and academia need to pay more attention to the problems of segregation and inequality.

Over recent decades, the economic status of women has changed significantly. Women's higher educational attainment and occupational status have led to higher participation as part of the active labor force. Moreover, sex segregation levels have decreased, and women have started participating in male-dominated occupations, especially in professional and managerial roles (Blau, Brummund and Liu, 2013; Jacobs, 1992; Weeden, 2004; Charles and Grusky, 2005; Blau, Brinton and Grusky, 2006; DiPrete and Buchmann, 2013). As a result, wage discrepancies between women and men have decreased slowly over time, and the pace has increased since the mid-1970s. Nevertheless, a pay gap still persists for women. According to the American Society of Civil Engineers (ASCE) 2017 Salary Survey, women civil engineers earned 81.8% of their men counterparts (Walpole, 2017). Similarly, according to Bureau of Labor Statistics, in 2018 women in construction management occupations earned 81.9% as a percentage of men and women in civil engineering occupations earned 82.7% of their male counterparts (The Economics Daily, 2018). In one study investigating the sources of stress among women and men construction workers, it was found out that the rate of pay was a statistically significant factor causing stress among women construction workers (Loosemore & Waters, 2004).

The Great Recession could be deemed as a boon to gender equality (Goldstein, 2009), which brought more attention to addressing gender wage inequality. Nevertheless, despite all of the efforts since the economic downturn, in 2017, women working full time in the United States were still getting paid only 80% of wages paid to men, showing a 20% gender wage gap (Fontenot, Semega, & Kollar, 2018).

It should also be noted that the gender wage gap varies among occupations. Cohen and Huffman (2007) found out that women working in female-dominated jobs earn less than other professions. However, women working in more male-dominated professions are facing other barriers. Several studies have highlighted the impediments that hamper women's participation in a male-dominated workforce, especially in the construction industry (Xie & Shauman, 2003). Lower salary, sexual abuse, fewer promotion opportunities, and gender clichés are some of the main obstacles women are facing in construction occupations (Abdullah, Arshad, & Ariffin, 2013; Azhar & Griffin, 2014; Infante-Perea, Román-Onsalo, & Navarro-Astor, 2016). Many studies have attempted to tackle the issues of the weak interest and low participation of women in construction and civil engineering, both in academia (Cantillo & García, 2014; Estes & Brady, 2011) and industry (Bigelow, Bilbo, Mathew, Ritter, & Elliott, 2015; Bureau of Labor Statistics, 2018; Moir, Thomson, & Kelleher, 2011). Also, there are some indirect forms of discrimination against women, such as being treated differently because of gender, being denied from informal networks (social isolation), and incompatibility of having children with construction work discouraging women working in the construction industry (Dainty & Lingard, 2006). To decrease some of the problems women face in engineering and construction professions, it has been highly recommended to recruit "critical mass" of women (Yates, 2001). Nevertheless, it should be considered that recruiting females without solving the existing impediments they have in the industry is complex.

However, very few studies have researched the gender wage gap in architecture, civil engineering, and construction (AEC) occupations (Choi, Shrestha, Lim, & Shrestha, 2018). While the existence of the gender wage gap in AEC occupations has received little attention, the spatial distribution and geography of this gender inequality have not been studied. Studying the spatial distribution patterns of the gender wage gap is critical to understanding its recent shift. The construction industry was greatly affected during the Great Recession. During the economic downturn, there was an average of 115,000 monthly job losses in the construction industry equal to 19.8% of the total nonfarm employment losses (Hadi, 2011). Considering the big impact of the great recession on construction industry, This study will map the gender wage gap in AEC occupations to analyze the spatial pattern of the gender wage gap before, during, and after the Recession. This study will try to answer the question of "whether there is any spatial pattern in the gender wage discrepancy in AEC occupations across the U.S.?" The researchers believe that the first step to reaching gender equality in AEC industries is by showing the gender wage discrepancy, both temporally and spatially, to gain lessons from past experience, as well as understand the current status of the industry.

2. RESEARCH BACKGROUND

In recent decades, the higher education levels of women have played significant roles in increasing women's earnings and reducing wage disparity potential (Bobbitt-Zeher, 2007; Frehill, 1997; Monks & James, 2000; Zhang, 2008). The gender wage gap has narrowed since 1960, not only because of improvement in women's educational attainment and higher participation in the workforce but also because men's wages have increased at a slower rate. If the decreasing rate of the gender wage gap continues at the same level at which it decreased from 1960 to 2017, women will reach equal pay in 2059 (Miller & Deborah J, 2018).

Sociologists have ascribed the gender wage gap and its decrease to various factors. They have argued that occupational segregation is one of the highest contributing factors to the wage gap between women and men. In other words, they believe that women earn less since they often work in low-paying, female-dominated areas (Bielby & Baron, 1986; Petersen & Morgan, 1995; Treiman & Hartmann, 1981). Surprisingly, based on the results of a study of 50 years of U.S. workforce data, average incomes for occupations decrease for both women and men when a large number of women start working in that occupation. Moreover, the wage gap was shown to be statistically significant in favor of men for 107 of 114 occupations (Levanon, England, & Allison, 2009).

The most remarkable factors related to the decline in the gender wage gap are occupational segregation, employer discrimination, labor supply, and labor market-related attributes. The decrease in the wage gap may reflect a decline in pay discrimination against women or more equality between women and men. The decline could also be as a result of improvement in women's education levels, their work experience, and their number of working hours. Also, a decrease in occupational segregation, providing more opportunities for women to work in more male-dominated jobs, could also decrease the gender wage gap (Cotter, Hermsen, & Vanneman, 2004; H. Mandel, 2013; Hadas Mandel, 2012). According to another study, occupational segregation is the second most dominant factor, after working hours, clarifying the wage gap between females and males in contemporary America (Hadas Mandel & Semyonov, 2014). Other researchers have argued that the gender wage gap is either because of organizational structures leading to inequity in salary and promotion or due to career patterns, with female workers having some career disruptions because of family and childbearing responsibilities (Bentley & Adamson, 2003). These commitments can also prevent women from getting enough work experience (Haignere, 2002; Monks & James, 2000).

Only a few studies have been conducted on the spatial distribution of the gender wage gap; among them is a study conducted on the top 1% metropolitan areas, which specified uneven distributions for women (Essletzbichler, 2015). Similarly, scholars studied the difference in wages or income, and the inequality, in terms of geography across U.S. metro areas (Florida & Mellander, 2016). There have also been studies, such as a Current Population Survey (CPS) driven by Smith and Glauber (2013) that analyzed the spatial gap in income amongst women and its correlation with different factors, such as education, occupation, and industry. Studies like Minooie et al. (2017) focused on particular trades in specific geographic locations in the United States and their related labor shortages. According to ACS data, California had the lowest gender pay gap (wage gap equals to 11% - female workers' average wage is 89% of that for male workers), and Louisiana had the highest gender pay gap (wage gap equals to 31% - female workers' average wage is only 69% of that for male workers) in 2017. This paper will provide a comprehensive geographic overview of the gender wage gap in Architecture and Civil Engineering (A&E), as well as construction occupations, to understand both the temporal and spatial patterns of the gender wage gap in the United States before the recession (2007), during the recession (2011), and in the recovery period (2015).

In factor price equalization theory by Samuelson (1948), a wage for labor input, a factor price for labor input for production, gets equalize across countries through factor mobility, migration in the labor market. The theory was mathematically proven by Heckscher-Ohlin model (Mussa, 1978). The interregional spatial scale in Samuelson's factor price equalization theory was applied to interstate migration patterns in the U.S. by Lim (2011). He found that the interregional migration of labor force has a limited impact on factor price equalization, rather intra-industry trade (IIT) plays complementary role towards factor price equalization in terms of wage among the U.S. states with the similar industrial structures. However, when applied to wage gaps in A&E and Construction occupations, labor forces are more mobile through interstate migration, attracted by wage gaps due to the limited IIT trades in A&E and Construction industries. Instead, labor force equipped with the required skillsets will be much more mobile across states, whereas labor forces lacking such skillsets tend to be less mobile. For states where A&E and Construction activities are booming, high wage due to the shortage of labor force will attract labor forces from the states with lower wages levels due to the depressed A&E and/or Construction activities. Consequently, the interstate gap in wage (factor price for labor input) can further stimulate industrial growths of booming states which can afford higher wage level, whereas such gaps will have negative impact on the industrial activities of states which cannot afford higher wage to attract relevant skillsets.

3. DATA and METHOD

3.1. Data sources

Data for the sample years (2007, 2011, & 2015) were extracted through the one-year American Community Survey (ACS) database. The main reason for choosing these three sample years is to study the wage gap in the AEC sector before (2007), during (2011), and after (2015) the Great Recession. The great recession of 2008 is defined as the period of the economic downturn during the late 2000s and early 2010s.

Nonetheless, according to BLS (Bureau of Labor Statistics), construction got the economic hit from the recession in 2011 (Hadi, 2011). The data collection for ACS was conducted through IPUMS database. The IPUMS database provides easy and user-friendly access to ACS data from 2000 and onward. The main benefit of using the IPUMS USA database (Ruggles et al., 2019) is the availability of the same variables over time, which allows for meaningful comparison across years. The geographical attributes of IPUMS variables make the spatial analysis of the wage gap possible. A spatial unit of observation for the wage gap is a state in the United States. For the analysis of spatial distribution patterns, the number of spatial samples is 49, including the 48 continental states and Washington D.C. (Alaska and Hawaii are not considered in this study).

