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THE ECONOMIC RESEARCH ORGANIZATION AT THE UNIVERSITY OF HAWAI'I

UHERO REPORT

A New Perspective on Hawaii's Economy: Understanding the Role of Clusters

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THE ECONOMIC RESEARCH ORGANIZATION
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EXECUTIVE SUMMARY

A cluster is a regional concentration of related industries connected by employee skills, technology, shared sources of supply or demand, and/or other inter-industry linkages. They arise because firms can benefit from being geographically close to one another. Simply put, proximity reduces transportation costs for products, labor, and ideas (Glaeser and Gottlieb, 2009). Spatial clustering of economic activity is often a defining characteristic of regions. To better understand Hawaii's economy and prospects for growth, we document Hawaii's economic clusters at the state and county level and make comparisons to other US counties with similar characteristics.[1]

We focus on clusters of traded industries, that is, those that produce goods and services for sale nationally or globally rather than primarily for local consumption. Our focus is motivated by research that finds important positive connections between the strength of a region's traded clusters and the growth of the region's establishments, employment, patents, and wages.[2]

In 2014, 37% of Hawaii's traded employment was in strong traded clusters, ranking it 25th among all states. The typical state has ten strong traded clusters. In contrast, Hawaii has only three. The Hospitality and Tourism cluster is by far the largest and strongest of Hawaii's traded clusters, with more than 55,000 jobs in 2014. Outside of Hospitality and Tourism, the remaining two strong traded clusters employ fewer than 4,000 workers. For each of Hawaii's counties, the basic picture is of a large, strong Hospitality and Tourism cluster and a handful of other small traded clusters.

Honolulu has nine strong traded clusters employing 57% of total traded employment, ranking it 79th out of 3,147 counties nationwide. While Honolulu's Hospitality and Tourism cluster is clearly dominant in terms of employment (26,000), it lost more than 1,000 jobs between 1998 and 2014. Honolulu's fastest growing traded cluster is the Education and Knowledge Creation cluster, with nearly 70% employment growth over the same period. The Education and Knowledge Creation cluster is a strong traded cluster. The cluster's location quotient, a measure of relative concentration, is greater than one, so employment in the cluster is more concentrated in Honolulu county than in the average county nation-wide.[2] In contrast, many of Honolulu's other "traded clusters" such as Business Services, Distribution and Electronic Commerce, Financial Services, Marketing Design and Publishing, and Construction Products and Services have location quotients well below one, so employment in these clusters is less concentrated in Honolulu county than in the average county nation-wide.

In 2014, the average Honolulu County traded cluster wage of $41,739, was almost $20,000 less than the US average of $61,568. This is partially due to the mix of clusters in Honolulu County. The majority of traded employment is in the Hospitality and Tourism cluster with an average wage of just over $38,000. It could also be in part due to what urban economists think of as "locational equilibrium." In Hawaii this has been referred to as the "price of paradise" – that residents of Hawaii receive significant lifestyle, cultural and other non-pecuniary benefits as a form of compensation for living and working in Hawaii.

Compared to Oahu, the Hospitality and Tourism cluster is much more concentrated on Maui, Kauai, and Hawaii County, with location quotients of 9.5, 8.5, and 7.0, respectively. In other words, Hawaii's county Hospitality and Tourism clusters are at least seven times more concentrated than in the average U.S. county. The Hospitality and

1 We use the benchmark cluster definitions and data from the U.S. Cluster Mapping Project (UCMP), see http://clustermapping.us

2 We rely on the UCMP definitions of traded clusters and criteria for "strong" clusters. A cluster location quotient is defined as the share of total regional employment in a specific regional cluster divided by the share of total US employment in that cluster. A strong cluster is one with a location quotient greater than one, with cluster employment in the top 25% when measured across all regions, a share of national cluster employment greater than the 25th percentile, and a share of national cluster establishments greater than the 25th percentile.

Tourism cluster in all three counties grew employment over the 1998-2014 sample period. Outside of the Hospitality and Tourism cluster, the remaining strong clusters employed a total of 1,000 workers in Maui, 240 in Hawaii, and 215 in Kauai County. Yet because of the strength of the Hospitality and Tourism cluster, all three counties rank in the top 3% nationwide on overall cluster strength— 43rd, 83rd, and 67th out of 3,147 counties respectively.

From 1998 to 2014, the Education and Knowledge Creation cluster was the fastest growing traded cluster in Kauai and Honolulu counties, and the second fastest growing traded cluster in Hawaii County. The Education and Knowledge Creation cluster also pays the highest wage of all clusters in Hawaii County, and its Research Organizations subcluster generally pays wages near the very top of traded cluster wages statewide.

The average traded cluster wage for each of Hawaii's four counties is $20,000 to $30,000 less than the US average "traded" cluster wage. These relatively low wages are due to the mix of clusters, i.e. the dominance of the relatively low wage Hospitality and Tourism cluster, as well as the tendency of Hawaii's traded clusters to be relatively small and evidently focused more on the local market than would be expected nationally.

The relatively small size and geographic remoteness of Hawaii's counties contributes to the lack of strong traded clusters outside of tourism. This is evident when comparing Honolulu County with five US counties based on the importance of Department of Defense spending. Honolulu tends to see most defense spending concentrated in base operations and maintenance. Because such spending is closely tied to the size of the military presence in the state, many of the largest Department of Defense contracts go to firms that are classified as part of local, not traded clusters. Unlike San Diego and other counties that are more concentrated in defense related research and development and manufacturing, Honolulu's distance from other markets, and high transportation and energy costs help to explain its dearth of manufacturing activity and the lack of defense related research and development clusters.

We describe the nascent Hawaii Energy Innovation cluster, but cannot make national comparisons because it is not part of the US Cluster Mapping Project benchmark definitions we use for this report. Innovation around renewable energy in Hawaii is occurring across a number of industries that are part of both the Education and Knowledge Creation cluster and the large Business Services cluster. Though Hawaii does not yet have a strong Energy Innovation cluster, it does have many promising characteristics that contribute to "competitiveness".

Though the literature on cluster development offers few salient policy recommendations, perhaps the most important is that policy should not aim to choose among clusters or individual industries but should support the upgrading of all clusters present in a region. Government has a role as a convener of cluster participants, and this is already happening in Hawaii. Identifying common needs between existing clusters, for example related to shared infrastructure and services, is likely a fruitful next step. A policy of upgrading all clusters in a region is consistent with the government's role in providing high quality public goods and services. In a world where people, ideas, and capital flow freely—yet location matters more than ever—maintaining the highest quality transportation and communication infrastructure, among others, is critical.

I. INTRODUCTION

In 2005 Thomas Friedman argued that the convergence of high-speed telecommunications, computing power, and workflow software was "flattening" the world. In other words, these forces were leveling the playing field so that location was becoming irrelevant. This notion flies in the face of a vast economic geography literature showing that economic activity clusters in a relatively small number of regions. Or in the words of Joseph Stiglitz, "[n]ot only is the world not flat: in many ways it is getting less flat" (Stiglitz, 2006, pp. 56-7). Agglomeration economies cause productivity to rise with density and lead to spatial clustering of economic activity. Simply put, proximity reduces transportation costs for products, labor, and ideas (Glaeser and Gottlieb, 2009). The resulting economies of scale and spillover effects make the spatial clustering of economic activity a defining characteristic of regions. Understanding a region's clusters—groups of industries closely related by skill, technology, supply, demand, and/or other linkages—is an important first step in understanding its economic strengths, weaknesses, and potential for growth.

This report summarizes a growing body of research that explains differences in regional patterns of economic activity through the lens of clusters. Our aim is to better understand Hawaii's economy and the potential to strengthen existing clusters as an economic development strategy. Using benchmark cluster definitions and data from the U.S. Cluster Mapping Project (UCMP),[3] we document Hawaii's economic clusters at the state and county level and make comparisons to other US counties with similar characteristics. We compare Honolulu County to US counties with similar population size and concentration of military personnel and spending. We do this because military spending and personnel are not directly measured in the UCMP data. This could distort comparisons that do not control for the dominant role federal spending plays, particularly in Honolulu where the majority of Hawaii based troops are stationed.[4] We then compare Maui County to US counties of similar size and specialization in the Hospitality and Tourism cluster (HTC). We do this because Maui County is more specialized in tourism than any other county in the state. While military and tourism are particularly large sectors in Hawaii, both are unlikely to contribute significantly to economic growth in coming decades. In contrast, Hawaii's rapidly growing Education and Knowledge Creation cluster (EKCC) may be a source of economic diversification and growth. We describe the current state of Hawaii's EKCC and the potential for growth in the area of renewable energy research and development.

