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Firm Clustering and Lek Mating: Similarities in the Clustering Behaviors of Firms and Lek Species

Gabriel Salitan-Alvarez
Skidmore College

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By

Gabriel Salitan

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Thesis Advisor: Qi Ge

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Abstract

This paper explores the causes behind firm clustering, specifically job density in computer and math occupations, and similarities between firm clustering and lek mating, a mating strategy among certain species, particularly avian, involving male clustering to attract female mates. I use a model that contains economic variables and Geographic Information System (GIS) mapping techniques to compare the similarities between the two phenomena visually. My findings suggest a significant positive effect of average annual salary for computer and math occupations and real GDP per capita on job density in those fields and a positive significant effect of job density and real GDP per capita on average annual wages.

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1 Introduction

Agglomeration economies is a well-researched phenomenon in economics about the many benefits firms receive from proximity to one another. There are many theories as to why firms cluster, the benefits they receive, the costs they endure, but overall, there are many clear real life examples of firm clustering, such as Silicon Valley, with thousands of tech firms packed into this small area of California. Interestingly, clustering is also used by males of certain species, particularly avian, as a strategy to attract females. Species that use this strategy, cluster into specific geographical areas called lek arenas to compete for females (Jiguet et al. 2000). Within these arenas will be one or two high ranking "alpha" males in the center with lower ranking males ("beta," "gamma," etc.) surrounding them. The males compete but also work together in competitive displays to entice visiting females to mate with them. Up to 30 males can gather into lek arenas just 32 feet in diameter (Jiguet et al. 2000). The parallels between these two phenomena are extensive, and will be used as a framework in this paper to describe the causes and impact of firm clustering, as well as to compare them.

In my paper, I use both mainstream economics and evolutionary economics to explore the topic of firm clustering. Evolutionary economics is a field of mainstream economics inspired by evolutionary economics. Evolutionary economists draw upon other disciplines, such as biology, anthropology, sociology, etc. to study transformations within the economy. Many traditional mainstream economic models are static and do not account for factors, such as human behavior, in everyday economic processes. Using evolutionary economic models to study economic phenomena can provide useful insight that is missed by more mainstream models. Because the literature on firm clustering, while extensive, does not often use these types of models, my main contribution to the literature is comparing firm clustering with lek mating. I explore firm clustering using a model inspired by more mainstream economic theories surrounding the phenomenon and an evolutionary economics approach by comparing firm clustering to lek mating. My model contains economic variables, so it will explore the economic reasons behind firm clustering. I also compare firm clustering to lek mating using a mapping software called Geographic Information System (GIS), which allows me to map job density of computer and math occupations to compare the visual differences between that and lek mating, which I simulate using Microsoft word shapes. The use of GIS will be discussed further in the literature review section of this paper. By using both mainstream and evolutionary economic techniques, I hope to expand the literature on firm clustering and gain new insights based around this unique approach. I also hope to add to inspire future research into economic topics using evolutionary economics.

This paper is organized as follows. Section 2 discusses and analyzes existing literature relevant to the topic of this paper, as well as my contributions to the literature. Section 3 introduces and describes the methodology and data used in this paper. Section 4 describes the results obtained from the regressions used in this paper. Section 5 discusses the results, including their robustness and implications, as well as the further analysis relating firm clustering to lek mating. In this draft, I also discuss plans for the final draft in the discussion section. Section 6 offers concluding remarks and discusses possibilities for further research.

2 Literature Review

While there is extensive literature on both firm clustering and lek mating, there is no literature that I could find that relates the two phenomena. However, there is some literature that compares similar economic phenomena to lek mating and uses evolutionary economic models to describe firm clustering, which I incorporate into my paper. Because of this, I separate the literature review into the following sections: literature regarding firm clustering, literature regarding lek mating, literature relating lek mating to other economic topics, and literature that use evolutionary economic frameworks and models to describe firm clustering. I also include a section to review literature that uses Geographic Information Systems (GIS), both for firm clustering and lek mating, since I plan to use GIS in this paper. Finally, I discuss my contributions to the literature.

Firm clustering

It is a well-established fact that firms and workers are much more productive in dense urban areas. Puga (2010) finds that firms are significantly more productive in dense urban areas based on three findings. First, firms cluster more than can be explained by chance or comparative advantage. Second, costs associated with wages and rents are significantly higher in urban areas where firms tend to cluster, but firms still decide to cluster because the benefits of increased production outweigh the costs associated with being in an urban environment. Third, there are systematic variations in productivity within firms in different environments, and the author finds that firms that are closer to each other are more systematically more productive. The author also describes some of theories as to why firms are more productive in clusters included in this paper, all related to spatial concentration, or proximity of firms: sharing facilities, sharing suppliers, sharing the gains from individual specialization, sharing a labor pool, better matching, and learning. In this draft, I will be focusing on labor pooling as an indicator of firm cluster; I will use job density in computer and math occupations, which will be discussed further in the methodology and data section of this paper. The key similarity in most of these causes is the sharing of resources. In clusters, it is much easier for firms to share all the resources they need, making them far more efficient. Sharing a labor pool is particularly important, since it offers a constant market for skill. Larger labor pools also allow workers to begin to specialize more, increasing their productivity. Also, with larger labor pools there is better matching between employers/firms and employees, making hiring a much more efficient process. Finally, learning refers to how individual workers can learn more from the large flow of information brought on by clustering.

While the author provides proof as to why firms are more productive in dense, urban areas, he does not explain the reasoning behind the theories he provides. His paper summarizes these theories related to spatial patterns well. However, while this paper did not offer any new ideas on why firms cluster, it was useful since it compiled previous theories and idea that have been offered on the subject.

As mentioned with the previous literature, the main theory surrounding agglomeration economies regarding the benefits of clustering have centered on the production efficiency due to spatial concentration, such as the minimization of transportation costs, labor pooling, labor matching, etc. However, Sorenson (2003) has a different idea as to why firms cluster. In his paper, he focused on the footwear manufacturing and biotech industries, both of which have firms that have been clustering in specific U.S. regions as far back as 1940 and 1995, respectively. Despite this, the author found that firms in these clusters consistently perform worse in the long-run due to increased competition. Focusing on the biotech industry, he found that there is a significant negative correlation between higher firm entry rates and time-to-IPO (which the author used as a measure of performance). In other words, locating in a region with increased competition brought on by clustering will decrease a firm's chance of launching an IPO. To reach this conclusion, the author used binomial regression while controlling for the following factors: firm age, firm financing rounds, firm capital raised, firm patents, the demand for public biotech stocks, the number of biotech firms nationally, and the age of the local biotech industry. To understand why firms in the biotech industry chose to keep clustering, Sorenson proposed the idea of social networks that are formed within clusters. These networks help entrepreneurs gain access to the resources and information they need to startup their firms, even if those resources are less valuable as the firm and industry matures. Thus, the conclusion of the paper was that social networks, provided by proximity, are needed in the short-run, even if it hurts businesses in the long-run. While this paper only does research on industry clumping within the footwear manufacturing and biotech industries, the theory can be applied to clustering within the tech and manufacturing industries in general, since firms in these industry cluster to gain access to resources and information they need even if there is increased competition and more firm failure within clusters. This draws parallels to lek mating since males within leks are simultaneously competing and working together for females, which is very helpful for linking the two phenomena.

Focusing on the tech industry, Zhang (2003) used a Nelson-Winter model to study the formation of tech firm clusters, such as those in Silicon Valley. The Nelson-Winter evolutionary model uses evolutionary economics, the field of economics that uses Darwinian principles to study ongoing transformations in an economy, to define the state of an industry by a list of firm level state variables such as physical capital and productivity. The important aspect of the model is that the "agents" in the model can evolve based on decisions they make. The author focused on concentrated entrepreneurship within these high-tech clusters and based his model off this idea. In the model, there is a set of agents that start (at time $t = 0$) with a random endowment of human capital, h_i^0. Each agent with no firm can choose to start one. If an agent wants to start a firm at any time *t*, he must raise capital, K_i^t, at a cost, *c*. For simplicity, labor is included with capital and factored into a cost. Altogether, the production function for an agent *i* that has a firm is $Y_i^t = h_i^t (K_i^t)^\alpha, \alpha < 1$. If he produces nothing, then $Y_i^t = 0$. Other features of the model include putting profit into research and development, which splits again into technological innovation and technological imitation, and the rest on capital accumulation. In the results section, the authors describe that over time, spatial patterns of industrial clustering emerge. The author also ran simulations with different initial conditions, such as technological advantage, knowledge spillovers, seed capital (in some regions entrepreneurs many have more difficulty raising capital than in others), and trying and learning by failing, which allows for trial and error with failed firms. Most of the existing literature on industrial clusters contends that firms choose to locate close to other firms to exploit the benefits from a cluster. However, through exploring the social science side of clustering, the author argues that clusters can also form through social effects; the appearance of one or more entrepreneurs in an area inspire many followers locally. This idea is very interesting and useful to my research as it explores the social and evolutionary economic side of industry clumping, which is more relevant when relating it to lek mating. For example, when an alpha male in a lek species decides to locate somewhere he may inspire other lower status males to cluster around him, forming a lek arena.