3.2. Definition and characterization of the variables

The gender wage gap is defined in this study as the ratio of the average wage for female workers to the average wage of male workers and is calculated for each state for all sample years. Therefore, the higher the wage ratio, the lower the wage gap, and vice versa. To calculate the wage ratio, several variables have been considered, including: *Gender*, *State (FIPS Code), Person Weight*, *Occupation* and *Pre-tax Wage, and Salary Income*. *Person Weight* is a value indicating how many individuals are represented by a given person in a sample, and have to be considered to obtain nationally representative statistics when conducting studies on person-level analyses. The variable *Occupations* reflects the primary occupation of the person. *Occupations* are classified into two categories, which are A&E and construction occupations, based on ACS occupation codes. *Pre-tax Wage and Salary Income* is the salary of the survey respondents for the year previous to the survey year. Also, during data cleaning, the minimum wage threshold was defined, since there is a distinct possibility that female workers could fall below the conventionally defined minimum hourly wage. Therefore, researchers considered a 10% tolerance. This means that individuals earning even 10% of the federal minimum wage, who worked at least 35 hours/week and 40 weeks/year, were included in the sample. To enable a comparison of temporal trends for the wage gap in real terms, the average incomes for the sample years 2011 and 2015 have been adjusted and expressed in 2007 U.S. dollar terms. The Consumer Price Indexes (CPI) for 2011 and 2015, in relation to 2007, are 1.08 and 1.15, respectively (Bureau of Labor Statistics). Table 1 represents a sample data for the gender wage gap in A&E and construction occupations for Alabama state.

[Insert Table 1 here]

3.3. Exploratory Spatial Data Analysis

This study utilizes Exploratory Spatial Data Analysis (ESDA) techniques to analyze both the global and local contexts of the gender wage ratio (female to male). ESDA is a collection of methods used to visualize spatial distributions and distinguish geographical characteristics of data, mainly focusing on spatial autocorrelation and heterogeneity. ESDA techniques also identify the locations of spatial outliers (extreme values) and existing patterns of spatial associations (clusters or hot-spots). The ESDA techniques are well-known methods in regional science research used to study the spatially varying patterns of the variables of interest (Anselin, Sridharan, & Gholston, 2007).

The authors have created a box map to visualize extreme values, which is an essential aspect of ESDA. A box map, which is a geographic box plot, allows for the identification of locations with extreme values (Anselin, 1999), by showing these locations in six categories that are four quartiles, as well as lower and upper outliers (Anselin, 1994).

In applying ESDA, the first step is to define the spatial thresholds, either based on proximity or contiguity (i.e., defining a spatial weights matrix that describes the neighborhood structure), among the spatial units of observation (the 48 states and Washington D.C., in this study). After experimenting with various spatial weights, the Queen Contiguity Weight Matrix was selected for this study. Figure 1 portrays neighbors of the highlighted area which includes all boxes sharing a border or vertices with the highlighted box.

[Insert Figure 1. Queen Contiguity Weight Matrix]

In the Queen Contiguity Weight matrix, all states sharing a border, or vertices of a state, are defined as the neighbors of that state.

3.4. Testing for Spatial Autocorrelation

3.4.1. Global Spatial Autocorrelation

Global spatial autocorrelation is determined by testing a null hypothesis of spatial randomness. Rejection of this null hypothesis suggests the existence of spatial autocorrelation (a systematic spatial distribution pattern of a variable). Global spatial autocorrelation tests the overall (dis)similarity between the value of the gender wage ratio for each state and the values of wage ratios in the neighboring states using all spatial observations, which include the 48 continental states and Washington D.C. in this study.

The most commonly used test for spatial autocorrelation at a global level is Moran's I statistics (Anselin, 1995). This value varies between -1 and +1., representing the slope of the line in Figure 2. Moran's I in Equation 1 identifies the existence of global spatial autocorrelation, which means it identifies the extent to which similar or dissimilar values create a cluster or outlier, in comparison to the values of neighboring states in a spatial dataset.

$$I = \frac{N}{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}} \left[\frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\sum_{i}^{N}(x_i-\bar{x})^2}\right] \qquad \text{Eq. 1}$$

Where, N is toal number of locations (states), i is location i (state i), j is neighboring location (neighboring state j), wij is spatial weight between location i and j, $\bar{x}$ is mean value of locations (average wage ratio of all states), x_i is measure at location i (wage ratio at states i) and x_j is the measure at location j (wage ratio at state j).

The closer the Moran's I is to -1, the greater the spatial dissimilarity, indicating the presence of potential outliers. In contrast, the closer the Moran's I is to +1, the greater the spatial similarity, indicating clustering is dominant. The clustering indicates there is some patterning in the data and similar values in the whole map are clustered in the map. However, when Moran's I is closer to zero, the test fails to detect global spatial autocorrelation. It should be noted that inferring the value for the Moran's I is associated with its significance and there will not be any conclusion derived from non-significant values indicating randomness. The inference of Moran's I is based on the null hypothesis, which is randomness. The null distribution will be generated by randomly reshuffling values of the dataset to different locations and calculating the associated Moran's I (Anselin, 1995). After that, the possibility of getting the same value of Moran's I with randomly permuted data will be computed resulting in an associated p-value (pseudo p-value). If the p-value is higher than the set significance (in this study 0.05), the null hypothesis cannot be rejected meaning that the observed spatial pattern of values is equally likely as any other spatial pattern.

[Insert Figure 2. Moran's I Scatterplot]

Moran's I is a useful visual tool enabling to assess how similar an observed value is to its neighboring observations. The horizontal axis in Moran's I scatter plot represents the values of the observations, here it shows the wage ratio for each state on X-axis. The vertical axis (Y-axis) is based on the weighted average of the corresponding observation (neighbors for the observation on the X-axis) on the horizontal axis. The vertical axis is also known as the spatial lag of the corresponding observation on horizontal axis. Therefore, based on the position of each observation, the Moran's I scatter plot expresses the level of association between each observation and its neighbors. The regression slope of the Moran scatter plot is equivalent to Moran's I value.

The upper right quadrants are cases in which both the value of the observation and the value of its neighbors are higher than the overall average value. The upper right quadrant is known as the first quadrant or High-High (H-H). For example, if the wage gap in one state is higher than the average wage gap of all states, and the wage gap for the neighbors of that state is also higher than the average of all states, this state will fall into the first quadrant. It is essential to keep in mind that when terms “high” and “low” are used, they have been compared with the average value of all observations. Similarly, the second quadrant represents spatial samples with *low* values of the variable of interest (lower than the average) surrounded by neighbors with *high* values (higher than the average) of the measure known as Low-High (L-H).

Similarly, the third quadrant represents spatial samples with *low* values of the variable of interest (lower than the average) surrounded by neighbors with *low* values of the measure (lower than the average) known as Low-Low (L-L). Likewise, the fourth quadrant represents spatial samples with *high* values (higher than the average) surrounded by neighbors with *low* values of the measure (lower than the average) known for High-Low (H-L). To simplify the concept of global spatial autocorrelation, Figures 3.1 to 3.3 represent types of spatial autocorrelation including positive and negative spatial autocorrelation as well as randomness.

[Insert Figure 3.1. Positive Spatial Autocorrelation]

[Insert Figure 4.2. Negative Spatial Autocorrelation]

[Insert Figure 5.3. No Spatial Autocorrelation, Randomness]

It should be noted that Moran’s I does not provide information about the geographic locations of outliers or clusters; however, it is still critical to test the presence of spatial autocorrelation at a global level, as the presence of local spatial clusters and/or outliers might differ by region. Similarly, the absence of global spatial autocorrelation does not necessarily mean there are no spatial clusters and/or outliers at the local level. Therefore, performing a local-level analysis is necessary to detect local spatial distribution patterns.

3.4.2. Local Spatial Autocorrelation

Local indicators of spatial association (LISA) determine the locations and significance level of clusters and outliers, which cannot be found through a global spatial autocorrelation test with Moran's I statistics. A LISA map shows the locations with significant Local Moran statistics and their types (outliers: low-high and high-low; clusters: low-low and high-high). LISA tests the presence of spatial clusters and/or spatial outliers for each state's (dis)similarity between its value of wage ratio and the neighboring states' wage ratio values, as shown in Equation 2. Spatial clusters are indicators of positive spatial autocorrelation, whereas spatial outliers are indicators of negative spatial autocorrelation.

Similar to the global-level analysis, local spatial autocorrelation of wage ratios is considered to be significant at 5% pseudo significance levels (pseudo-p-value). That is to say, they were confirmed by the redistributing of simulated values of neighbors for each location using permutation. The number of permutations is set at 999, indicating precision is 0.001. LISA maps only portray the spatial units that passed the user-defined significance level (0.05). A highlighted cluster is a core of clusters; therefore, neighbors of a highlighted state should also be considered as parts of the identified clusters (H-H or L-L). However, in the presence of outliers, they are the actual locations of interest.

$$I_i = \left[\frac{(x_i - \overline{x}) \sum_j^N w_{ij}(x_j - \overline{x})}{\sum_i^N (x_i - \overline{x})^2}\right] \quad \text{Eq. 2}$$

Where, N is toal number of locations (states), i is location i (state i), j is neighboring location (neighboring state j), wij is spatial weight between location i and j, $\overline{x}$ the is mean value of locations (average wage ratio of all states), x_i is measure at location i (wage ratio at states i) and x_j is the measure at location j (wage ratio at state j).