This report is organized as follows. Section II presents an overview of the economic forces that lead to agglomeration, economic growth, and innovation. Section III presents benchmark cluster data for Hawaii's four counties. Section IV presents county comparisons for tourism and military spending. Section V discusses Hawaii's Education and Knowledge creation cluster and Section VI describes Hawaii's nascent Energy Innovation cluster. Section VII provides discussion and concluding remarks.

3 See http://clustermapping.us

4 UCMP clusters are defined using data on private business establishments and private non-farm employment. While government employment and military personnel are not counted in UCMP data, Department of Defense (DOD) spending in a regional economy will show up through its impact on the mix and strength of clusters, particularly in regions where DOD spending is a dominant share of total economic activity.

II. UNDERSTANDING THE FORCES BEHIND ECONOMIC CLUSTERS

WHAT IS AN ECONOMIC CLUSTER?

A cluster is a group of interconnected companies, intermediate suppliers and service providers that choose to locate in close geographic proximity. While clusters are often defined by a grouping of industries, they also include government agencies and other institutions that provide specialized training and education, information, research, and technical support. Clusters exist in all types of economies. They emerge naturally when economic activities in a set of related industries in a given location reach critical mass — so that local linkages begin to impact the performance of companies, and opportunities for local collaboration among firms and other organizations arise. The strength of clusters play a fundamental role in driving regional economic growth by encouraging higher rates of job growth, wage growth, new business formation, and innovation in the regions in which they are located.

At first blush, co-location seems counter to what we know about firm-level competition. As additional firms enter an industry, competition or congestion eventually leads to declining returns—a phenomenon known as convergence. However, even after controlling for convergence effects within industries, Delgado, Porter and Stern (2012) find strong positive spillover effects from co-location (i.e. agglomeration effects). Agglomeration economies occur because firms can: 1) share intermediate inputs, 2) share ideas, and 3) benefit from deep labor pools and better labor matching. When agglomeration economies occur within a single industry, they are referred to as "localization economies," and tend to lead to cities that are highly specialized. When they occur within multiple industries, they are referred to as "urbanization economies" and lead to cities with a greater diversity of industries.

An example of localization economies is the movie industry in Los Angeles. "Hollywood" is an area in which strong clustering has occurred within largely one industry. Other well-known examples include Silicon Valley for high-technology companies, Boston for its biomedical industry, and New York City for its financial services. Urbanization economies, on the other hand, lead to cities with more diversity because the presence of firms in one industry attracts firms from other industries. San Diego provides an example of a regional economy with multiple specialties, including Hospitality and Tourism, Aerospace and Defense, Biopharmaceuticals, Communication Equipment and Services, and Recreational Goods Manufacturing. Although localization and urbanization economies have different impacts on the scope and scale of jobs available to residents of a city, the economic forces underlying these two forms of agglomeration economies are similar.

PROXIMITY ALLOWS FOR THE SHARING OF INPUTS

Firms often locate close to one another to share the products of a firm that supplies intermediate inputs. Back to the example of the movie industry in Los Angeles, this could include sharing of movie sets, equipment, or even specialized legal services. On the flip side, by having more buyers for their product, the intermediate firm benefits from economies of scale and so do their buyers. In other words, the more they produce, the more efficient they become. There is a particular benefit for products that do best with face-to-face interaction (O'Sullivan, 2012, p. 48). In addition, proximity allows for spillover effects between firms. Take for example, activities like advertising and marketing. If a hotel chain pays for advertisements to travel to Hawaii, other hotels and tourism services in Hawaii may also benefit.

PROXIMITY ALLOWS FOR THE SHARING AND MATCHING OF LABOR

Agglomeration economies also occur because of both labor sharing and better matching of skills when firms cluster. When labor is shared across like firms, labor can be absorbed at the cluster level, as some firms contract while others expand (O'Sullivan, 2012, p. 52). Having a cluster of firms makes it is more likely that out-of-work employees find work quickly nearby, because other firms are looking for workers with similar skills. The gains from clustering are

highest for firms that rely on workers with similar skills but experience a variety of external shocks or different cycles in their demand for labor (Glaeser and Gottlieb, 2009). Co-location of firms and industries also sends stronger signals about the skills that are most valued within the cluster leading to a better matching of workers and jobs. The labor market response to these signals then leads to a wider selection of well-matched applicants and creates efficiencies because appropriate skill matching decreases training costs and increases productivity. And, the existence of large numbers of firms with similar labor requirements allows for greater labor specialization because of the increase in inter and intra-firm job ladders.

PROXIMITY CREATES OPPORTUNITIES TO SHARE KNOWLEDGE

An important attraction of urban environments is their role as the cornerstone of innovation and ideas (Jacobs, 1969). While the theoretical implications of cluster-driven knowledge spillovers are difficult to measure directly, there is strong evidence from research that uses patents as a proxy for knowledge and innovation. For example, Jaffe et al. (1993) found that patents are more likely to cite prior patents that are geographically close. Delgado, Porter and Stern (2010, 2014) find that the presence of a strong economic cluster within a region can increase the growth of start-ups and patenting activity. Interestingly, idea-oriented industries and the positive externalities associated with knowledge spillovers are highly localized, as narrow as only a few miles (O'Sullivan, 2012, p. 58).

TRADED VERSUS LOCAL INDUSTRIES

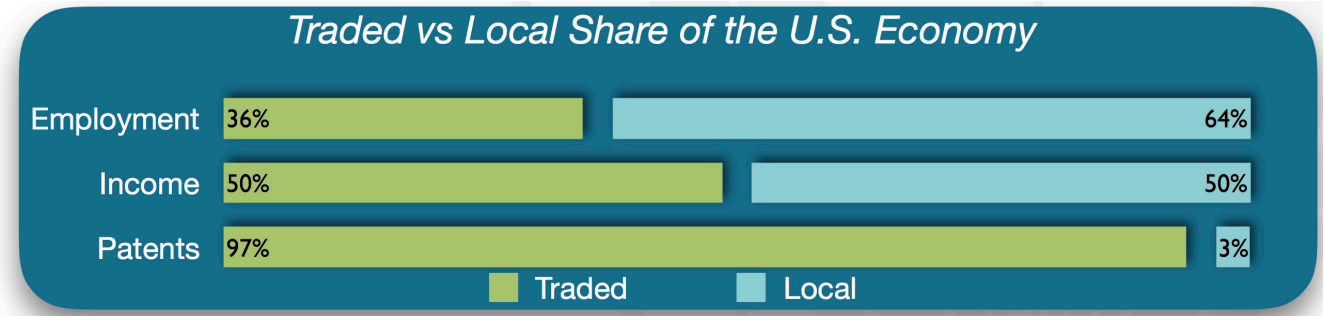
Clusters can occur within and between many types of industries, but their relative importance in driving economic growth is primarily a function of whether they are clusters of traded, local, or resource-based industries. Traded industries are those that are heavily concentrated in only a small subset of geographic areas while selling goods and services to other regions and countries. For example, auto manufacturing is heavily concentrated in a handful of states, but sells its products internationally.

Some traded industries arise due to natural advantages. Resource-based industries can drive co-location. Using U.S. state-level data, Ellison and Glaeser (1999) find that natural advantages drive about 20 percent of measured geographic concentration. They argue that this proportion is likely higher if a wider set of resources is considered. Arguably, Hawaii's HTC and earlier clustering of whaling, sugar and pineapple plantations, and today's astronomy and seed corn research and development are all due to Hawaii's natural advantages and location, at least in their initial presentations. But the existence of natural advantages cannot explain all observed co-location, and the remaining co-location is due to the existence of agglomeration effects.

In contrast to traded industries, local industries are found in all geographic areas and sell primarily to local buyers. For example, local health care is found in virtually all regions providing local services, and only a handful of states exhibit higher than average concentration of health care employment or establishments.