Focusing on the manufacturing industry, Head & Swenson (1995) studied the location choice of 751 Japanese manufacturing plants in the United States between 1980 and 1995. The agglomeration measures where broken down by US state and included: A^{US}: US activity – the number of US manufacturing establishments, A^J: Japanese activity – the number of Japanese plants, A^G: Industry Group member activity – Number of establishments in same manufacturer-led *keiretsu* (a conglomeration of Japanese businesses linked together), and *Border-state activity*:

activity of border states based on the three other measures. The authors ran simulations that estimated that a US state increased its probability of future selection by a Japanese firm by 5-7% when there was a 10% of the agglomeration measures used in the paper, meaning that Japanese firms do indeed locate based on these measures of agglomeration. The two most significant variables were A^J and A^G, meaning that the location of Japanese firms within the US is significantly influenced by previous investment of other Japanese firms within the same industry or *keiretsu*. The other two variables, A^{US} and *border-state activity* were also significant, meaning that state borders do not define the economic boundaries for agglomeration effects, but rather the general regions the firms are located within. Interestingly, the authors came to this conclusion even when controlling for factors such as state effects, state time trends, and flows of U.S. investment, such as incentive packages. For example, in 1985, Kentucky offered $300 million to attract a Toyota manufacturing plant. The authors' simulations found that incentive packages like these would have little effect on a firm's decision to locate in a certain state. This is interesting as it shows the power of the benefits of agglomeration, since Japanese manufacturing firms are willing to forgo many other benefits to receive benefits from agglomeration. There may also be cultural incentives for Japanese manufacturing firms to cluster, but because A^{US} and *border-state activity* were also significant, it suggests that agglomeration of manufacturing firms in general, American or Japanese, plays an important role in the decision making of where to locate.

Another paper, written by Brown et al. (2009) had similar findings; the authors used spatial models to measure the spatial interaction of investment flows in U.S. manufacturing, using local agglomeration within states. They concluded that local agglomeration, among other factors, have positive direct effects on investment flow at state level, which concurs with the previous study mentioned on Japanese manufacturing firms.

Determining the impact of agglomeration economies on different aspects of the economy such as wages, house prices, etc. has not been researched as extensively as the benefits it provides to individual firms. Glaeser & Gottlieb (2009) study how agglomeration economies increase the wealth of cities. They made all the same connections that the other papers in this literature review have made: there is powerful connection between density and productivity across states, due to greater efficiencies and reduced costs in the flow of information, labor, transportation, etc. However, the authors also discuss the impact of agglomeration on various factors such as higher wages, higher prices, and higher population levels, all driven by agglomeration into cities and metropolises. This is an obvious observation as cities are clearly much more expensive and provide higher wages since there is much more demand for labor. Whether the impact is positive or negative is determined by amenities and housing supply elasticity; the supply of migrants to a city affects the elasticity of housing supply since the number of homes in a city is proportional to the number of people. Also, the amount of land available as well as regulation of that land will help determine housing supply elasticity. For example, according to the authors, in Houston there is abundant land and permissive land use regulations, so an increase in productivity in Houston brought on by agglomeration would increase the housing supply and the population. Because of a large elastic supply of labor, wages and prices would probably stay relatively flat. However, in a city like Boston where the housing supply is more inelastic, an increase in productivity should increase wages and housing prices since the population cannot increase as much. This paper is interesting because it studies not just the causes and benefits of agglomeration economies, but also the impact on different variables like wages, housing prices, etc. It is a useful starting point for my thesis, since I want to explore the impact of industry clumping on wages and prices, an area of focus that remains largely uninvestigated. This paper also measured the effects of agglomeration economies on different variables, such as average annual wage, which is one of the variable I use for in this paper.

Lek mating

There are many definitions of lek mating and theories as to why it is a successful strategy for males among certain species. One paper describes several important requirements of a lek species, including the congregation of males in a lek arena to work together in display rituals and the fact that females select their mates (Jiguet et al. 2000). For example, certain species of bees and ants, such as red harvester ants, congregate and release pheromones that attract females. In this case, the more males that are present to give off the pheromone, the stronger the attraction is for the females, which gives them an incentive to work together to attract mates (Velthuis et al. 2005). The paper also mentioned that there is no paternal investment beyond providing sperm (i.e. the males do not help raise their offspring). Another paper described the correlation between territory position and mating success (in this case mating success is defined by how many females some individual male mates with) and found males that are more proximate to the lek arena center are more successful (Fiske et al. 1998). In other words, males that agglomerate more closely to the center of a lek are more successful.

One interesting aspect of males in lek species is their ability to cooperate in display rituals to be more successful in their mating (i.e. mate with more females). It draws parallels to firm clustering, since firms in clusters both compete and cooperate to gain increased access to resources they need. McDonald and Potts (1994), discuss cooperative displays among long-tailed manakins, a species of bird that uses lek mating. In this species, beta males assist alpha males in courtship displays. Alpha males are responsible for the clear majority of the mating, and the beta males do not receive any direct short-term benefits from helping the alpha males. While this altruism seems evolutionarily unsustainable, given that the beta males are not directly related to the alpha males and therefore there is no genetic advantage to helping them in the short-run, it benefits the beta males in the long-run through occasional copulation and possible ascension to alpha male status. This is interesting in its similarity to the benefits firms receive from clustering. Small firms (comparable to beta males) cluster near big firms (comparable to alpha males) to exploit resources from them. The only difference with firms is that they receive short-term benefits in exchange for long-term costs, whereas the beta males receive the opposite. It is an interesting strategy from an evolutionary standpoint since beta males cannot compete with alpha males, so their best chance of mating in the long-run is to help alpha males in the short-run. Similarly, small firms usually cannot compete with large firms, so they must use the large firms to gain resources in the short-run and then either get acquired by large firms or grow to become large firms themselves. Understanding the long-term benefits of this altruism may help understand why firms cooperate with each other sometimes.

Another important topic with lek mating is the lek paradox. As mentioned, there is no paternal investment from males within lek species, so females must choose males solely based on what genes they can pass on to their offspring. Since this is the case, genetic variation should erode within lek species, since natural selection would dictate that females will usually choose the alpha males since they have the best genes. However, genetic variation is maintained in lek species. Miller and Moore (2007) propose two theories as to why this may be the case. The first is direct genetic effects; non-alpha males may have more elaborate traits (unlike alpha males that purely exhibit aggressive traits) with “good genes” that can be passed on to their offspring. The second is indirect genetic effects; non-alpha males may exhibit traits that reflect genes they obtained from their mothers. These traits may signal females that these males have good "maternal" genes for their daughters, which may be something some females would be interested in obtaining.

Reynolds and Gross (1990) discuss lek mating from an economic perspective, questioning the validity of the lek paradox through a cost and benefit analysis of female mate choice in lek species. The authors study the cost and benefits of searching for a mate and choosing a mate in both economic (paternal investment beyond just the sperm) and noneconomic (or lek) mating systems. Typically, the lek paradox, in terms of a cost/benefit analysis, is explained as follows: assuming the search costs (finding the optimal mate) are the same for females in both types of mating systems, one would expect females to be spend more time searching for an optimal mate in economic mating systems, since there are more factors to consider. For example, since there is paternal investment past providing sperm in economic mating systems, a big factor to consider would be how good the male will be at raising his offspring. Therefore, one would also expect that females in noneconomic systems spend less time searching for the perfect mate and just choose the male with the best genes (i.e. the alpha male). However, this is not the case; genetic variation in lek species persists. This is considered the lek paradox. The authors of this paper suggest a solution; if search costs are not assumed to be the same in both mating systems, the search costs in noneconomic mating systems are much lower since males congregate in a geographical area, making it much easier for females to find a mate. In fact, the low search costs in lek species may offset the smaller benefits females in lek species receive compared to females in economic mating systems. The authors explain that low search costs may explain the lek paradox, and that there may be no paradox at all.