To formally test the existence of global and local spatial autocorrelation, GeoDa 1.12, which is a spatial analytic tool, is employed. GeoDa is a powerful open-source, free software implemented for spatial data analysis (Anselin, Syabri, & Kho, 2006).

4. RESULTS AND DISCUSSION

4.1. Gender wage discrepancy in A&E occupations

The box plot maps in Figure 4 to Figure 6 describe the overall spatial distributions of the gender wage ratios (female to male) in A&E for three sample years: 2007, 2011, and 2015.

[Insert Figure 6. Box Plot Map for gender wage ratios in A&E occupations in 2007]

[Insert Figure 7. Box plot map for gender wage ratios in A&E occupations in 2011]

[Insert Figure 8. Box plot map for gender wage ratios in A&E occupations in 2015]

The spatial patterns and temporal trends of the gender wage ratios for A&E occupations can be observed in Figure 2. There was one lower outlier in 2007 (New Mexico), two in 2011 (North Dakota and New Mexico), and no lower outlier in 2015. The identified lower outliers are the states with the highest wage gaps (measured by the lowest wage ratios) across the U.S. Three upper outliers existed in 2007 (West Virginia, Delaware, and Mississippi), and there were three different states as upper outliers in 2011 (New York, District of Columbia, and Vermont). However, there were no upper outliers in 2015. Although the upper outliers in 2007 are not neighbors, all three of the upper outliers in 2011 are neighbors. The upper outliers on the maps are the states with the lowest wage gaps (measured by the highest wage ratios) across the U.S. None of the outliers (upper or lower) were common across all three sample years.

4.1.1. Global spatial autocorrelation

As discussed earlier, Moran's I statistics are employed to test the null hypothesis of spatial randomness in the distribution patterns of wage ratios at the global level, among all of the sample states in this study. A significant pseudo-p-value of the estimated Moran's I statistics rejects the null hypothesis, and accept the alternative hypothesis of spatial association in wage ratios. Table

2 shows the test results of the estimated Moran's I, with pseudo-p-values.

[Insert Table 2 here]

The results of the Moran's I statistics and p-values suggest that there is no evidence to reject the null hypothesis at a 5% significance level since the p-values in all of the sample years are higher than 0.05. Therefore, it can be concluded that there is no global spatial autocorrelation in the gender wage ratios in A&E occupations, and the spatial distribution of wage ratios is random. However, one study explored the geography of the gender wage gap through the Great Recession, and it was found out that the recession exacerbates the gender wage gap in many western metros(Goodwin-White, 2018). Nevertheless, the spatial analysis of the gender wage gap in A&E occupations does not indicate any clustering in western states. This highlights the importance of analyzing the geography of the gender wage inequalities separately for different occupation groups. Also, considering the study on the overall gender wage gap in the United States equal to 20% (Fontenot et al., 2018), it can be noted that the gender wage gap within A&E occupations is lower or higher than 20% depending on different states. With the median of gender wage ratio equal to 0.743, 0.779, and 0.779 in 2007, 2011, and 2015 respectively, it can be concluded that almost half of the states have more than 20% of gender wage gap in A&E professions.

4.1.2. Local spatial autocorrelation

Although the results, at a global level of analysis, show no statistical evidence to support the presence of global spatial autocorrelation, LISA values show the presence of spatial outliers and clusters in all sample years. The LISA maps in Figures 7,8, and 9 show the local clusters and outliers among state-level neighbors at a 5% significance level for gender wage ratios in A&E occupations.

[Insert Figure 9. LISA map for gender wage ratios in A&E occupations in 2007]

[Insert Figure 10. LISA map for gender wage ratios in A&E occupations in 2011]

[Insert Figure *11*. LISA map for gender wage ratios in A&E occupations in 2015]

In 2007, there were four core states of low-low clusters, which were Colorado, Kansas, Oklahoma, and Texas. The neighbors of these core states were also part of the low-low clusters, including Nebraska, Wyoming, Utah, New Mexico, Arizona, Missouri, Arkansas, and Louisiana. Therefore, the value of the wage ratio (female to male) is low in the core of these clusters, which are also surrounded by neighbors with low values of wage ratios. The identified low-low clusters are in the region where the high wage gap against female workers is geographically concentrated. There was also one low-high outlier in 2007, which was Alabama, meaning that the attribute variable (wage ratio) in Alabama was low (high gender wage gap), whereas it was surrounded by neighboring states (Tennessee, Mississippi, Georgia and Florida) with high values of wage ratios (low gender wage gaps).

In 2011, similar to 2007, there existed both low-low clusters and low-high outliers. Montana was the core of the low-low cluster, with its surrounding neighbors, including North Dakota, South Dakota, Wyoming, and Idaho. Therefore, Montana was a state with a low wage ratio, which was also enclosed by states with the same attributes. In other words, in the low-low cluster with Montana as a core state, a high wage gap in A&E occupations against female workers was geographically concentrated. In 2011, Massachusetts was the low-high outlier, meaning that the wage ratio was low (high gender wage gap) in Massachusetts. However, its neighbors (New Hampshire, New York, Rhode Island, Connecticut, and Vermont) had high wage ratios (low gender wage gaps).

The LISA map for 2015 indicates the presence of both low-low and high-high clusters. Utah was the core of the low-low cluster, in which the wage ratio was low (high gender wage gap) and was surrounded by neighbors that share similar attributes. On the contrary, Maryland was the core of the high-high cluster. The wage ratio in Maryland was high (low gender wage gap), and it was also surrounded by neighbors (Delaware, Virginia, West Virginia, and Pennsylvania) with high wage ratios. Although there had not been any high-low outliers either before or during the Great Recession (years 2007 and 2011, respectively), there existed two high-low outliers during the recovery period in 2015. South Dakota was the core state of a high-low outlier. South Dakota had a high value of wage ratio (low gender wage gap), but it was surrounded by neighbors that had low wage ratios (high wage gap). Another core state of a high-low outlier in 2015 was Montana. It is interesting to note this rapid change in Montana; although Montana was the core of the low-low cluster in 2011, it became the core of the high-low cluster during the recovery period in 2015. Therefore, Montana had a high wage ratio (low wage gap). However, its neighbors (North Dakota, South Dakota, Wyoming, and Idaho) had low wage ratios (high wage gaps). Finding the reasons why the spatial patterns change over time is not the scope of this study as mentioned earlier. However, some anecdotal pieces of evidence can help to understand why there exist such Spatio-temporal changes, such as the one found in Montana. Again, this is not the result of formal testing. Between 2011 and 2015, Montana and its four neighboring states (North Dakota, South Dakota, Wyoming, and Idaho) had experienced the rapid growth in construction labor market according to BLS's annual sectoral employment estimations. Among the five states, Montana had a lower growth at 16.7%, compared to other states, Idaho (61.5%) and South Dakota (41.1%). For 2011-2015 period, the relatively small and sluggish construction labor market in Montana might have lost its construction labor forces to its closest neighbors with the larger and booming construction activities (e.g., North Dakota, South Dakota, and Idaho). This might have resulted in the shortage of local labor supply in Montana's constriction industry, and motivated industry to pay higher wages to latent (and/or currently not in labor force due to discouraged worker effect due to low wage levels) female workers to bring them to out to construction jobs.

4.2. Gender wage discrepancy in construction occupations

The spatial distribution patterns of the gender wage ratio (female to male) in construction occupations are shown in the box plot maps of Figures 10,11, and 12.

[Insert Figure *12*. Box plot map for gender wage ratios in construction occupations in 2007]

[Insert Figure 13. Box plot map for gender wage ratios in construction occupations in 2011]

[Insert Figure *14*. Box plot map for gender wage ratios in construction occupations in 2015]

In 2007, there existed two lower outliers (high gender wage gaps), including Maine, and Rhode Island. Although there was no upper outlier (low gender wage gap) in 2007, two upper outliers could be seen in 2011, including Oregon and South Dakota. Surprisingly, both Oregon and South Dakota were in the range of the lower quartile before the recession and during the recovery period, but they were upper outliers in the middle of the economic recession in 2011, which hit the construction industry tremendously. In 2015, there was no upper or lower outlier. Previously, it was found out that the difference in the median weekly earnings of women and men working in the construction industry increased in 2011 compared to 2007, indicating an increase in the gender wage inequalities (Choi et al., 2018). However, the status of gender wage inequalities in different states was not studied accordingly. Considering the box maps for gender wage ratios in construction industry (Figures 10 to 12), it can be observed that different states responded differently in terms of gender wage ratios. For instance, Maine was observed to have a lower gender wage gap in 2011 (gender wage ratio between 0.819 to 1.00 during the recession) than 2007 (gender wage ratio between 0.29 to 0.35 before the recession. Whereas, some states like North

Dakota followed the general trend of increase in the gender wage gap as Choi et al. (2018) found in their study. Moreover, comparing the overall gender wage gap in the United States equal to 20% (Fontenot et al., 2018) with the median value of gender wage ratio in the construction occupations (0.83, 0.819 and 0.846 in 2007, 2011 and 2015 respectively), it can be noticed that the gender wage gap in almost half of the is higher than 20% similar to A&E occupations as was discussed earlier.