Because of the importance of traded industries for economic growth and innovation, it is important to distinguish between traded and local clusters. Using 2009 data from the US Census County Business Patterns, Delgado, Bryden, and Zyontz (2014) find that employment in traded industries represented 36% of total US employment, but 50% of income. Moreover, traded industries accounted for more than 90% of patenting activity. Research on the role that clusters play in regional development has naturally focused on the strength of traded clusters in fostering growth in and outside of the clusters. Specifically, traded cluster strength[5] is found to have a positive impact on overall regional job growth, average wages, the growth rate of establishments, patenting activity, and entrepreneurship (see among others, Porter, 2003; Delgado, Porter, and Stern, 2010, 2014; Neffke, Henning, and Boschma, 2011).

5 See footnote 7 for a definition of strong clusters.



SOURCE: DELGADO, BRYDEN AND ZYONTZ (2014)

What does this mean for policy?

Regional agglomeration effects drive economic activity and growth (Delgado, Porter, and Stern, 2012). In short, we care about clusters because we care about economic prosperity, and regional economic performance is strongly related to the strength of its clusters. According to Porter (2009), the fundamental goal of regional economic development policy is to increase "competitiveness" so as to increase the standard of living of a region's citizens. In contrast, according to economic theory, the goal for policy is to maximize social welfare by addressing market failures and inefficiencies that may result in sub-optimal levels of clustering. In Porter's work competitiveness seems to be synonymous with both productivity and productivity growth. Here, we will use competitiveness or competitive advantage to mean productivity, a measure of how efficiently the region uses natural, human and physical capital to produce valuable goods and services. Economic development policy has typically focused on improving the general business environment affecting all firms and/or designing industrial policy that benefits individual industries. The latter includes policies aimed at individual firms and groups of workers. There is widespread agreement that the outcomes of industrial targeting have been uneven at best and most often unsuccessful (Markusen, 2004). Supporting individual industries can be distortive and "picking the winners" through subsidies or protectionist policies is rarely successful. "Far too often, government officials have sought to encourage funding in industries or geographic regions where private interest simply was not there. Whether driven by political considerations or hubris, the result has been wasted resources" (Lerner, 2013, p. 69).

In contrast, Porter (2009, p. 2) argues that cluster-based policies are more efficient, minimize distortions to competition, and are better aligned with the nature of competition and should therefore replace industry-level and firm-level policies.[6] Porter suggests several forms of policy, beginning with work to identify existing clusters to better understand their composition, membership, employment, and performance. Another role for government is to convene cluster participants where the private sector has not already done so. Once clusters become well organized through associations or other advocacy groups, government's role is to actively engage cluster participants to understand how policy can facilitate cluster growth. Specifically, by engaging directly with cluster participants, government agencies can better understand which policies are unnecessarily constraining cluster growth and learn about potential for investment in cluster specific assets. Government policy can facilitate the investment in such assets, and because these investments benefit many different firms in different industries, the risk of distorting competition is lower than in the case of industrial policy (Porter, 2009, p. 6). However, focusing of policy solely on clusters deemed "desirable," for example in an effort to replicate the high technology boom in Silicon Valley, are likely to lead to failed outcomes (Markusen and Schrock, 2006; Duranton, 2011). Instead, policymakers should focus on the conditions necessary to

6 See Duranton (2011) for a wide-ranging critique of the cluster literature.

foster productivity and leverage a region's "strong" clusters, regardless of their sector composition (see Porter, 2003; Rodríguez-Clare, 2005, 2007; Ketels and Memedovic, 2008; Delgado, Porter and Stern, 2014). In addition, Markusen (2004) suggests that there is a role for workforce development through occupational targeting within a region's clusters.

While Porter's list of suggested policy interventions may seem less distortionary than directly supporting individual industries, they are also only tenuously related to the market failures that lead to agglomeration economies and clustering. Because clusters emerge from spillover effects, or positive externalities, economic theory tells us that regions economic activities will be less "clustered," or synergistic, than is socially optimal, implying that small policy interventions could have potentially large effects. And, while there is consensus that agglomeration economies exist, the implications for policy are less clear-cut. Because clustering is driven by several different mechanisms, different policy responses are also required. For example, policies to address labor market matching failures are distinct from policies designed to encourage knowledge diffusion. Furthermore, the scale of intervention matters. The fact that knowledge spillovers exist implies an underinvestment in research and education, but given worker mobility, federal support of education may be more effective than regional support (Glaeser and Gottlieb, 2009). However, Duranton (2011) and Chatterji et al. (2013) strongly argue there is little empirical evidence that policy actions around clusters actually lead to the development of clusters. "Even if clusters of entrepreneurship are good for local growth, it is less clear that cities or states have the ability to generate those clusters" (see Chatterji et al., 2013, p. 14).

What little consensus exists within this literature suggests that government policies that choose to elevate certain industries over others have a poor track record. Porter (2009) argues that efforts should prioritize leveraging complementarities across related economic activities. Government should not choose among clusters but should support the upgrading of all clusters present in a region. This argument is akin to supporting a broader business climate, including through the provision of high quality public goods and services like effective transportation systems, public schools, and safety services.

III. HAWAII'S BENCHMARK CLUSTERS

To study Hawaii's clusters, we use a standardized set of benchmark cluster definitions developed by Delgado, Porter, and Stern (2014). They group individual industries into a unique set of clusters that can be used to make systematic comparisons across regions within the U.S. Their first step in developing the benchmark clusters is to classify industries as either traded or local.

Identifying Traded Industries

To select traded industries, Delgado, Bryden and Zyontz (2014) focus on Economic Areas defined by the Bureau of Economic Analysis using 2009 US Census County Business Patterns data on region-industry employment. They use three different criteria to select traded industries from the 1,088 6-digit North American Industry Classification System (NAICS) industries:

1. Is the industry one in which 50% or more of the 179 Economic Areas (EA) have very low employment (10 employees or fewer)?
2. Among Economic Area industries with employment based location quotients (LQ)[7] in the top decile, does the industry have a national employment share of 25% or higher?

7 Location quotients are a measure of specialization used extensively in the cluster literature.
LQ = % of total regional employment in a specific regional industry divided by the % of total US employment in the specific US industry. Or, $LQ_{i,r} = (E_{i,r}/E_r)/(E_{i,US}/E_{US})$, where $E_{i,r}$ is non-farm employment in region r's industry i, E_r is total non-farm employment in region r, and similarly for industry i and total national employment indexed by US.

3. Is the industry one where the difference between the LQ at the 90th percentile and the LQ at the median of all EAs is 1.5 or higher?

Industries meeting all three criteria are classified as traded. Those meeting one or two criteria were examined on a case-by-case basis to identify a total of 778 traded industries. The remaining industries are treated as being local in nature. As will be seen in the discussion of Hawaii's clusters, this approach to characterizing traded versus local industries can fail to capture distinctive regional features of Hawaii's island economy. The result is that some clusters that are traded in the continental US are local clusters in Hawaii.

Characterizing Clusters and Cluster Strength

To identify clusters of traded industries, Delgado, Porter, and Stern (2014) use inter-industry linkages based on co-location patterns, input-output links, and similarities in labor occupations to group the 778 traded industries. By varying parameter choices, cluster functions, and co-location measures, they assign each industry to a single cluster, and score the quality of the resulting industry groupings to evaluate and compare groupings across parameter settings and co-location measures. An important advantage of their clustering algorithm is avoiding the subjective methods used by many region-specific cluster studies. Having standardized measurements of a regions clusters also allows for comparison between regions. See Appendix I for a list of traded clusters, and Appendix II for a more complete, technical explanation of Delgado, Porter, and Stern (2014).

Identifying & Understanding Hawaii's Benchmark Clusters

Here we illustrate and describe the mix, size and strength of Hawaii's benchmark traded clusters.[8] We begin with an overview of clusters at the state level. Figure 1 below plots the LQ of Hawaii's traded clusters against the rate of change in employment in the cluster over the 1998-2014 time period.[9] Strong traded clusters are shaded orange. Recall that we are interested in Hawaii's strong traded clusters because the literature has found important connections between the strength of a region's clusters and the growth of establishments, employment, patents, and wages. One measure of a regions overall cluster strength is the share of total traded employment in strong clusters. In 2014, 36.9% of Hawaii's traded employment was in strong traded clusters ranking it 25th among all states.