As mentioned, I will use this research as a guide to define lek mating, which I need to draw comparisons between the two phenomena.

Literature relating lek mating and economic concepts

While there is no literature that directly compares industry clumping with lek mating, two main ideas come to mind in terms of how they are related: clustering by both males and firms to gain access to resources and investment by outside parties. The first is the obvious connection; both strategies require clustering even though they are both counterintuitive phenomena. In both situations, there is heavy competition since there are so many firms/males in a small geographical area, so it seems strange that it is such an effective strategy. However, in both cases the firms or males help each other gain access to the resources they need. In lek species, lower status males will help alpha males in their ritual displays to mate with as many females as possible, and in return they will have access to other females that come to the lek arena. Similarly, when firms cluster, they have increased access to information and resources they made need.

In terms of outside investment, while there is no literature directly relating the two subjects, there is a paper that relates lek mating with economic models of negotiation. Patricelli et al. (2011) describes the similarities between negotiation in lek arenas and bazaars and how economic models of negotiation can offer insights into animal courtship dynamics in lek species. Because, as mentioned, females choose their mates in lek species and since there is no paternal investment beyond providing sperm, females in lek arenas can be compared to buyers in bazaars while males can be compared to sellers. The authors break down negotiation in the lek into four factors: display territory, partner choice by males, building trust with a negotiating partner, and courtship bargaining. They argue that these factors can be related to negotiations between buyers and sellers in a bazaar. Regarding display territory, both males and sellers must choose where they display. There are countless considerations a seller must make when choosing to locate and many of these considerations are mirrored by males in a lek arena. For example, just as sellers must consider consumer behavior in bazaars, males must consider female cognitive processes, such as whether they compare males to their own standards or to other males. The authors list many other considerations both sellers and lek species males must make and concludes that just as in bazaar, where a male locates will influence the next stages of negotiation. The next three factors are the stages of negotiation both sellers and males must go through to complete the transaction. First, males must choose females to target in the same way sellers must choose which consumers to target. For example, in a lek arena, a lower status less competitive male may choose to target lower quality females in the same way that sellers may avoid buyers who are in negotiations with superior sellers. Second, buyers and seller, or males and females, must build a foundation of trust to complete a transaction. This could be compared for firms within a cluster, which build social networks and must learn to work together to maximize the productivity and profit of each individual firm. So, in effect, the two important components associated with both sellers and buyers in a bazaar and lek mating and are "access to assets," which describes the males' traits, or the sellers' products, and "courtship/bargaining tactics," which describes the strategies the males or sellers use to effectively display their "assets." This can also be looked at from the perspective of outside parties, such as shareholders that invest in a firm or the females in a lek species that "invest" in the male they choose. Similarly, when a bank or person invests in a startup or buy shares in an established firm, they are doing so with sole purpose of receiving more money than they invested in return.

This paper was very interesting since the authors used evolutionary economics to study an economic concept by comparing an economic activity to a biological activity, which is the foundation of my paper. The economic models of negotiation in this paper offers a conceptual framework that can be used for understanding social interactions and negotiation behaviors in both humans and animals in courtship displays. This is useful for making predictions on complex decision making behaviors humans make when negotiating that are missed by more mainstream models. In my paper, I hope that the comparisons made between lek mating and firm clustering can provide useful insights and predictions into firm clustering behavior.

Literature that uses evolutionary economic frameworks and models

As mentioned in the introduction section of this paper, literature studying firm clustering from an evolutionary economics point of view has not been as extensive. However, Ismalina (2012) studied the theories surrounding creative industry clustering, and finds that the three dominant theories used to describe agglomeration economies do not adequately describe the changes that take place in the processes that lead to agglomeration economies in creative industries nor the socio-economic context of these formations. As a result, the author reviewed theories that use new institutional economics (NIE) and new economic sociology (NES) perspectives, which are both evolutionary economics perspectives, to help fill those gaps in the mainstream theories. She then provides a conceptual framework that uses NIE and NES and applies it to three different creative industry clusters in Indonesia. The framework provided uses both economic and social factors. The two perspectives complement each other because they each add value that the other does not. For example, while the NIE perspective emphasizes rational behavior in market relations, it fails to incorporate other social factors, such as information access, opportunistic behavior, and other irrational behaviors that NES models do not incorporate since they assume people act rationally (not the case). One example of an NES perspective is looking at the role of social relationships in firm clusters, and how they benefit individual firms within clusters. NIE perspectives typically ignore this factor because it is does not focus on the rational aspect of business, but instead the more human aspects, such as friendships, reciprocity, trust, etc. To test this framework, the author studied three creative industries in Yogyakarta, Indonesia: the Kotagede silver handicraft firm cluster, the Manding leather handicraft firm cluster, and the Kasongan ceramic handicraft firm cluster. The author finds that social and economic factors indeed both play an important role in these clusters. She finds that these creative industries compete, but also cooperate to some degree, to strengthen the social tie within the cluster. This can be likened lek mating systems, wherein males compete, but also cooperate in mating rituals to attract more females. Using this framework provides useful insight into firm clustering that is not provided by more mainstream frameworks, and I plan to incorporate both economic and social factors into my thesis.

Geography Information System (GIS)

In my paper, I use GIS to map out different variables, including the job density of computer and math occupations within different metropolitan statistical areas (MSAs), which will be discussed more in the methodology and data section. The process for creating these maps include downloading a map template for MSAs, which came from the US census bureau, and joining the data into the relevant MSAs used in this paper by matching MSA codes from my data with MSA codes from the MSA map. GIS maps are very useful in economics because they allow readers to visualize data, which can make it clearer. For example, when comparing job density and average annual wage, mapping the two using GIS can help the reader visualize the relationship between the two variables. Also, it will help visualize similarities between job density, or firm clustering, and lek mating. Because of this, using GIS will be useful in helping to visualize clusters and leks and drawing similarities between the two phenomena.

Wallsten (2001) uses GIS to explore agglomeration and knowledge spillovers at the firm level. The study conducted was to conclude whether a firm that clusters with firms that have won a Small Business Innovation Research (SBIR) award over short distances affects the probability that it will win an SBIR award. His conclusion was that firms cluster with SBIR winners are indeed more likely to win this award than isolated firms, even when controlling for regional, firm, and industry characteristics. This result is not particularly surprising; most literature agrees on the benefits of agglomeration economies, such as increased productivity, so it is not surprising that high-tech firms near other SBIR-award winning firms will increase their likelihood to win an SBIR award. However, the interesting part of this paper was that the author complied a large dataset of small, high-tech firms using GIS to measure their longitude and latitude to create density variables. Mapping these SBIR firms not only helped the author measure their longitude and latitude, but also helps visualize the clustering and concentration of these firms. I plan to use this technique in this paper to help visualize the job density of computer and math occupations, and compare it to lek arenas.

In terms of lek mating, Aspbury & Gibson (2004) used GIS to investigate how male greater sage grouse select their lek locations. They studied their visibility to two factors, potential female mates and a major avian predator, the golden eagle, and how they selected their lek arenas based on these factors. They analyzed visibility from four different perspectives to maximize the accuracy of their results: golden eagles searching for a lek from the ground, female sage grouses searching for the lek from the ground, golden eagles searching from the air at various altitudes, and male sage grouses on the lek scanning for a flying eagle. After mapping these variables using GIS, the authors found that sage grouse males choose to site their lek in places that enhance their short-range visibility to females and decrease their long-range visibility predators in the same area. These findings are not entirely relevant to my thesis, but they help me understand how leks are formed and what factors go into helping lek species males decided where to cluster. The techniques used in this paper were useful since I will be using GIS to map lek arenas in the final draft and comparing these leks to clusters formed by firms.

Contributions

The main contribution of this paper to existing literature on firm clustering is studying firm clustering from a more evolutionary economics point of view. Evolutionary economics, while part of mainstream economics, uses disciplines outside of mainstream economics, such as evolutionary biology, to study different economic processes. Evolutionary economists study transformations in firms, employment, production, trade, and other aspects of the economy using evolutionary methodology. For example, by comparing firm clustering to lek mating, new insights about firm clustering are offered since comparing the two can lead to predictions about how firms cluster, which will be discussed later in the paper. Clustering for economic purposes, like most economic phenomena, is an ongoing and dynamic process, and should be studied as such. However, there is little literature that uses evolutionary economic methods to study firm clustering, and by studying the similarities between lek mating and firm clustering using GIS mapping techniques, I hope to add to that literature.