4.2.1. Global Spatial Autocorrelation

Similar to the global spatial autocorrelation analysis performed for the gender wage ratio in A&E occupations, the same analysis was conducted for the gender wage ratio in construction occupations to test whether the pattern of the gender wage ratio in construction occupations is random (null hypothesis). Table 3 exhibits the estimated Moran's I statistics, with pseudo-p-values. On the contrary to the findings of the study indicating the western metros were observed to have higher gender wage gap during the recession (Goodwin-White, 2018), such pattern of clustering is not present within the construction occupations during the recession. In other words, the global spatial autocorrelation test did not prove any clustering of the gender wage ratio in the construction industry in 2007.

[Insert Table 3 here]

The pseudo-p-values for all three years are higher than the 5% significance level. Therefore, the null hypothesis of random spatial distribution at a global level cannot be rejected. Consequently, it can be concluded that the spatial pattern of the gender wage ratio in construction occupations is random, and there is no global spatial autocorrelation at a 5% significance level.

4.2.2. Local Spatial Autocorrelation

The local level analysis of the gender wage ratio in construction occupations can detect the presence of regional clusters and/or outliers, although there is no global spatial autocorrelation in the pattern of gender wage ratio in construction occupations for all sample years. Figures 13,14, and 15 portrays local clusters and/or outliers among state-level neighbors, significant at 5%.

[Insert Figure 15. LISA map for gender wage ratios in construction occupations in 2007]

[Insert Figure 16. LISA map for gender wage ratios in construction occupations in 2011]

[Insert Figure *17*. LISA map for gender wage ratios in construction occupations in 2015]

In 2007, Oklahoma and New Mexico were the cores of high-high clusters. This means that Oklahoma had a high wage ratio (low gender wage gap) and was also surrounded by neighbors with similar attributes. Therefore, the wage ratios in Oklahoma's neighbors (Texas, Colorado, Kansans, Missouri, New Mexico, and Arkansas) were also high (low gender wage gaps). Similar to Oklahoma, the value of the wage ratio was high in New Mexico (the core of high-high cluster), and its neighbors (Utah, Arizona, Texas, Colorado, and Oklahoma) also had high values of wage ratios, indicating low gender wage gaps in these states. It was also observed that the core of high-high clusters, Oklahoma and New Mexico, are also neighbors of each other. One high-low outlier was observed in 2007, which was New Hampshire. This means that although the value of the wage ratio was high in New Hampshire (low gender wage gap), the value of the wage ratios in its neighbors (Maine, Vermont, and Massachusetts) were low, which indicates high gender wage gaps in the neighboring states. There was also one low-high outlier in 2007, which was Maine. The value of the wage ratio was low (a high gender wage gap) in Maine, whereas its neighbor, New Hampshire, had a high value of the wage ratio (low gender wage gap).

In 2011, there was one core high-high cluster, which was Idaho. Therefore, the value of the wage ratio in Idaho and its neighbors (Montana, Wyoming, Utah, Nevada, Oregon, and Washington) were high. Maine and Illinois were the cores of the low-low clusters in 2011. The value of the wage ratio was low in Maine, and its only neighbor (New Hampshire) had a similar attribute. Similarly, Illinois also had a low value of the wage ratio, and its neighbors (Wisconsin, Indiana, Kentucky, Missouri, and Iowa) did also. Four low-high outliers were observed in 2011, including Nevada, Wyoming, Washington, and North Dakota. Nevada was one of the low-high outliers, meaning that although the value of the wage ratio was low in Nevada (high gender wage gap), it was surrounded by neighbors, including Oregon, Utah, Idaho, California, and Arizona, in which the values of the wage gap were high (low gender wage gaps).

Similarly, the value of the wage ratio was low in Washington (the core of a low-high outlier), but it was surrounded by neighbors (Idaho and Oregon) with low values of the wage gap. Likewise, the value of the wage gap in Wyoming was low. However, it was surrounded by neighbors (Idaho, Utah, Montana, Colorado, Nebraska, and South Dakota) with high values. Finally, North Dakota was another core of low-high outliers. Therefore, although the value of the wage ratio was low in North Dakota, it was surrounded by neighbors (Montana, Minnesota, and South Dakota), which had high values.

In 2015, all types of clusters and outliers could be observed. Montana, North Dakota, and Minnesota were the cores of the low-low clusters. Therefore, the values of wage ratios in these three states and their associated neighbors (Montana neighbors: Idaho, Wyoming, North Dakota, and South Dakota; North Dakota neighbors: Montana, Minnesota and South Dakota; and Minnesota neighbors: North Dakota, South Dakota, Iowa, and Wisconsin) were low. There were four high-high clusters in 2015, including Arizona, New York, Rhode Island, and Connecticut.

Arizona and its neighbors (Nevada, California, New Mexico, and Utah) shared similar variable attributes, high wage ratios (low gender wage gaps). New York was another high-high cluster state. Therefore, the value of the wage ratios in New York and its neighbors (Connecticut, Pennsylvania, Vermont, Massachusetts, and New Jersey) were high. Likewise, Connecticut and its neighbors (New York, Rhode Island, and Massachusetts) also had high values of wage ratios. Finally, Massachusetts and Connecticut, which are neighbors of Rhode Island, also had high values of wage ratios. It can be noted that among the four high-high clusters, New York, Rhode Island, and Connecticut are all located in the northeastern U.S. However, the only high-low outlier, which was Maine is located in the same region. Therefore, although the value of the wage ratio was high in Maine, its only neighbor (New Hampshire) had a low value of the wage ratio.

One of the interesting observations in the clusters and outliers overtime in construction occupations is the trend of Maine. Maine has shown up across all sample years being a Low-High in 2007, a Low-Low in 2011, and finally a High-Low in 2015. According to the statistics for Maine, the recession caused massive displacement in construction occupations and caused wage stagnation for those who continued to work in these fields and also led so many workers to work in lower-paying jobs. This trend in the loss of construction jobs continued until 2012 (Maine Department of Labor). In addition to this piece of information, according to the data source of this study, women average income in construction occupations decreased by 34% from 2007 to 2011. However, in 2007, the only neighbor of Maine, New Hampshire, was booming in construction projects due to Hospital Construction Projects equal to $178.1 million. The authors speculate that one of the possible reasons that the gender wage gap was low in New Hampshire in 2007 and high in Maine could be because of these construction projects providing lots of opportunities for women as well. Therefore, it could have been the possibility that women in Maine have moved to New

Hampshire seeking higher-paying jobs. Nevertheless, in 2011, hospital projects were finished, and it was not an option for women workers. Therefore, Maine became a low-low cluster indicating both Maine and New Hampshire were states in which women were paid significantly lower than men compared to the national average. However, and interestingly, Maine became a High-Low outlier in 2015, indicating the gender wage gap was statistically lower than its only neighbor, New Hampshire. There has been some anecdotal evidence for this rapid change. Some reports about Maine have indicated that Maine is suffering from the labor shortage, driving up construction costs. As a result, construction industry is reaching out to women and providing them well-paying positions (Flaherty, 2018), which in turn can decrease the gender wage gap. This could be a potential reason that Maine turned to be high-low outlier in 2015. It should be noted that this possible reason for the change in Maine has not been formally tested using econometric models and is just a speculative discussion with anecdotal pieces of evidence.

In addition to analyzing some of the temporal changes in the local level output like Maine, combining the results of LISA maps with findings of Minooei et al. (2017) about states with high labor demand can be beneficial. Through their study, future labor demand in different states was studied and some states were found to face severe labor shortage in some construction professions such as electricians, welders and pipefitters (Monooie, Albattah, Goodrum, & Taylor, 2017). Considering the labor shortage in some states besides the higher gender wage gap in some states than neighboring states or national average, women suffering from inequality might migrate to states with high labor demand seeking better pay and more equal opportunities. Although at first glance, this might seem to be a reasonable response to labor shortage issue, it should be noted that this will have negative impact on the industrial activities of states which cannot afford higher wage to attract relevant skillsets.

5. Conclusions and Recommendations

This paper provided a comprehensive geographical overview of the gender wage gap in Architecture and Civil Engineering (A&E) as well as construction occupations in order for practitioners to understand both the temporal and spatial patterns of the gender wage gap in the United States before the recession (2007), during the recession (2011) and in the recovery period (2015). The summary of the findings and their discussions follow.

The spatial patterns of the gender wage gap in both construction and A&E occupations in all sample years are random at the global level, and therefore, there is no evidence to support a global spatial autocorrelation in the gender wage gaps in these occupations. Nevertheless, LISA analysis detected local clusters and outliers in both A&E and construction occupations across sample years. The lower outliers in A&E occupations are not in common with the lower outliers in construction occupations; this is also true when considering upper outliers. Therefore, the geography of the gender wage gap in A&E occupations differs from construction occupations, while considering the extreme values from the outlier maps. Surprisingly, there are no upper nor lower outliers in either A&E or construction occupations in 2015.

The results of this study indicate that the spatial distributions of the gender wage gap in construction and A&E occupations are random globally. However, the spatial patterns of the gender wage gap for different ethnicities of females might exhibit different patterns. Therefore, the researchers suggest studying the spatial distributions of women of color (Hispanics, African Americans) separately from White, Non-Hispanics, to determine whether there is any spatial autocorrelation at a global level for women of color in the United States.