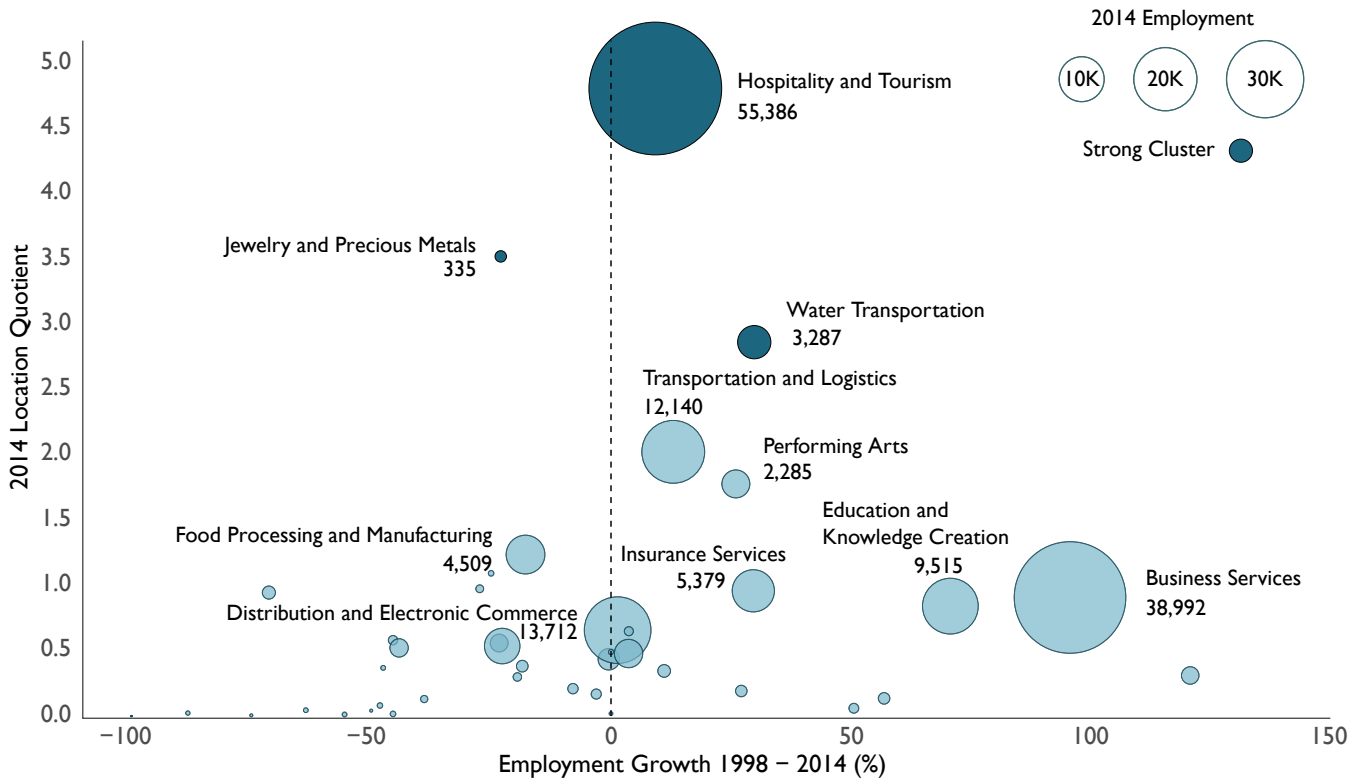
As shown in Figure 1, the state has only three strong traded clusters (whereas the typical state has ten).[10] Outside of the Hospitality and Tourism cluster (HTC), with a LQ of almost 5 and more than 55,000 jobs, the remaining two strong traded clusters are small, employing fewer than 4,000 workers combined. Arguably, some of those jobs should

8 We drop two traded clusters included in the UCMP database—Electric Power Generation and Transmission, and Environmental Services. Both of these clusters consist of industries that tend to be highly geographically concentrated but sell electricity and waste management services across the country. For example, out of 179 Economic Areas, only 52 had Electric Power Generation and Transmission cluster employment LQs above average, and only 95 had LQ above 1.0. Hawaii's Electric Power Generation cluster has a LQ of 5, 11th highest out of all 179 Economic Areas. Clearly Hawaii is not exporting electricity to the rest of the world. And, while most of Hawaii's recycled waste is likely sold to the rest of the world, the vast majority of waste management activity in the state is serving the local market. We do not import and process the waste of other regions.

9 We calculate LQ for a cluster in the same manner as for an individual industry. LQ = % of total regional employment in a specific regional cluster divided by the % of total US employment in the specific US cluster. Or, $LQ_{c,r} = (E_{c,r}/Er)/(E_{c,US}/E_{US})$, where $E_{c,r}$ is non-farm employment in region r's cluster c, E_r is total non-farm employment in region r, and similarly for cluster c and total national employment indexed by US. Here, we use either states or counties as the regional division.

10 The UCMP defines a strong cluster as one with a LQ of cluster employment in the top 25% when measured across all regions. To differentiate marginal cases, they also require a strong cluster to have a LQ greater than one, a share of national cluster employment greater than the 25th percentile, and a share of national cluster establishments greater than the 25th percentile. As discussed in footnote 5, throughout this report we drop two traded clusters included in the UCMP database—Electric Power Generation and Transmission, and Environmental Services.

FIGURE 1. HAWAII'S TRADED CLUSTERS: MOST STRONG TRADED CLUSTERS ARE SMALL



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

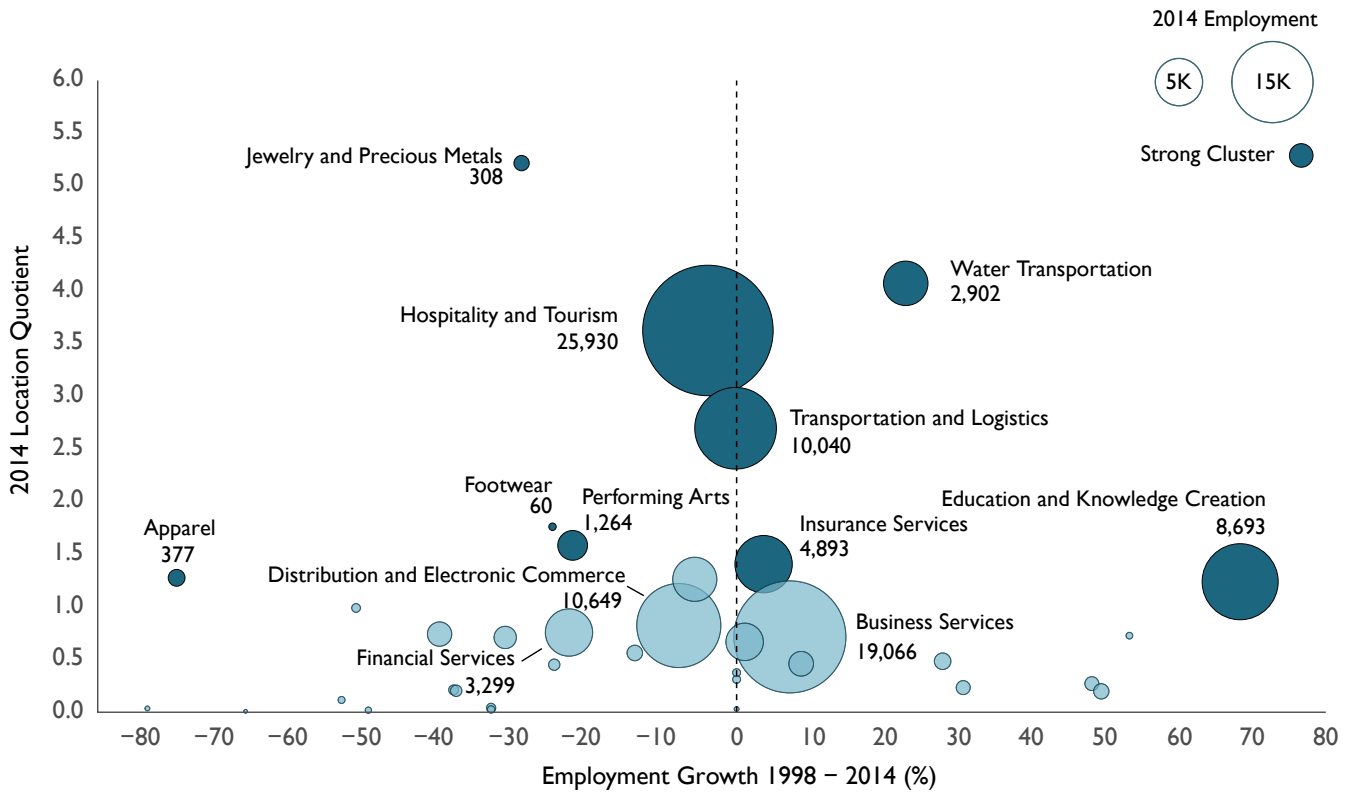
be counted as part of Hawaii's HTC. For example, more than 800 of the jobs in the Water Transportation cluster are part of a subcluster in Water Passenger Transportation, at least part of which includes cruise industry jobs. The other strong traded cluster is the Jewelry and Precious Metals cluster with total employment of 335 workers in 2014. With a LQ of 3.5, the cluster is very highly concentrated but shrinking, shedding 100 jobs since 1998. Of course, Hawaii's economic structure varies widely across counties. Honolulu County is headquarters for the state's transportation networks, state government, and federal defense activities, while the other counties are even more dominated by the HTC.