3 Methodology and Data

For this study, I test the effect of several independent variables on firm clustering within computer and mathematical occupations, including average annual salary of those occupations, as well as the effect of firm clustering on average annual wage. I specifically look at job density within computer and math occupations. Computer and math occupations are defined by a Bureau of Labor Statistics Program (BLS) program called Occupational Employment Statistics (OES) as occupations related to computer and mathematics fields. I chose to study computer and math occupations because social networks and information sharing play an especially important role in the technology industry (Sorenson 2003). All data collected came from two primary sources (OES and Federal Reserve Economic Data (FRED)) and all data analyzed was from 2011-2014 and at the metropolitan area level, meaning each observation was a metropolitan statistical area (MSA). MSAs are defined by the BLS as geographical regions with a relatively high population density and a population of at least 50,000 people. Every MSA has a unique code, called a Core Based Statistical Area (CBSA) code. I chose to analyze 51 MSAs, one from each state, including D.C., with the highest employment of computer and math based occupations from each state to test the independent variables' effect on job density of computer and math occupations. For example, in California, the San Jose MSA has the highest employment of workers with computer and math occupations, therefore it was selected to be used in my data analysis as the MSA for California. This process was used for all 50 states and D.C.

Variables – Causes of Firm Clustering

To measure the causes of firm clustering, the dependent variable used, $jobs1000_{it}$, measures the clustering of firms within computer and mathematical occupations by measuring the number of computer and math occupation jobs per 1000 total jobs (total jobs refers to *all* jobs within the MSA, not just computer and math occupations) within the 51 MSAs mentioned. While this measure does not necessarily reflect the density of firms, I decided to use it as a reasonable measure for the clustering of firms that hire workers specializing in computers and math since finding data on the number of firms that specifically hire employees in the computer science or other tech fields was challenging. I acknowledge that this could potentially make the results less accurate, which will be discussed more in the discussion section of this paper, but it was the closest approximation of firm clustering I could find.

To measure the variables that cause firms to cluster, I tested the significance of five independent variables on firm clustering: wages, total number of computer and math employees in each MSA, real GDP per capita, proximity to universities with good computer science programs, and those university scores. Wages, $amean_{it}$, were measure by average annual wages of employees with computer/math occupations, collected by OES. This variable could be a potential cause of firm clustering because people may move to areas that pay more for their expertise. Total employment, *totempit*, also collected by OES, and is an estimate of total employment in each metropolitan area, excluding self-employment. Real GDP per capita, gdp_{it}, was calculated each year in each of the 51 MSAs as a measure of productivity. I chose to use GDP per capita because it was the most accurate reflection of output when measuring by metropolitan area. Productivity may also cause firm clustering, since productive employees tend to congregate, as concluded by much of the literature in the literature review section. Proximity to universities with good computer science programs, uni_{it}, is a dummy variable, 0 or 1, where 0 means that the MSA does not have a computer science university located within its borders and 1 means it does. I chose to include this variable because it ties into the literature regarding access to resources, such as Puga (2010). Universities with good computer science programs may provide useful resources to firms in the area, in the form of research, information, and even creating more experts in the field. In this case, universities with good computer science programs are defined as universities with a score of 3 or higher, based on a U.S. News survey of academics, such as department heads and directors of graduate studies, in computer science. Scores were measured between 1 and 5, 5 being the best. As an example, Stanford University is located within the San Jose MSA, so the value for the variable uni_{it} within this MSA is 1. The university scores, $score_i$ from 1 to 5 as mentioned, are included as well as to analyze whether higher ranking computer science schools had any effect on computer and math related firm clustering. Using Stanford University as an example again, it has a maximum score of five, so the value for the San Jose MSA variable $score_{it}$ is 5. I also included $score2_{it}$, $score_{it}$ squared, to make the variable more significant. For MSAs that did not contain a university with a score of at least 3, $score_{it}$ and $score2_{it}$ were assigned a value of 0. This was because I consider universities with scores lower than 3 did not have a "good" computer science program, and therefore were not included in the data.

Variables – Impact of Firm Clustering

To test the impact of firm clustering I chose to analyze whether firm clustering ($jobs1000_{it}$) had any effect on wages ($amean_{it}$). I included all the other variables mentioned in this regression to limit omitted variable bias, since they may also have on effect on firm clustering. Total employment could influence wages competition among jobs may decrease or increase wages. GDP per capita could influence wages because it is a measure of productivity and productivity influences wages. Finally, proximity to a good university may affect wages because better universities may produce more productive employees.

I chose to test the impact of firm clustering on wages, as well as vice versa, to see which had the greater effect on the other. Of course, the fact that firm clustering and wages can both impact each other can lead to problems with reverse causality in the regressions, something that will be discussed in the discussion section of this paper. However, I wanted to see which had a greater effect on the other, if any.

Regressions

I ran two separate panel regressions to test the causes and impact of firm clustering:

1. $jobs1000_{it} = b_0 + b_1 amean_{it} + b_2 totemp_{it} + b_3 gdp_{it} + b_4 uni_{it} + b_5 score_{it} + b_6 score2_{it} + \mu_{it} + e_{it}$

2. $amean_{it} = b_0 + b_1 jobs1000_{it} + b_2 totemp_{it} + b_3 gdp_{it} + b_4 uni_{it} + b_5 score_{it} + b_6 score2_{it} + \mu_{it} + e_{it}$

*Note, I use the log of GDP per capita and average annual wage values to scale them since those figures were much higher than the job density figures.

Equation 1 tests the causes of firm clustering. Equation 2 measures the impact of firm clustering on wages within computer and math occupations, with the other variables included as control variables. I decided to test the impact of firm clustering on wages since it is an important measure in the health of the local MSA economies. Each MSA is represented by *i* and each year is represented by *t*.

Summary Statistics

The summary statistics are provided in table 1 (all tables and maps are included in the appendix). One important observation to note is that the mean of job density for computer and math jobs is relatively small. The maximum is much higher than the mean, suggesting that most of the MSA in the dataset have a small density of these jobs. This may skew the results and therefore is worth noting. Similarly, the mean GDP per capita is much closer to the minimum than the maximum, which may again skew results. Also, the range is very high for the total employment, since some of the MSAs in the dataset are much smaller than others. The average annual wages are less skewed, with a more evenly dispersed minimum, average, and maximum. In terms of universities, as can be seen by the mean of the variable, uni_{it}, there are fewer MSAs in the dataset that contain "good" computer science programs located within them than not, which is as expected. Also, the average score is low because if an MSA had a university with a computer science program score lower than 3, the score value for that university was assigned a 0. This could potentially skew the results, but I felt as though a university with a score lower than 3 did not constitute a "good" program.

4 Results

As seen in table 2, average annual wage, total employment, and real GDP per capita all have a significant positive effect on job density. Interesting, access to universities with good computer science programs does not have any significant effect on job density. Also, as expected, the average annual wage for computer and math occupations has a significant positive effect on job density for those occupations since higher wages for computer and math employees would attract those employees. Interestingly, real GDP per capita also has a significant positive effect on job density for computer and math occupations, which suggests that these occupations have a significant impact on local economies. Finally, proximity to a university with a good computer science program has a significant effect on job density. The scores of these universities also have no significant effect on job density.

As seen in table 3, job density does have a significant positive effect on average annual wage. None of the other variables were statistically significant. This result is expected, since previous literature has concluded that employees working in areas that contain a high density of other employees working in the same industry or occupation earn higher wages. For example, Glaeser and Gottlieb describe how one benefit of agglomeration economies is increased wages for employees. This could be due to the larger demand in these areas and the increased competition between firms in these areas. The fact that none of the other variables were statistically significant is interesting, but not entirely unexpected since these variables do not have as direct an influence on wages as job density.

5 Discussion

The results from the regressions ran are mostly as expected; average annual wages, productivity, and total employment have a positive effect on job density, and job density, productivity, and total employment have a positive effect on job density. Beginning with productivity, as per the literature, firms and workers are much more productive in dense urban areas. Therefore, the results in this case are as expected, since increased productivity leads to increased job density. An interesting result is that average annual wages have a significant positive effect on job density and vice versa. This result indicates a cycle that because higher job density increases productivity, it also increases wages, which then attracts more workers, increasing job density, etc.