Low-low clusters were more dominant in A&E occupations in 2007, compared to 2011 and 2015. Also, although there did not exist any high-low outliers or high-high clusters in 2007 or

2011, there existed two high-low outliers and one high-high cluster in 2015 in A&E occupations. Considering construction occupation LISA maps in the sample years, the presence of the low-high outliers in 2011 (the recession period) is quite apparent. This indicates that women working in construction occupations in low-high states were impacted more, compared to the neighboring states, in terms of experiencing higher gender wage gaps. However, in 2015, the presence of clusters (both low-low and high-high) was more dominant.

The researchers are mindful that determining the reasons behind each change in the spatial status of every state over the sample years is beyond the scope of this study. However, determining some of the potential reasons for sudden shifts, for example the change in Montana from being a low-low cluster in 2011 to a high-low outlier in 2015 in A&E occupations, or the change in Maine from being a low-high in 2007 to low-low in 2011 and to high-low in 2015 can provide meaningful insight to better understand the gender wage gap and how it can be affected by construction industry ups and downs, equal pay legislation and other factors in the state of interest and its neighbors. Therefore, the researchers suggest further study to determine whether there is any connection between the spatial changes of states over the sample years and when equal pay legislations have been implemented in states.

The findings of this study can also provide some useful insight for Human Resources directors in A&E and construction firms. Human resources and CEOs can use the findings to compare the gender wage gap in their states with neighboring states. Since the labor shortage is an ongoing issue in construction occupations, it is possible that some well-paying positions can open up in neighboring states, which can attract women and finally leading to immigration of some labor resources. Continuous loss of construction labor force to its surrounding neighboring states will eventually increase the overall cost in the long-run. So, public policies can be developed to reduce the higher wage gaps than neighboring states, potentially with some government subsidy to struggling A&E and Construction industries of a state.

The authors believe that when practitioners do not measure and fully understand the problem, it cannot be solved. This paper is one of the authors' first efforts to measure and understand the problem. This study will contribute to the existing body of knowledge in the area of Labor and Personnel Issues, specifically Workplace Diversity and Discrimination, and help the construction industry to better understand the wage gap, further investigate the problem, and make an effort to decrease the wage gap, which will help the industry to attract more females.

The authors would like to note that the existence of wage discrepancies in these findings does not mean that all females are paid unequally. Further, there are various factors involved in determining wage discrepancies, such as overtime work, higher risk-taking, and others. The authors plan to address these additional factors one-by-one in future research in order to better understand the problem.

The researchers recommend conducting the spatial analysis of the gender wage gap in A&E and construction occupations in a controlled environment by controlling some variables like age, years of experience, educational level, and women workers in union vs. non-union, to get more accurate results in the geographical study of the gender wage gap. Also, considering that ESDA approach cannot provide the reasons for the changes in the gender wage gap, it is suggested to use other tools like Spatial Econometric Models to formally tests the reasons for the gender wage gap changes in A&E and construction occupations across states and different sample years.

Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request (items: aggregated level data by each state for the

sample years (2007, 2011, & 2015) which was extracted through the one-year American Community Survey (ACS) database).

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Table 1. Sample data for the gender wage gap

Years	**2007**	**2011**	**2015**
A&E Occupations			
Women Average Wage ($)	40,388.47	33,240.00	57,065.94
Men Average Wage ($)	54,853.31	57,218.74	64,404.96
Wage gap (%)	73.63%	58.09%	88.60%
Construction Occupation			
Women Average Wage ($)	27,695.04	26,684.25	40,411.94
Men Average Wage ($)	33,358.88	33,344.99	34,586.88
Wage gap (%)	83.02%	80.02%	116.84%

Table 2. Moran's I statistic for global spatial autocorrelation (A&E)

Year	**Moran’s I Statistics**	**Pseudo p-Value**
2007	-0.0077	0.427
2011	0.0016	0.393
2015	-0.0149	0.448

Table 3. Moran's I statistic for global spatial autocorrelation (Construction)

Year	**Moran’s I Statistics**	**Pseudo p-Value**
2007	-0.1278	0.125
2011	-0.0241	0.472
2015	-0.0874	0.138