Honolulu County Cluster Overview

Honolulu has many more strong traded clusters than the state—nine (excluding Electric Power Generation and Transmission and Environmental Services, see footnote 5). Of course, the HTC is the largest in terms of employment, but the remaining eight clusters have a total employment of almost 15,000 workers. And 56.5% of Honolulu's total traded employment are in strong traded clusters ranking Honolulu 79th out of 3,147 counties nationwide. Yet only three of Honolulu's strong traded clusters grew employment over the 1998-2014 period. The Education and Knowledge Creation cluster (EKCC) added the most jobs—3,550, an annual growth rate of 3%, while the Water Transportation cluster added 542 jobs with an annual growth rate of 1%.[11] Transportation and Logistics jobs were unchanged, and the HTC saw a loss of roughly 1,000 jobs over the period.

11 The UCMP data reported here for the EKCC (and all clusters) is for private sector employment and wages. As a result, the EKCC does not include University of Hawaii employees. In Section V below we provided a more detailed look at the EKCC and supplement the UCMP data to include data on public sector University of Hawaii employees.

FIGURE 2. HONOLULU'S TRADED CLUSTERS: NINE STRONG TRADED CLUSTERS

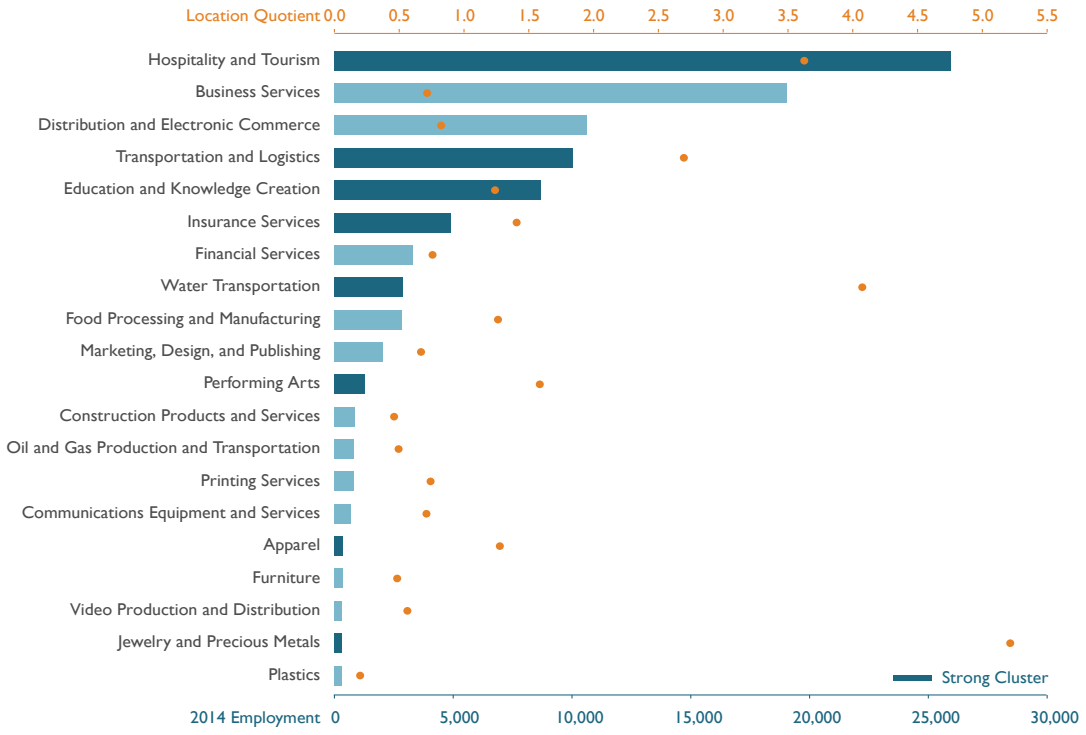


SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

To make it easier to distinguish job counts by LQ for each cluster, the bar charts in Figures 3a and 3b below split the clusters into two groups based on employment. For example, in Figure 3a, Business Services and Distribution and Electronic Commerce are the second and third largest clusters by employment with almost 20,000 and more than 10,000 employees, respectively. Yet both of these clusters have LQ less than one. In other words, both clusters are less concentrated in Honolulu than the average cluster at the county level nationally. This suggests that these clusters may primarily serve the local community as opposed to competing nationally or globally. This is true for many other Honolulu "traded clusters" such as Financial Services, Marketing Design and Publishing, and Construction Products and Services. Figure 3b shows the smaller Honolulu clusters that employ fewer than 300 workers, ranging from Livestock processing the largest by employment with more than 250 jobs, to Metalworking Technology, the smallest for which we have data, with 20 jobs. One of Honolulu's strong traded clusters is in this group of small clusters—Footwear with 80 jobs.

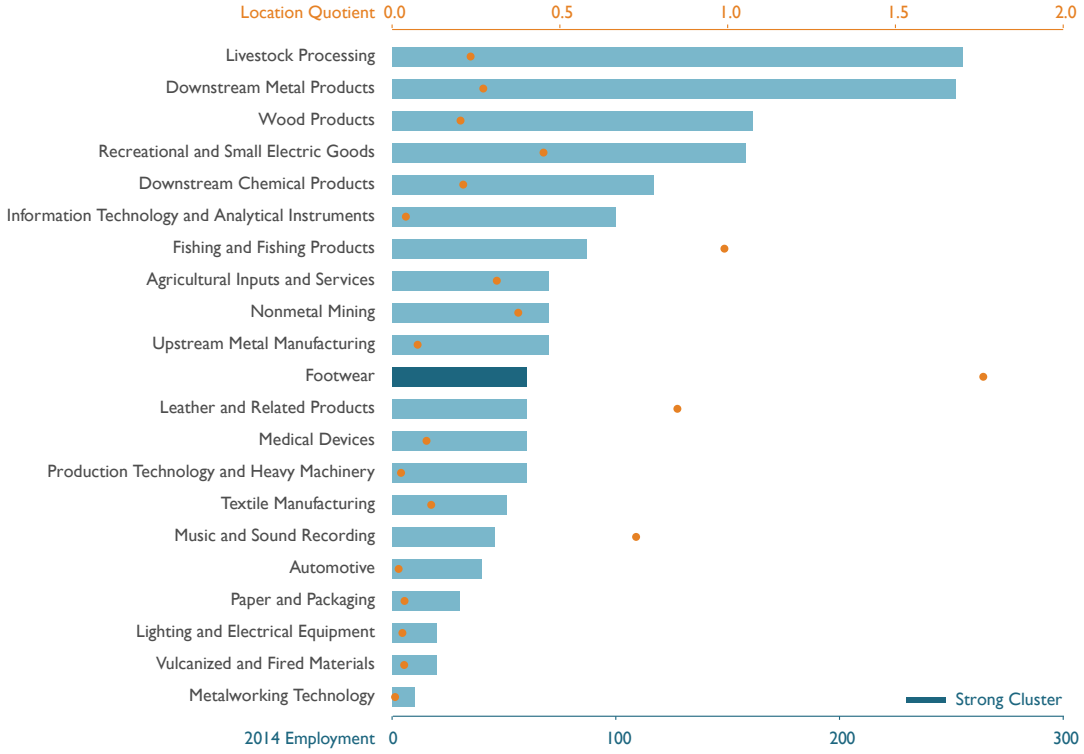
Finally, in Figure 4, we focus on the wages paid by Honolulu's Traded clusters. In 2014, the average Honolulu County traded cluster wage of $41,739, was almost $20,000 less than the US average of $61,568. This could occur because the mix of clusters in Honolulu County is significantly different than that for the US as a whole, with Honolulu dominated by lower wage clusters. Or, it could be that the typical Honolulu County traded cluster is not as productive as the typical traded cluster nationally, and therefore workers tend to earn lower wages. It could also be in part due to what urban economists think of as "locational equilibrium." In Hawaii this has been referred to as the "price of paradise" – that residents of Hawaii receive significant lifestyle, cultural, and other non-pecuniary benefits as a form of compensation for living and working in Hawaii.