Proximity to universities with good computer science programs as well as their U.S. news survey scores did not have a significant effect on job density or average annual wages. This is interesting since a big theory behind firm clustering is access not just to physical resources, but also to intellectual resources, such as information. For example, the clustering of tech firms in Silicon Valley may have been a result of Stanford University being in that region. Because of this, I theorized that access to universities with good computer science programs would increase job density in computer and math occupations. However, this was not the case. One reason may be because students do not necessarily reside in towns or cities in which they attend colleges and may move to other areas where there are more opportunities available. Another reason may be the limitation of the data; because the data for universities came from a survey, it may not completely accurately reflect the success of their computer science programs. This will be discussed more in the limitations subsection below.

Limitations

The first limitation of my model is that the use of job density as a measure of firm clustering. This can be misleading since there may be high job density in a region, but few firms hiring those employees specializing in those jobs. Another limitation is the simplicity of the model. I chose a few variables based on the literature I read, but there may be many other causes and impacts of firm clustering not accounted for in this paper. The main variables omitted were socioeconomic variables that may account influence firm clustering. A major theory behind firm clustering is that social networks allow firms to share information with one another. These variables are left out of many mainstream theories regarding firm clustering that only account for measurable variables, such as sharing of physical resources. However, as shown in the literature of Ismalina (2012) and Sorenson (2003), human behavior and cooperation also play a key role in firm clustering. As mentioned, Ismalina described the various foundations of trust required in some firm clusters in Indonesia, which required talking directly to the owners of several firms in the region. However, because these variables are hard to quantify, I was unable to include them in the model.

For the university variables, including proximity to universities with good computer science programs and their scores, because the data collected is based on survey it is susceptible to bias. Although the survey was targeted towards academics specializing in the field of computer science, it is still subjective and certainly not an objective measure of the "goodness" of the universities' programs in the dataset. Also, other factors about the universities were not considered. For example, the number of students and percentage of students majoring in computer science and the size of the university were not taken into consideration. These variables may change the significance of universities with good computer science programs on job density, since the size of the major or university can influence the local economies. For example, a university known for being a tech school, like Stanford, may attract more students interested in entering the tech industry, which may be one of the factors behind the huge tech bubble in Silicon Valley.

Endogeneity may also be a problem in the models due to reverse causality – according to the results, there is a significant positive effect of wages on firm clustering, but also a significant positive effect of firm clustering on wages. Therefore, it is hard to determine causality. It is possible that wages may increase job density, vice versa, or that the two variables work together, meaning that increase job density may increase wages, leading to more density, etc.

<u>Similarities to lek mating</u>

There are many different factors to consider when choosing what firm to work for, such as salary, benefits, work environment, etc. Similarly, there are different factors for females to consider when choosing males, especially in lek mating systems where all they receive are paternal genes. As mentioned in the literature review, Patricelli et al. (2011) compared the female experience in leks to the consumer experience in bazaars, and in the same respect, females and males in leks can be compared to employees and employers, respectively, in firm clustering. There is a major difference because in a lek, females choose males whereas employers hire employees, but the underlying principal is similar; firm clustering creates a labor pool, which is beneficial to employers, and leks gather all the females in one location, which is beneficial to males.

When observing lek mating and firm clustering from a cost/benefit analysis, the similarities are striking. The main benefits of clustering in both phenomena is increased success in firms and males that are successful due to the easy access to resources they need. However, the cost in both cases comes from increased competition. As shown in the results, increasing job density increases average annual wages. This is just one of the higher costs firms must take on when they cluster. In this type of environment, with heavy competition, many firms do not survive. Similarly, in leks, increased competition makes it harder for some males to attract a mate. However, overall it is worth clustering because the benefits outweigh the cost, given the increased productivity of firms in clusters as well as the increased mating success of males in lek arenas (Jiguet et al 2000).

When observing the lek paradox from a cost/benefit analysis, it recalls the firm clustering paradox mentioned by Sorenson (2003) wherein he describes the fact that even though firms that cluster perform consistently worse in the long-run due to increased competition, they still cluster. Similarly, even though females in lek species should only choose males with very specific traits since the paternal genes are the only male investment they receive, genetic variation persists. It is interesting, however, that in both cases firms and females choose the option that seems less beneficial in the long-run because of the low short-run search costs; for firms, search costs are lowered by clustering since resources are much more proximate, and for females that are part of lek species, search costs are lower for the same reason. While there are of course differences beyond search costs, it is interesting that the two phenomena can be related this way and may help explain why firms choose to cluster even if it hurts them in the long-run. If the short-run costs outweigh the long-run benefits, firms will choose to cluster.

Finally, a big similarity is in the clustering patterns, as shown in figures 3 and 4. Figure 3 is a GIS map of job density in San Jose, CA and surrounding MSAs from 2000-2014. Clearly, through the years, computer and math based occupations clustered in San Jose, where the increase in job density is more apparent than in surrounding MSAs. While the job density in some of the MSAs surrounding San Jose has increased over those 14 years, it has increased much more in San Jose. This draws parallels to lek mating, shown in figure 4. These three pictures simulate the clustering of the Sage-grouse lek species into a lek arena based on descriptions of this species' lek mating behavior as described by Aspbury and Gibson (2004). In this species, during the mating seasons, anywhere between 10 and 30 Sage-grouses cluster into small arenas guarded by an alpha male. These arenas are typically around 30 feet in diameter and there can be thousands of arenas within a certain geographic region. When comparing this behavior to the behavior of people and firms, the similarities are striking; in both cases, the sage-grouse males and people working similar occupations cluster into relatively small geographic locations. For example, in Figure 3, it is evident that most of the computer/math occupation clustering happens within the San Jose MSA in California. Similarly, over time, Sage-grouse males congregate into leks formed by alpha males. Across the literature discussed in this paper regarding firm clustering and lek mating, there is strong consensus that firms and workers are much more productive and profitable in dense urban areas and males that cluster nearer to the center of leks, where alpha males root their territories, have much more mating success, meaning they breed with more females. These maps provide a visualization for both types of clustering, and show the similarities in how males and firms cluster to exploit the benefits gained from clustering.

6 Concluding remarks

Overall, according to the results, average annual wages have a significant effect on job density and vice versa. This is expected, since job density is a good indicator of demand for that occupation in each region, with affects the price of labor. It is interesting that none of the other variables had a significant impact on wages, but it may be due to other limitations in the model, as discussed in the discussion section of this paper. It is expected that all the variables had a significant impact on job density, although the impact from most of the variables was small, expect for the impact of universities proximity and score. I do not understand why the impact of the university score on job density is significantly negative; I would expect that MSAs with good computer science programs would increase job density, especially in dense, large urban areas where a lot of these firms are clustered. However, it may be due to the small variance in the scores (between 3 and 5 for MSAs that contained universities with "good" programs).

While the causes and impacts of firm clustering have been widely studied, examining this phenomenon from an evolution economics has not. Using socioeconomic frameworks to provide an evolutionary perspective, as done by Ismalina (2012) when she used a socioeconomic framework to study industry clusters, or comparing economic phenomena to phenomena in other disciplines, as done by Patricelli et al. (2011) when he studied the similarities between lek arenas and bazaars, can provide a different point of view on certain economic topics, one that considers human behavior. Using evolutionary economic models in general can help provide useful insight that more mainstream economic models do not. For example, mapping lek mating arenas and job density and comparing the two provides useful insight into how firms and employees in similar occupations cluster over time, moving towards smaller denser geographic locations, such as computer and math related occupations in the San Jose metropolitan area. Also, because clustering behaviors of firms/people of the same occupation and lek species are similar, these simulations can help predict clustering behavior of firms in different regions.

Further evolutionary economic research into firm clustering will provide newer perspectives on the subject, but I hope to see more research done with evolutionary economic techniques in general. In many economic papers, so many factor are missed by leaving out variables that account for social behavior in humans. Of course, evolutionary economics makes many of the same limiting assumptions as other mainstream economic disciplines, but because it usually takes more of the irrational human behavior into account, it produces more accurate result on the ongoing dynamic changes within the economy. I hope that this paper inspires further research in this discipline.