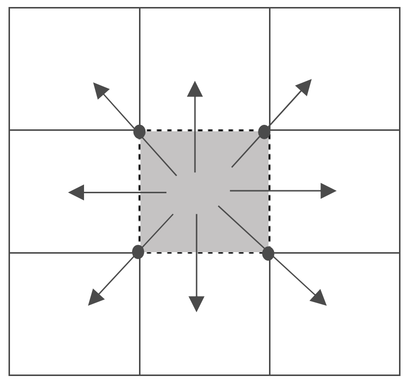

Figure 1. Queen Contiguity Weight Matrix

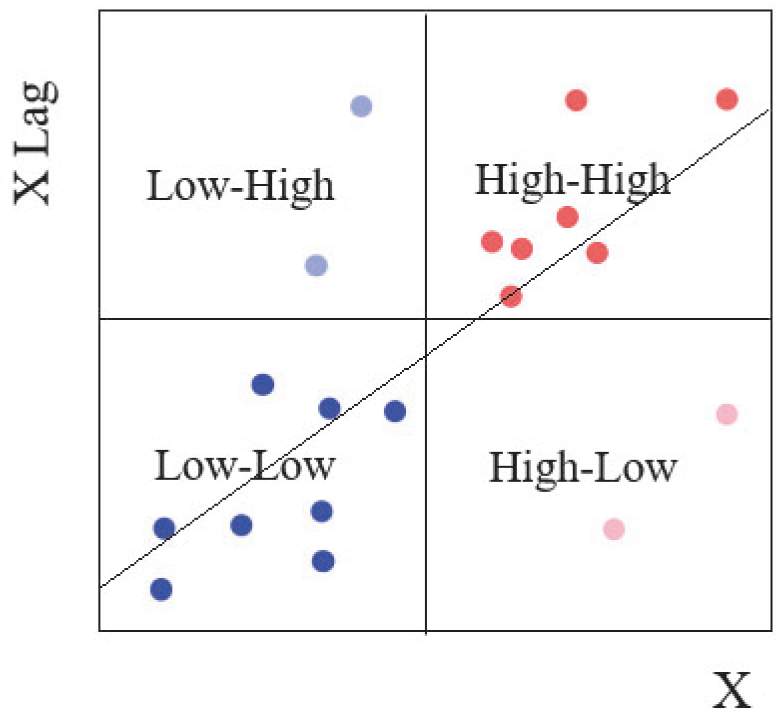

Figure 2. Moran's I Scatterplot

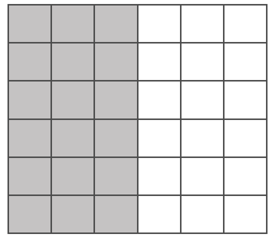

Figure 3.1. Positive Spatial Autocorrelation

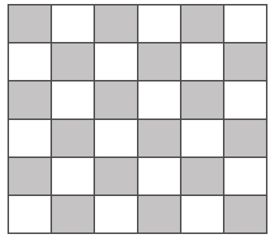

Figure 3.2. Negative Spatial Autocorrelation

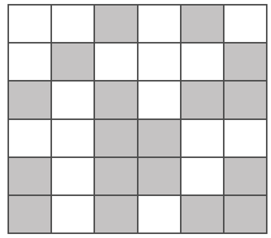

Figure 3.3. No Spatial Autocorrelation, Randomness

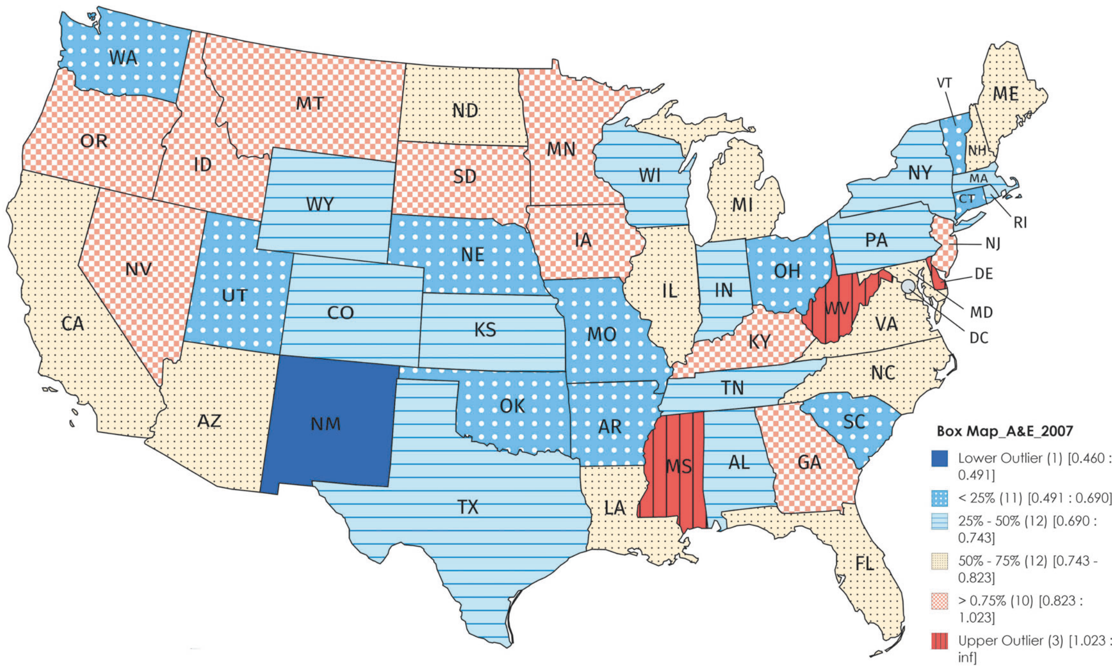

Figure 4. Box plot map for gender wage ratios in A&E occupations in 2007

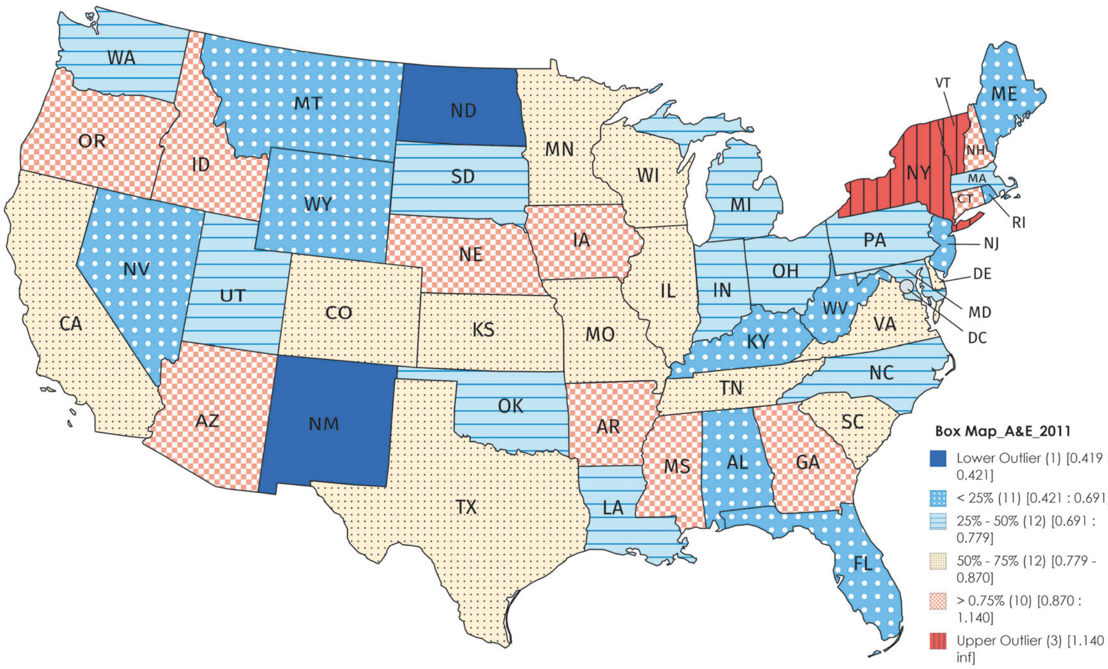

Figure 5. Box plot map for gender wage ratios in A&E occupations in 2011

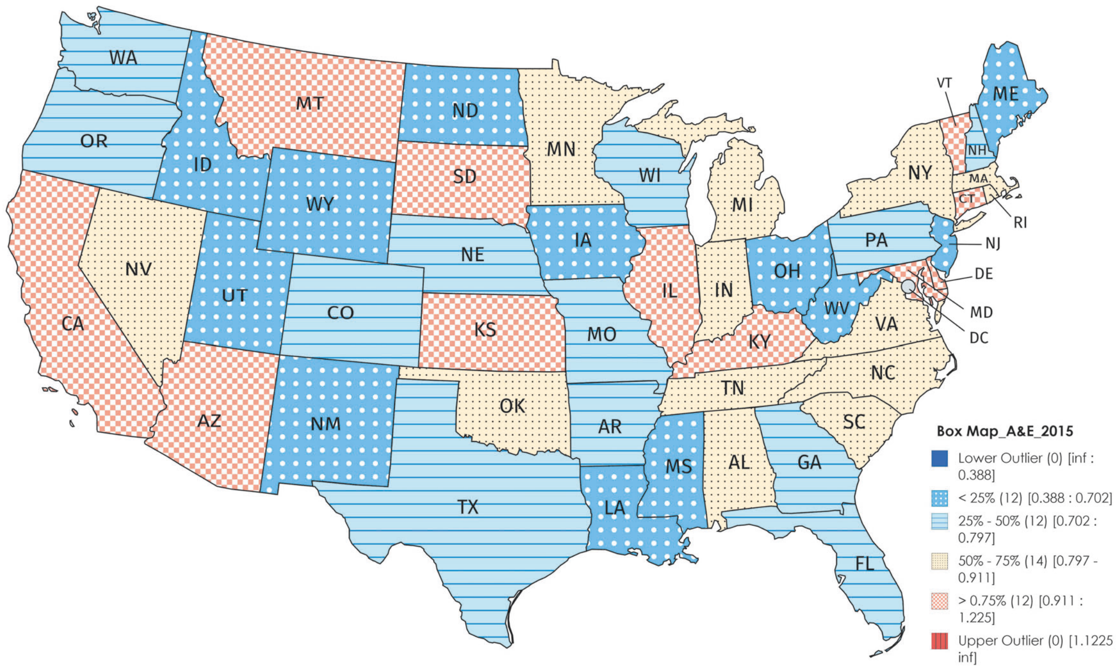