FIGURE 3A: HONOLULU'S LARGE TRADED CLUSTERS, 2014 TOTAL EMPLOYMENT AND CLUSTER STRENGTH



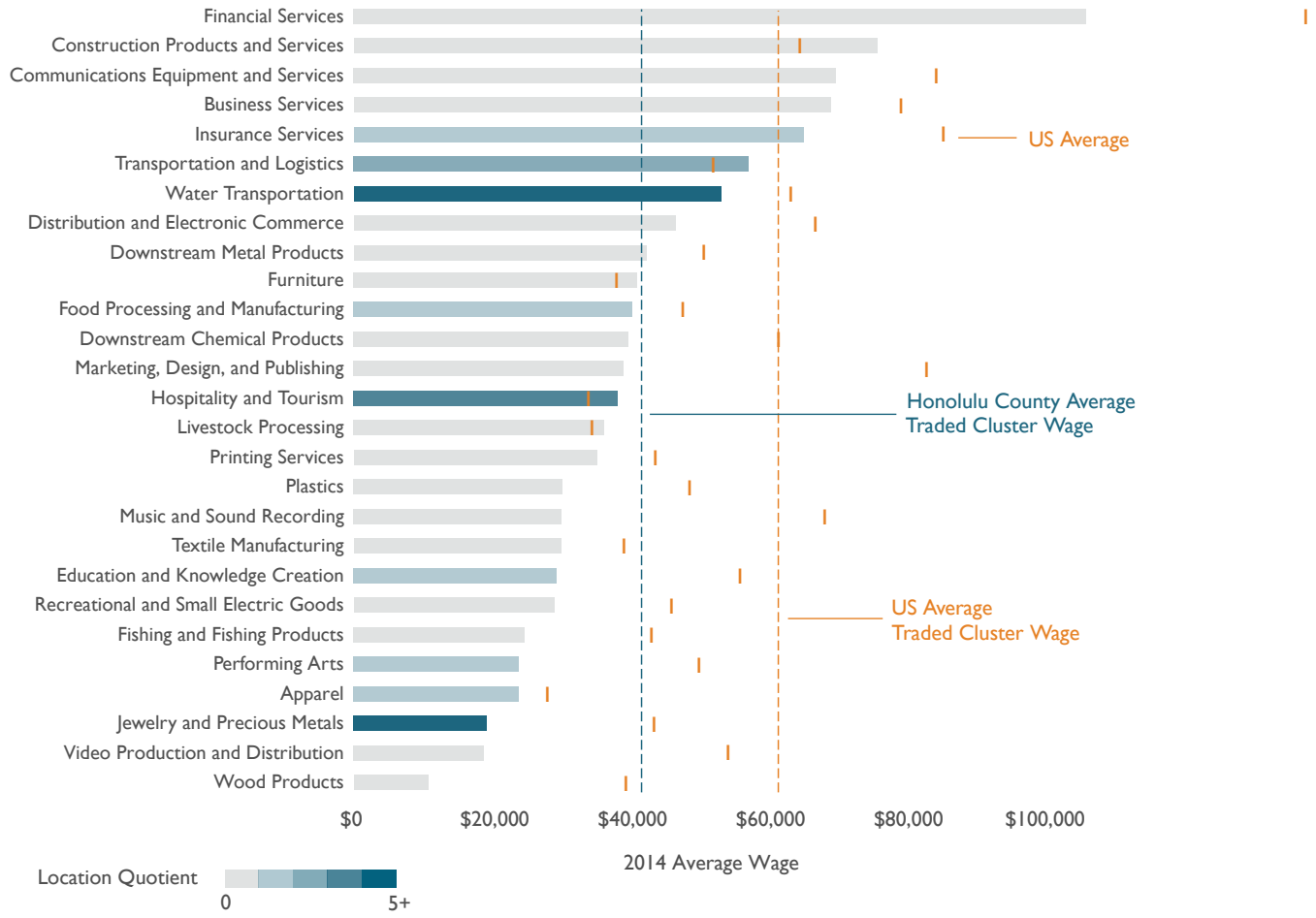
SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 3B: HONOLULU'S SMALL TRADED CLUSTERS, 2014 TOTAL EMPLOYMENT AND CLUSTER STRENGTH



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 4: HONOLULU TRADED CLUSTER WAGES, 2014 AVERAGE WAGE AND LOCATION QUOTIENT VS US WAGE



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

Note that of the twenty-seven traded clusters for which we have unsuppressed wage data for Honolulu, nine of the corresponding clusters at the national level are high wage clusters in the sense that they pay wages that are higher than the US average traded cluster wage. For example, the US average Communication and Equipment Services cluster wage is over $80,000, almost $20,000 higher than the US average traded cluster wage. The remaining eighteen traded clusters in Honolulu are relatively low wage clusters nationally as they pay below average traded cluster wages. In Honolulu County, three of those "low wage" clusters, Transportation and Logistics, Hospitality and Tourism, and Livestock processing, pay wages that are higher than the US average wage for that cluster. Finally, it is important to note that the data on average wages reported by the UCMP is calculated at the industry level by dividing industry payroll by total employment in the industry. To the extent that Hawaii clusters employ a larger number of part time workers than clusters nationwide, cluster wages will be lower in Hawaii even if the average hourly wage for each individual worker is the same in Hawaii as it is nationwide. This will occur when employees are counted multiple times because they work for more than one establishment in the same or different clusters.