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Appendix:

Table 1: Summary statistics

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Job density	306	33.43	16.90	10.64	116.43
Total employment	306	34424.67	40505.20	480	191060
Average annual wage	306	78605.88	11845.53	48810	123910
Real GDP per capita	306	54694.58	10571.06	38480	105482
University	306	0.24	0.43	0	1
Score	306	0.93	1.69	0	5
Score^2	306	3.70	7.11	0	25

Table 2: Causes of firm clustering

Dependent Variable: Job density	**Coefficients (Standard Error)**
Average annual wage (log)	34.32726*** (7.594235)

Total employment	0.0002667*** (0.000027)
Real GDP per capita (log)	24.96141*** (9.319129)
University	-9.130077 (16.39873)
Score	3.937096 (8.215881)
Score^2	0.4244111 (1.004358)

*statistically significant at the 10% confidence level or more
**statistically significant at the 5% confidence level or more
***statistically significant at the 1% confidence level or more

Table 3. Impact of firm clustering on annual wages

Dependent Variable: Average annual wage (log)	**Coefficients (Standard Error)**
Job density	0.0018872*** (0.0003163)
Total employment	0.00000055*** (0.00000014)
Real GDP per capita (log)	0.1828062*** (0.058574)
University	0.0320122 (0.1285357)
Score	-0.0194096 (0.0644246)
Score^2	0.0028076 (0.0078797)

*statistically significant at the 10% confidence level or more
**statistically significant at the 5% confidence level or more
***statistically significant at the 1% confidence level or more

Figure 1: Dots represent job density and shaded regions represent MSAs. Darker regions represent MSAs with higher average annual wages for math and computer occupations

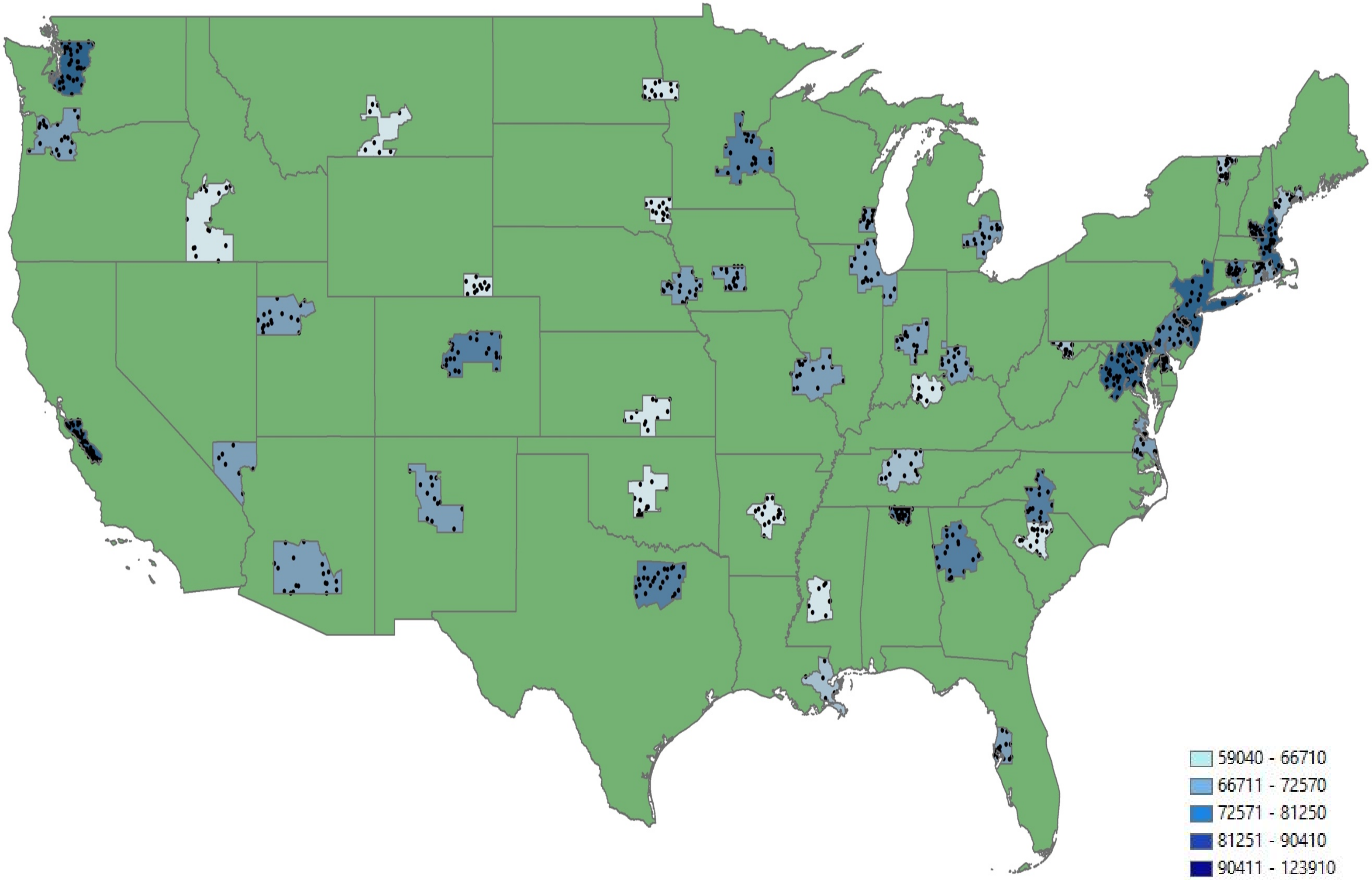


Figure 2: Dots represent job density and shaded regions represent MSAs. Darker regions represent MSAs with a higher real GDP per capita