Figure 6. Box plot map for gender wage ratios in A&E occupations in 2015

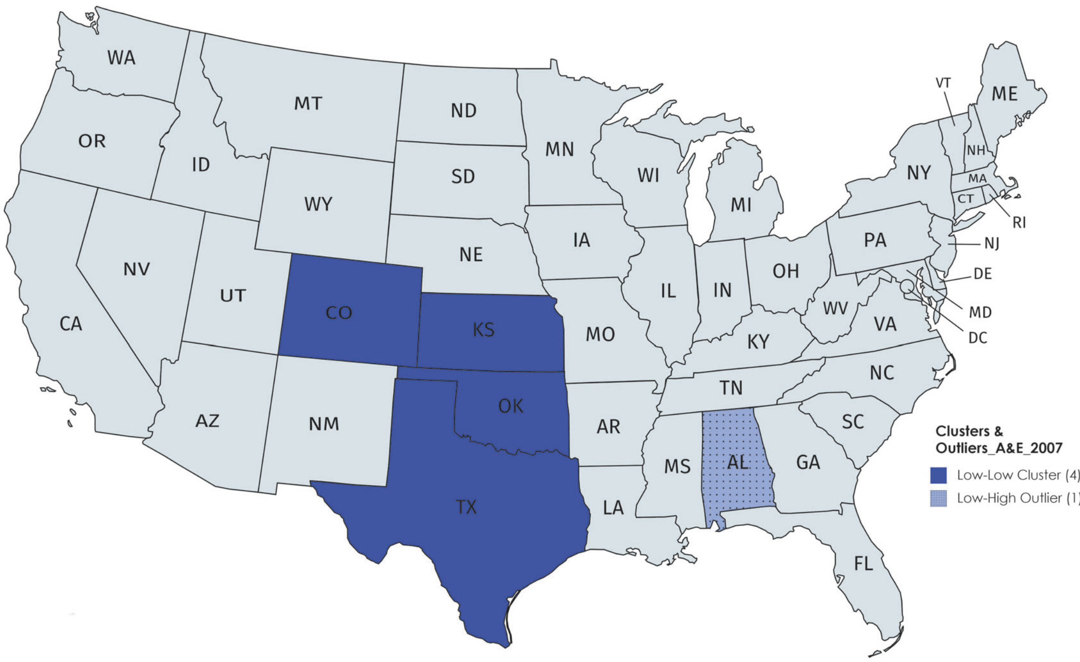

Figure 7. LISA map for gender wage ratios in A&E occupations in 2007

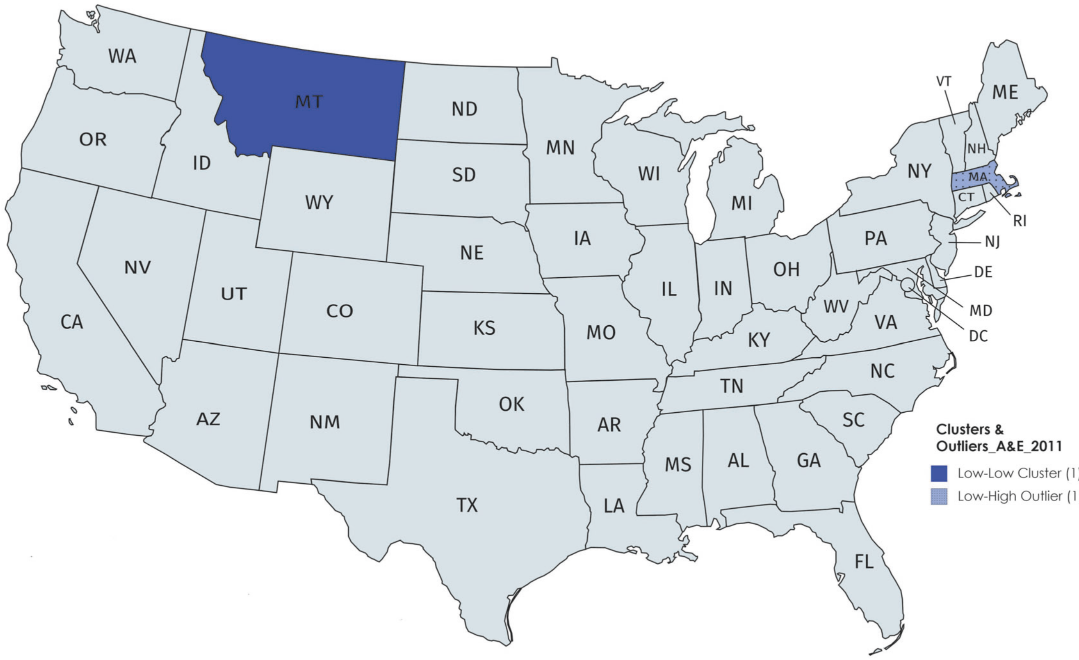

Figure 8. LISA map for gender wage ratios in A&E occupations in 2011

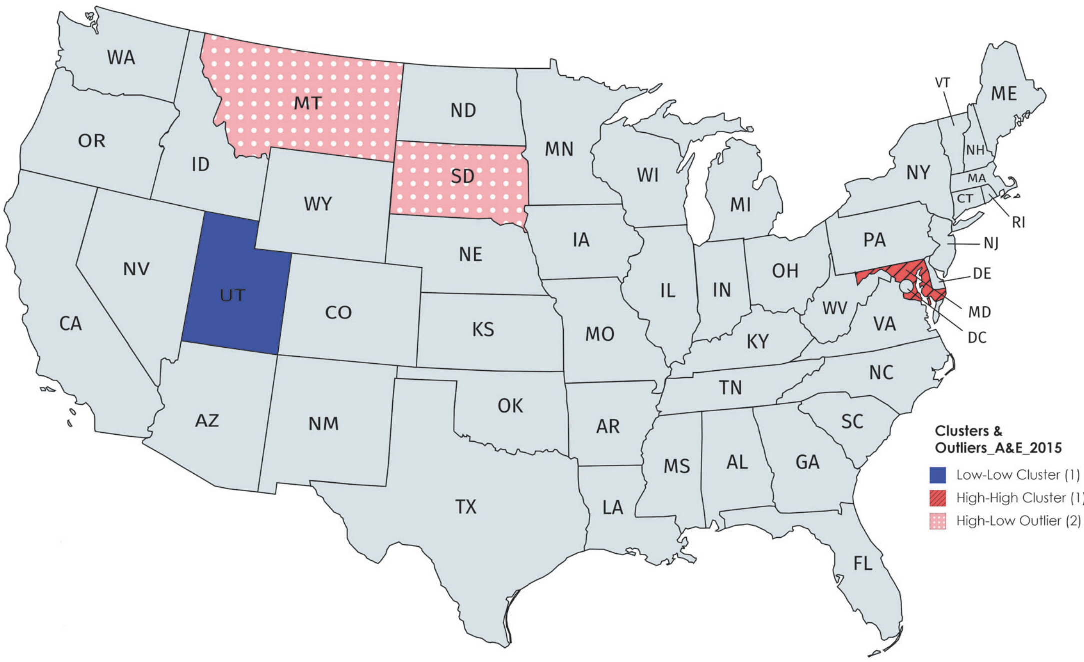

Figure 9. LISA map for gender wage ratios in A&E occupations in 2015

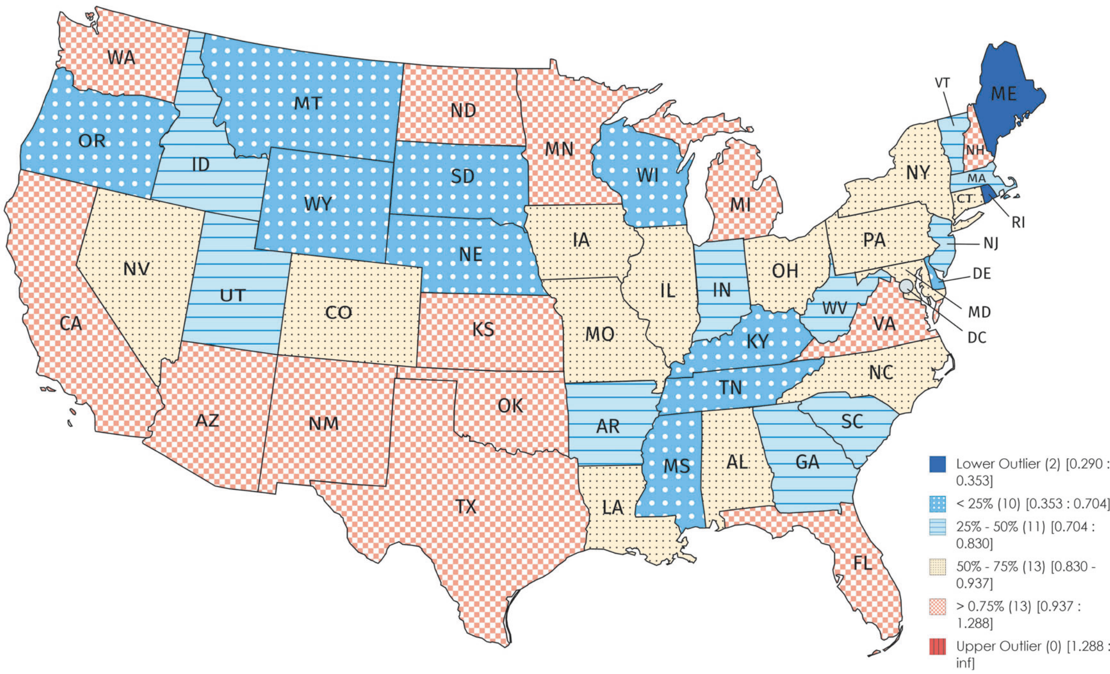

Figure 10. Box plot map for gender wage ratios in construction occupations in 2007

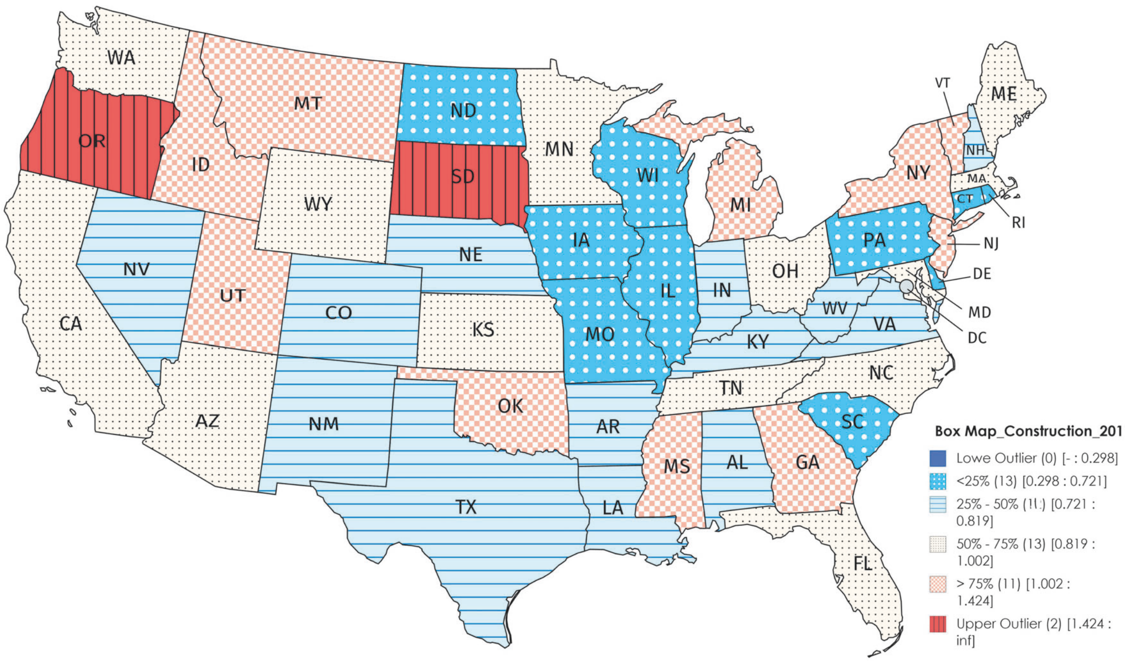

Figure 11. Box plot map for gender wage ratios in construction occupations in 2011

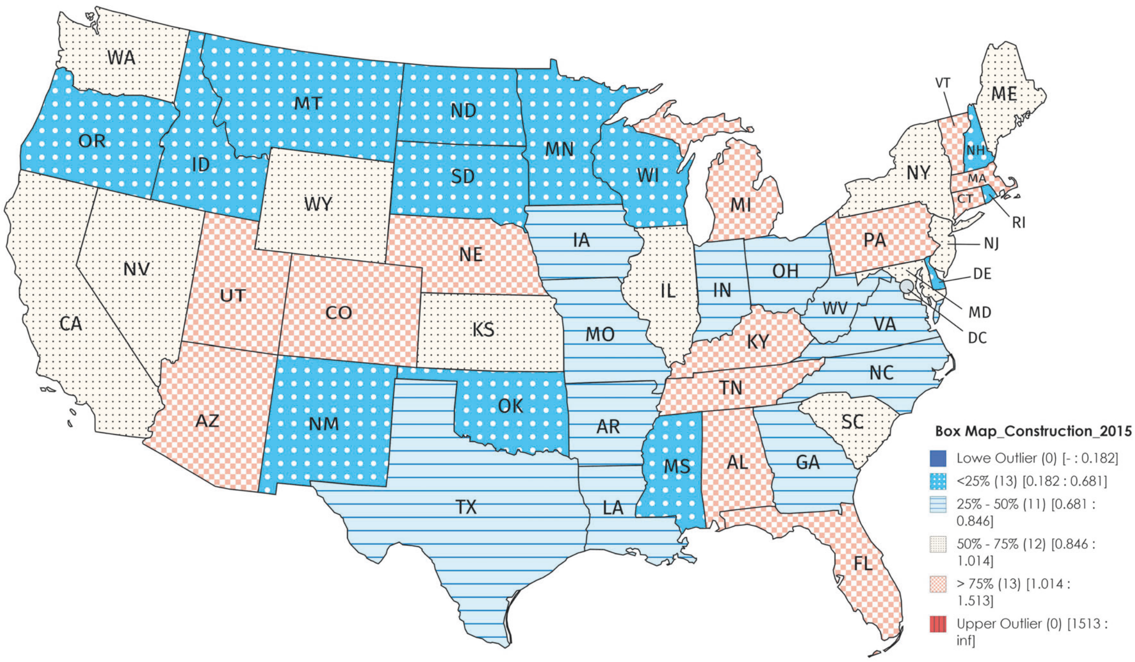

Figure 12. Box plot map for gender wage ratios in construction occupations in 2015

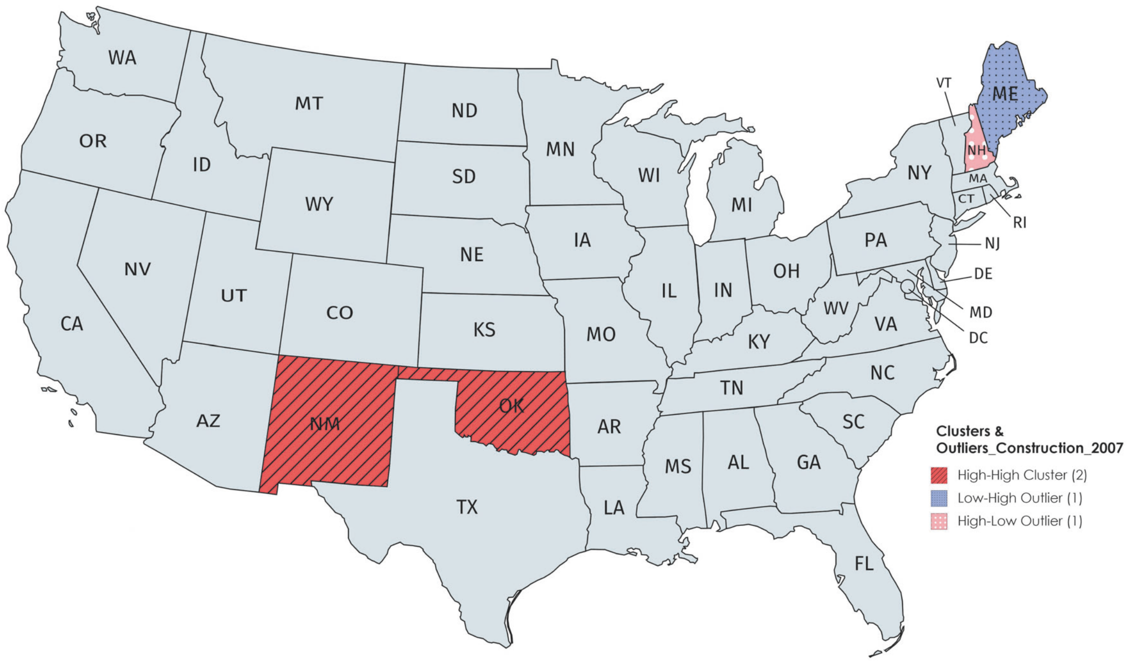

Figure 13. LISA map for gender wage ratios in construction occupations in 2007

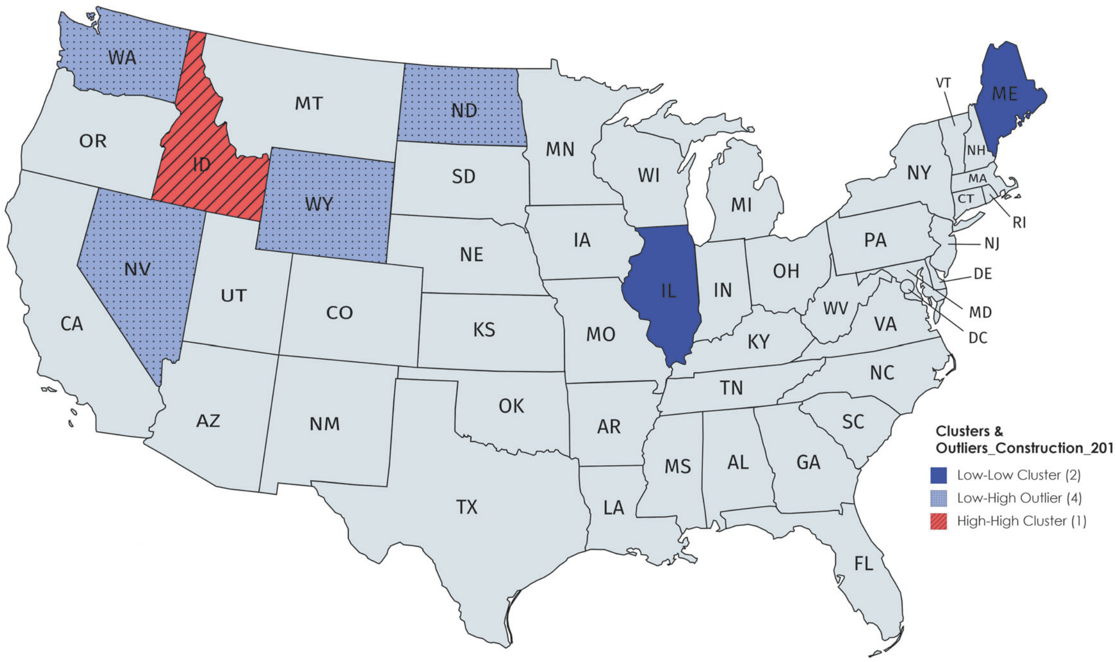

Figure 14. LISA map for gender wage ratios in construction occupations in 2011

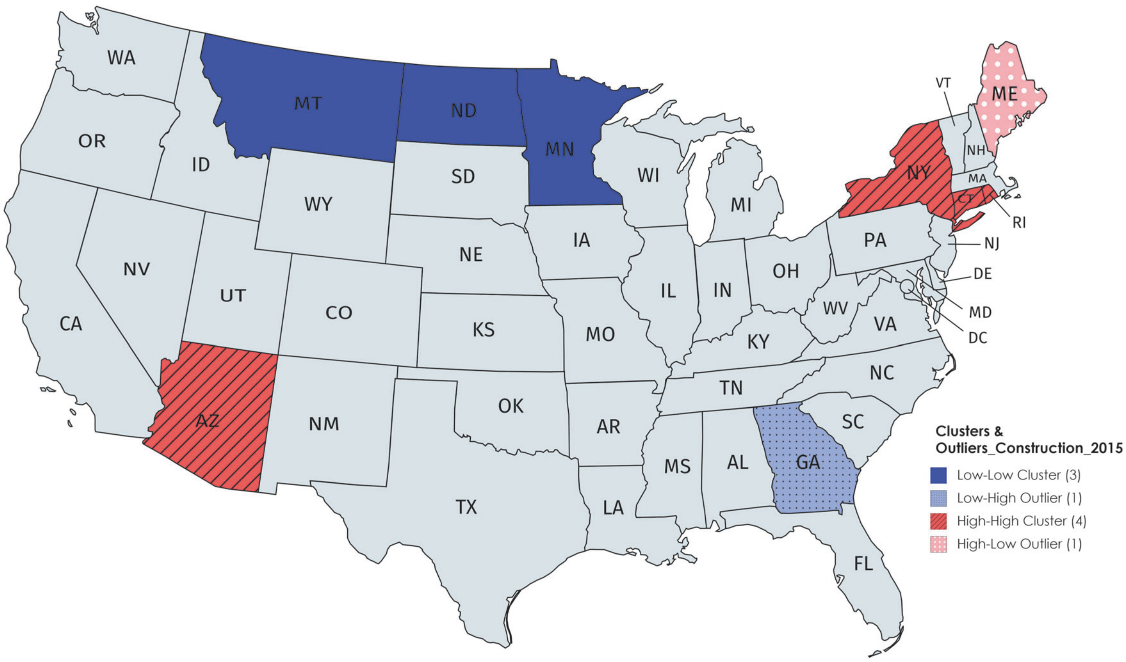

Figure 15. LISA map for gender wage ratios in construction occupations in 2015

List of Figures