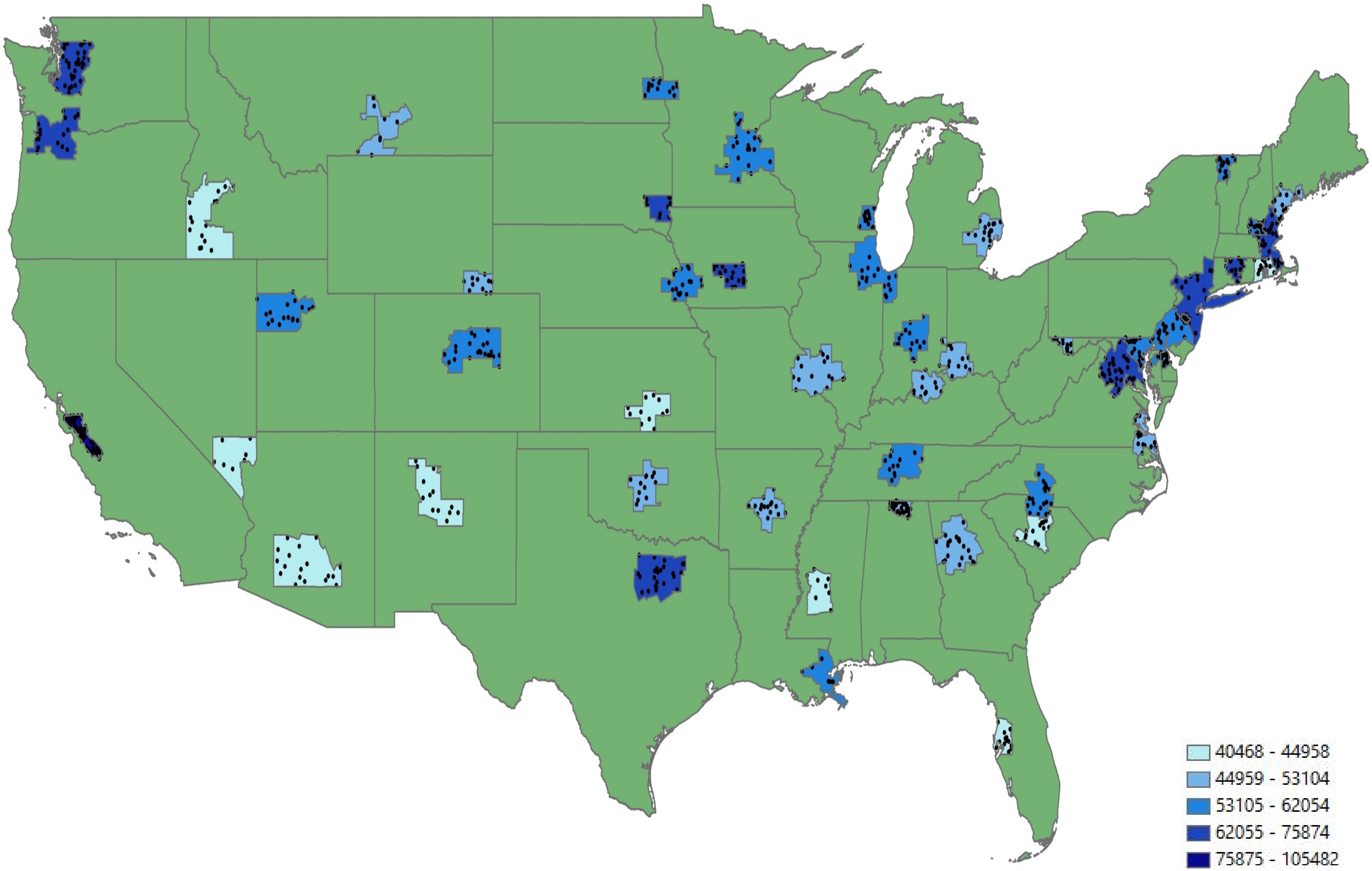
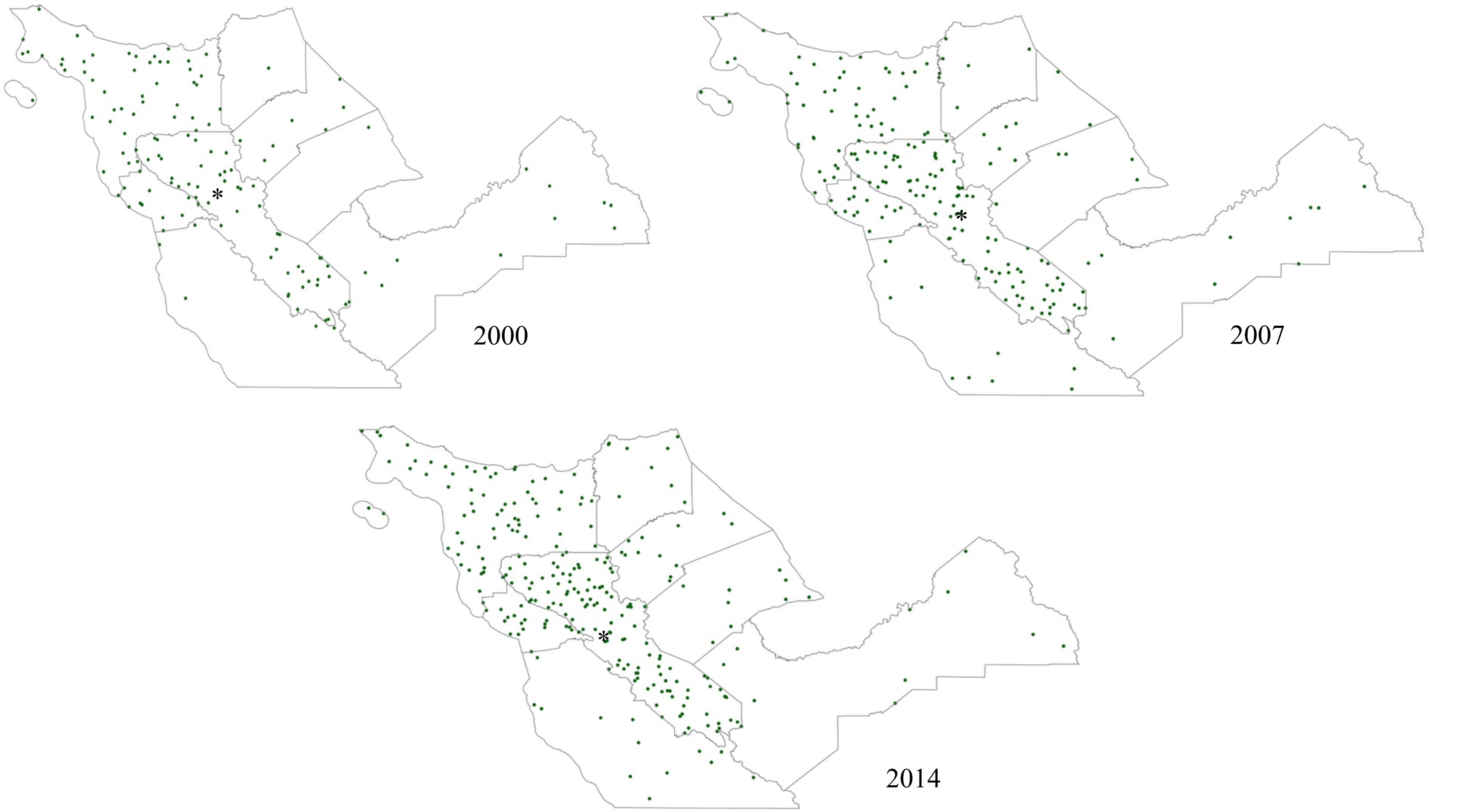
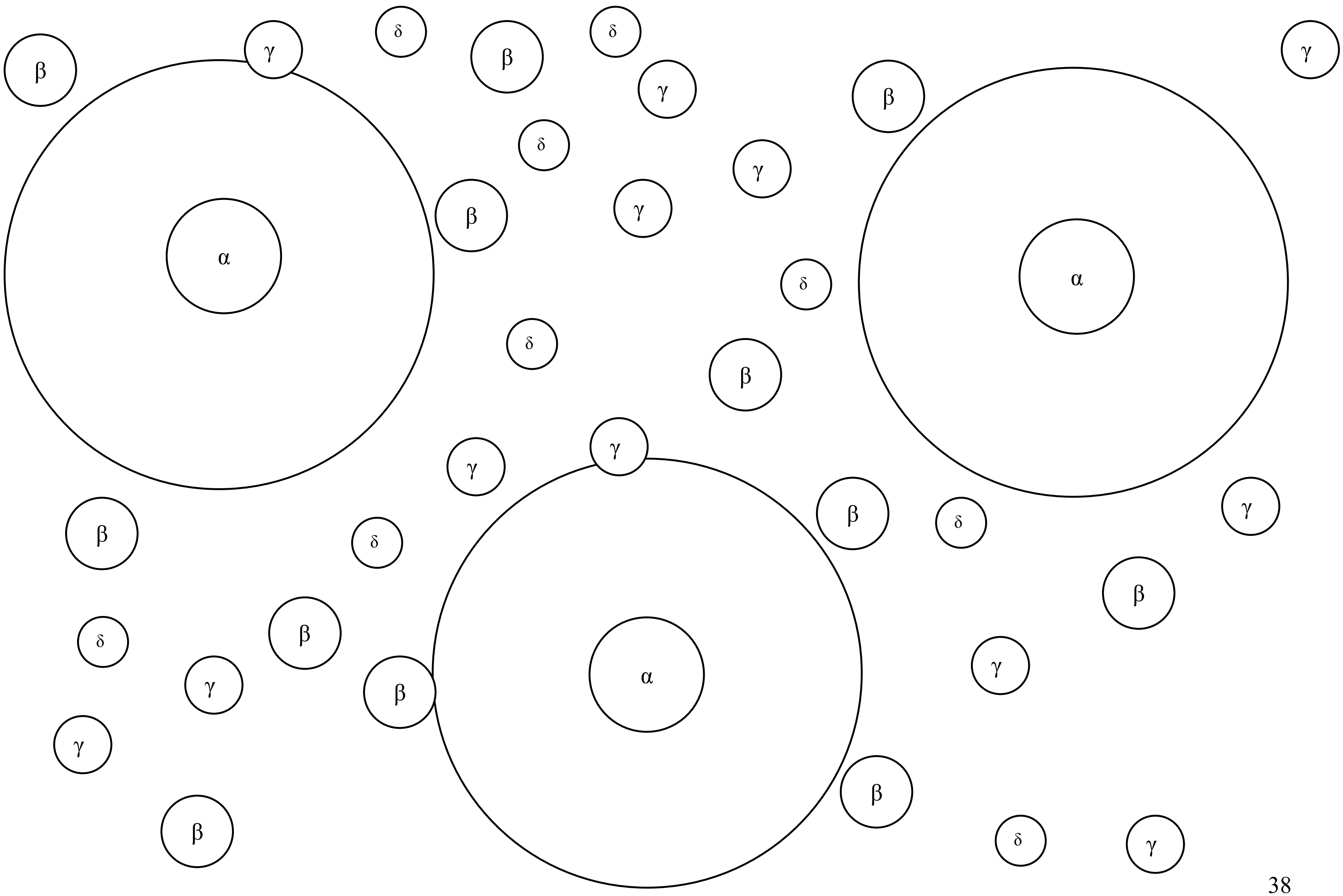


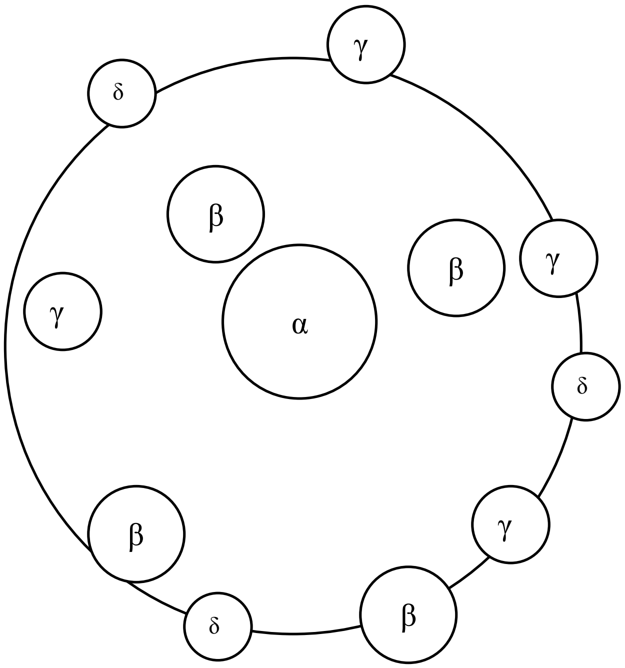
Figure 3: Job density in the San Jose MSA, CA and surrounding MSAs from 2000-2014.



*Marks San Jose MSA

Figure 4: The next three images simulate the typical process of clustering of Sage-grouse males into lek arenas. Alpha males are in the center of a lek arena, guarding their territory, and males of lesser status congregate into the arena to help the alpha with mating displays. These images were created using Microsoft word shapes.

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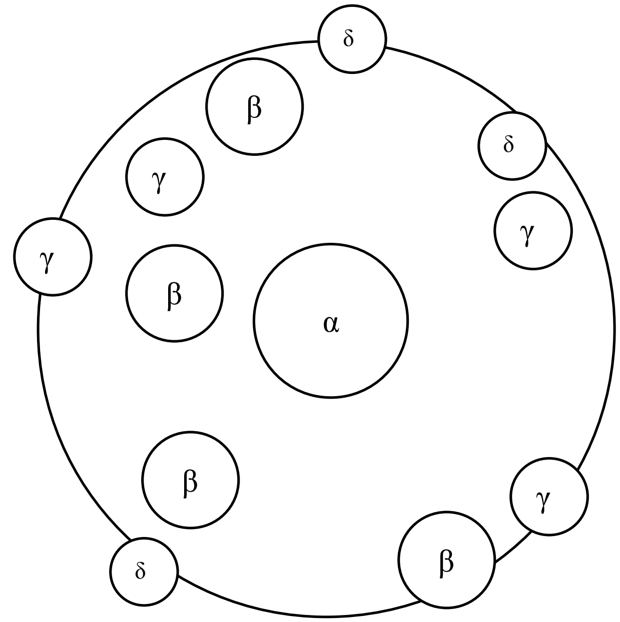
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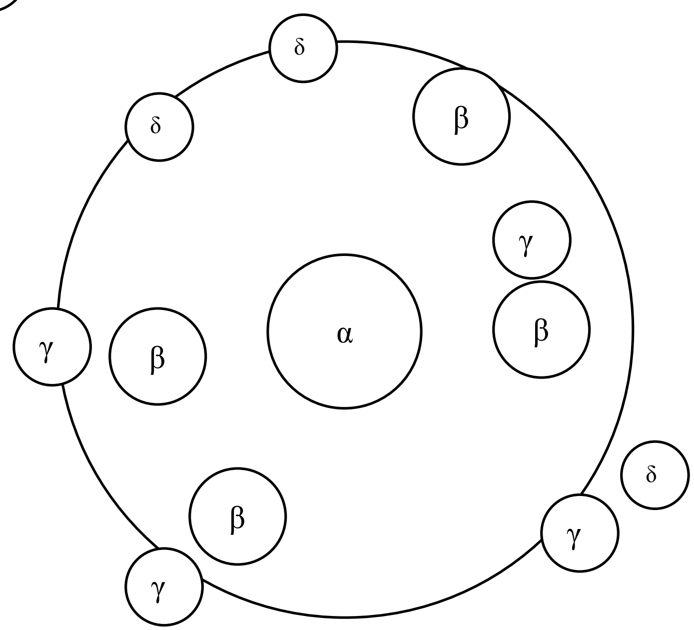
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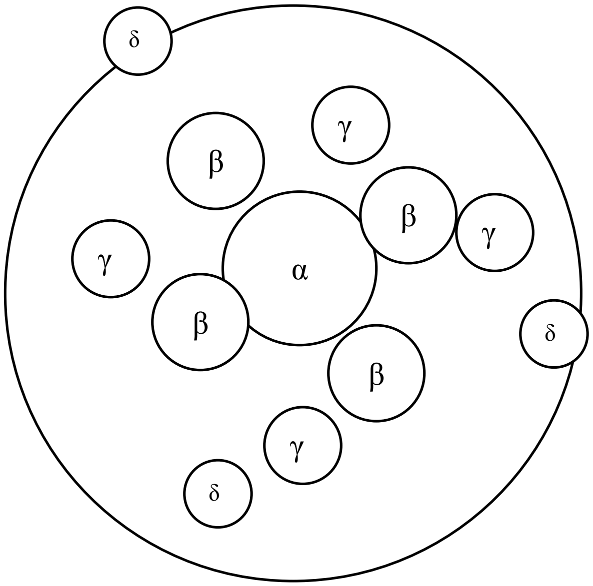
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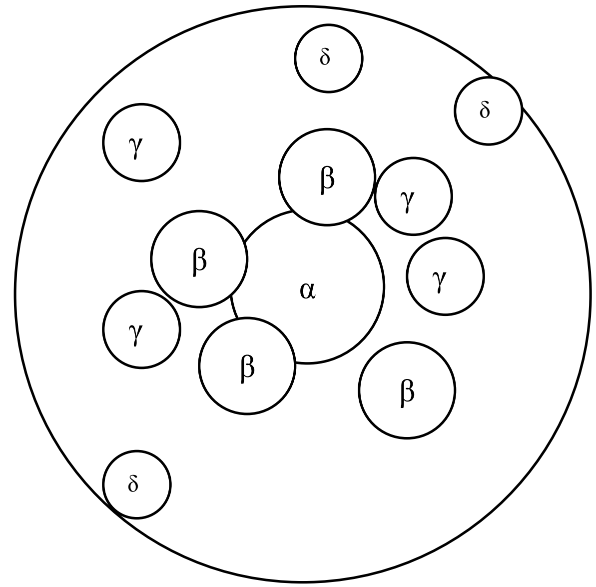
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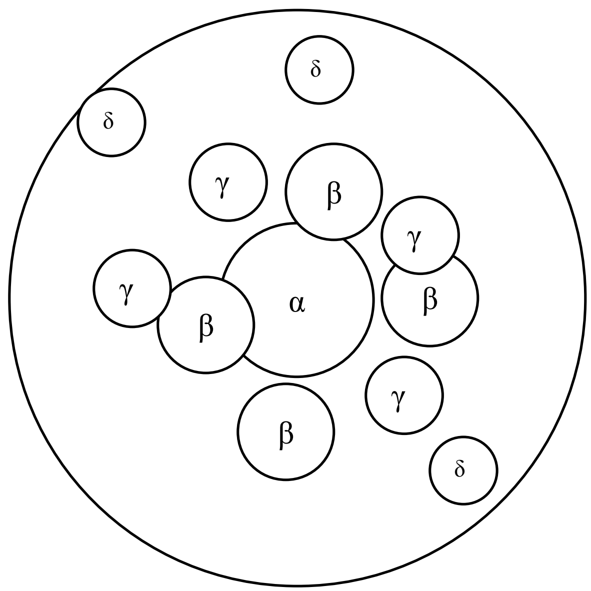
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