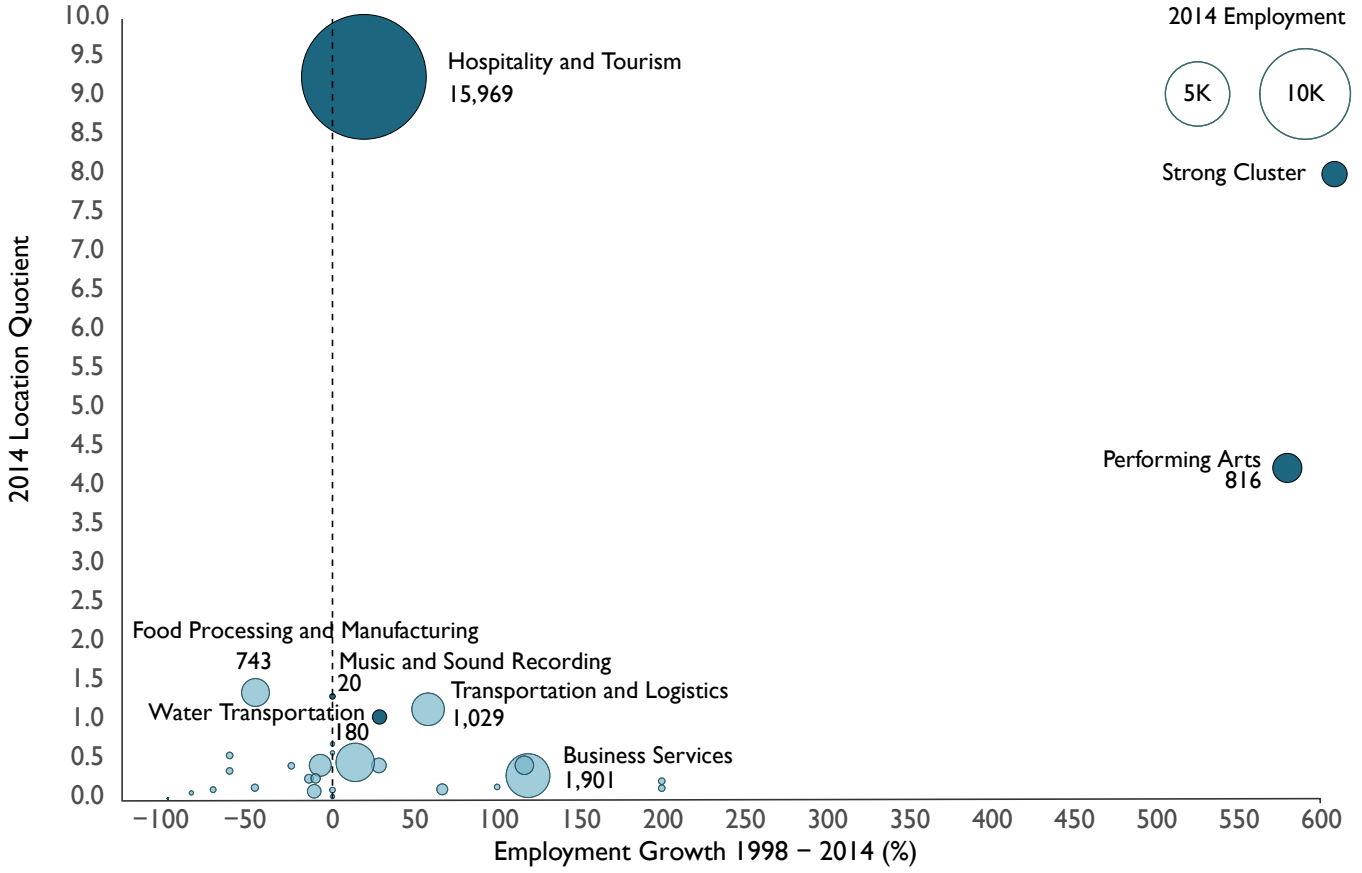
Honolulu's traded employment is predominantly in clusters that are relatively low wage nationally, with the majority of the traded employment in the HTC with an average wage of $38,272. All but four of Honolulu's traded clusters pay below US wages and many have relatively small LQ. This suggests that these clusters primarily serve the local market rather than compete nationally or globally.

Maui County Cluster Overview

The HTC in Maui County employs almost 16,000 workers. With a location quotient of 9.26, the share of Maui County employment in the HTC is more than nine times greater than the average county nationwide. The dominant role of tourism is clear in Figure 5, as is the relatively small size of Maui's remaining three strong traded clusters. Outside of the HTC the remaining three strong clusters have a total employment of 1,000 workers. While Maui County has only four strong traded clusters, because of the large size of the HTC, 71.8% of Maui's total traded employment is in strong clusters giving Maui a cluster strength ranking of 43rd out of 3,147 counties nationwide. Between 1998 and 2014, the Performing Arts Cluster added almost 700 jobs, an annual growth rate of 13%, while the Water Transportation Cluster and the HTC grew at an annual rate less than 2%, and Music Sound Recording did not grow at all.

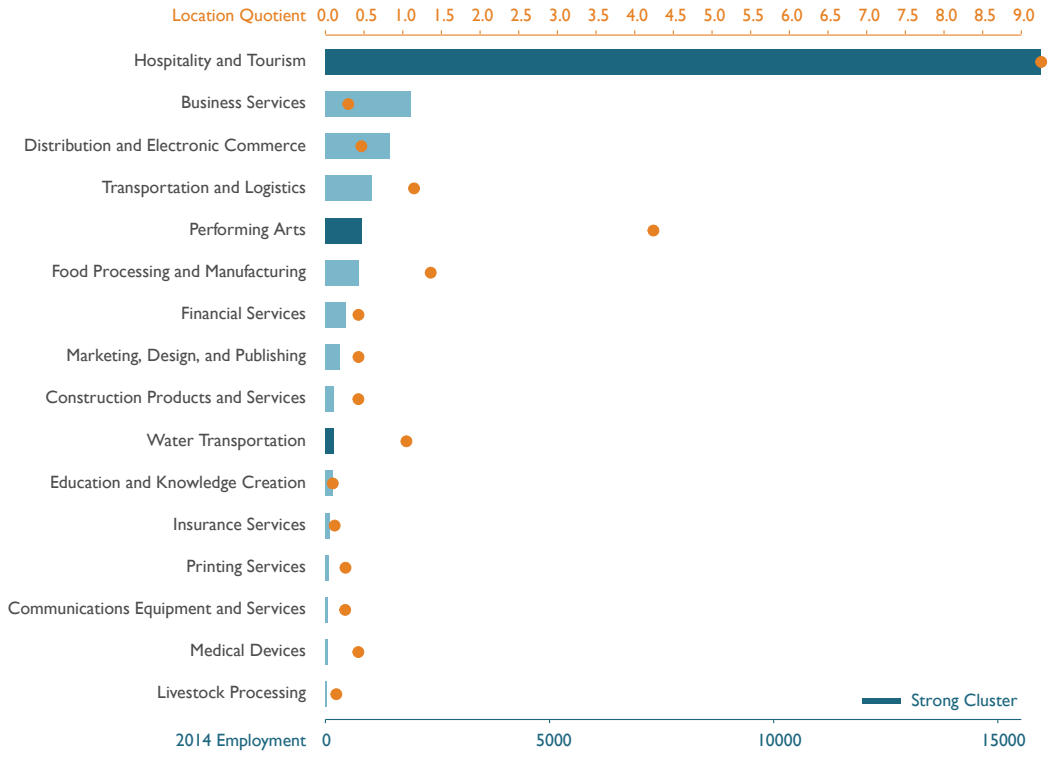
The bar charts in Figures 6a and 6b below split the clusters into two groups to make it easier to read the job counts and compare them to the LQ for each cluster. For example, just like Honolulu County, the Business Services and Distribution and Electronic Commerce are the second and third largest clusters by employment with almost 2,000 and 1,500 employees, respectively. Yet both of these clusters have LQ at or below 0.5. In other words, both clusters are at most half as concentrated in Maui as the average cluster at the county level nationally. Again, this suggests that these clusters may primarily serve the local market. In contrast, Transportation and Logistics, Performing Arts, and

FIGURE 5: MAUI COUNTY TRADED CLUSTERS ONE LARGE, STRONG TRADED CLUSTER



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 6A: MAUI LARGE TRADED CLUSTERS, 2014 TOTAL EMPLOYMENT AND CLUSTER STRENGTH

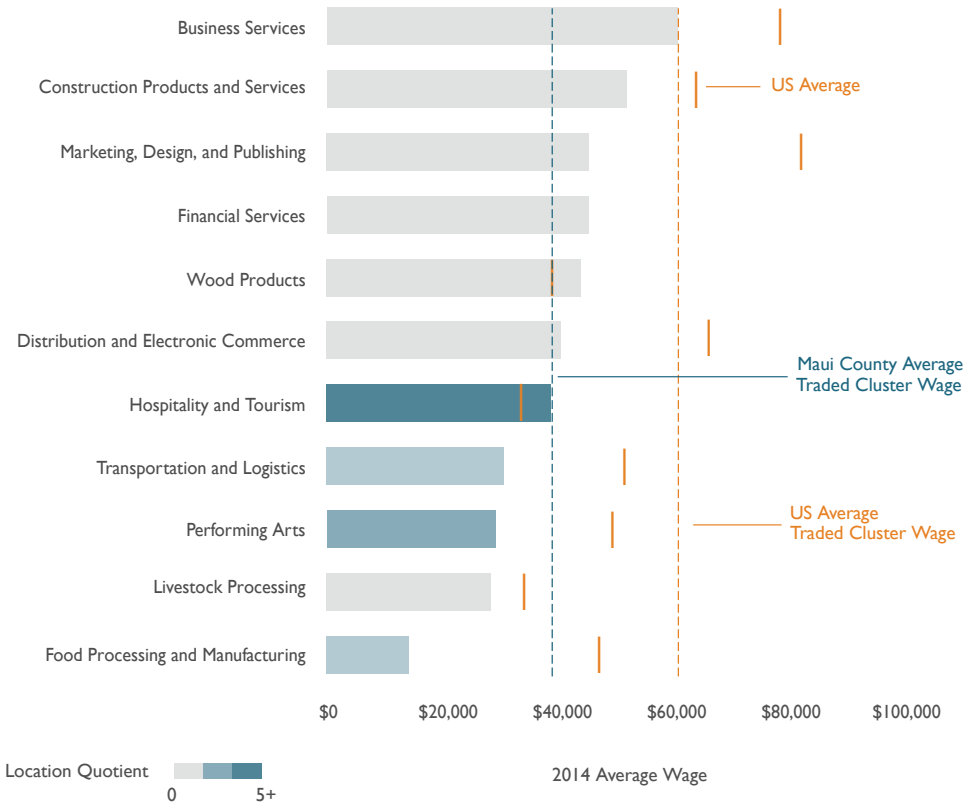


SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 6B: MAUI SMALL TRADED CLUSTERS, 2014 TOTAL EMPLOYMENT AND CLUSTER STRENGTH

SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 7: MAUI TRADED CLUSTER WAGES, 2014 AVERAGE WAGE AND LOCATION QUOTIENT VS US WAGE



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

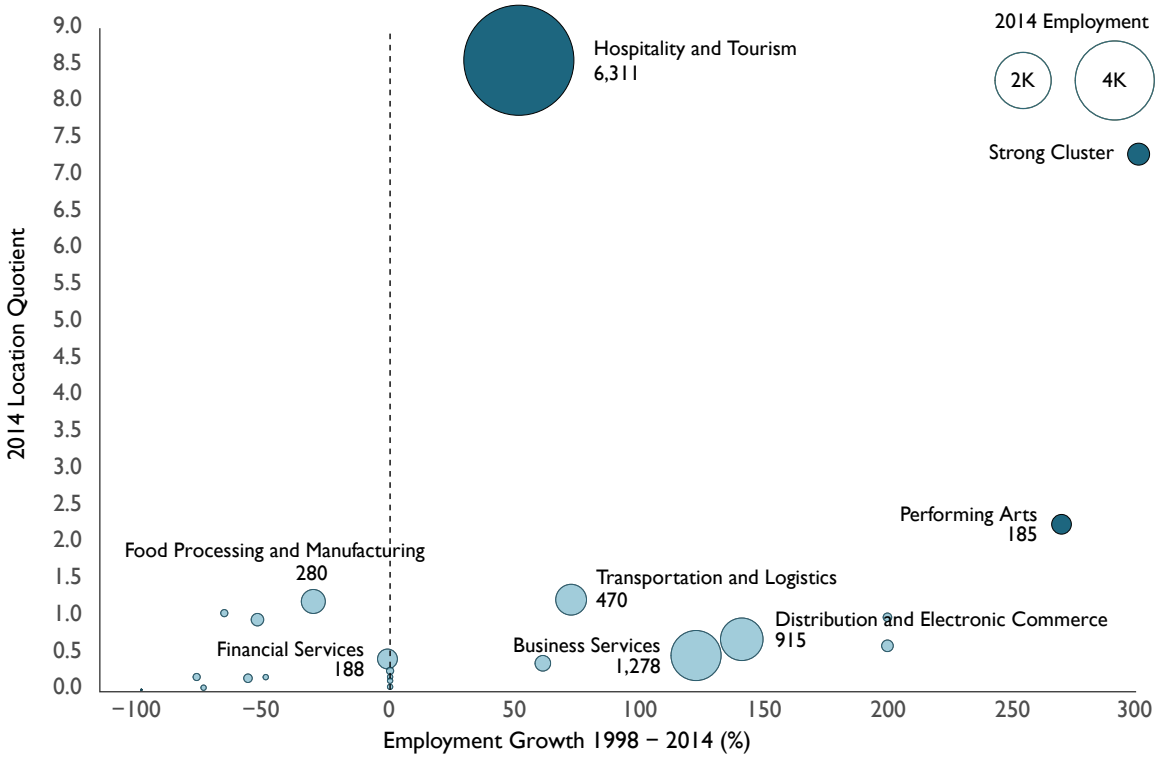
Food Processing and Manufacturing all have LQ greater than one with job counts ranging from almost 750 to 1,000 employees. Figure 6b shows the smaller Maui clusters, with employment counts below 50. All but the strong cluster in Music and Sound Recording have LQ below one.

The average Maui County traded cluster wage of $39,486, is just a bit lower than the average traded cluster wage in Honolulu but more than $20,000 lower than the US average of $61,568. Only Wood Products and the HTC pay wages that are higher than the US average wage for that cluster. Note that the Wood Products cluster employed 22 people in 2014. As was the case for Honolulu County, all but two of Maui's traded clusters pay below US cluster wages, and most have relatively small LQ. It seems likely that these clusters primarily serve the local market and the relative lack of competition leads to lower productivity and lower average wages.

Kauai County Cluster Overview

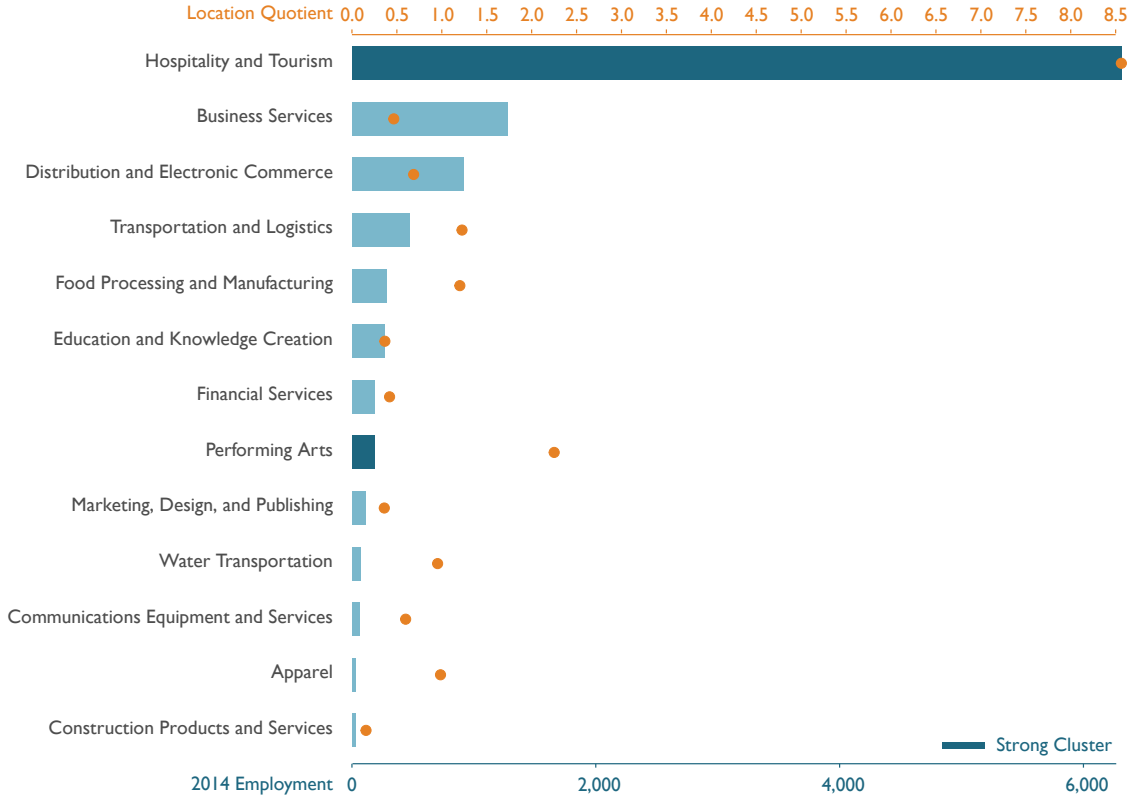
The HTC in Kauai County employs more than 6,000 people, almost five times as many as the next largest cluster, Business Services. With a location quotient of 8.56, Kauai's HTC is only slightly less concentrated than Maui's. The dominant role of the cluster is clear in Figure 8, as is the small size of Kauai's other four strong traded clusters. Outside of tourism, the remaining four strong clusters have a total employment of 215 workers. While Kauai County has only five strong traded clusters, because of the large size of the HTC, 62.9% of Kauai's total traded employment is in strong clusters ranking Kauai 67th for overall cluster strength out of 3,147 counties nationwide. Between 1998

FIGURE 8: KAUAI COUNTY TRADED CLUSTERS ONE LARGE, STRONG TRADED CLUSTER



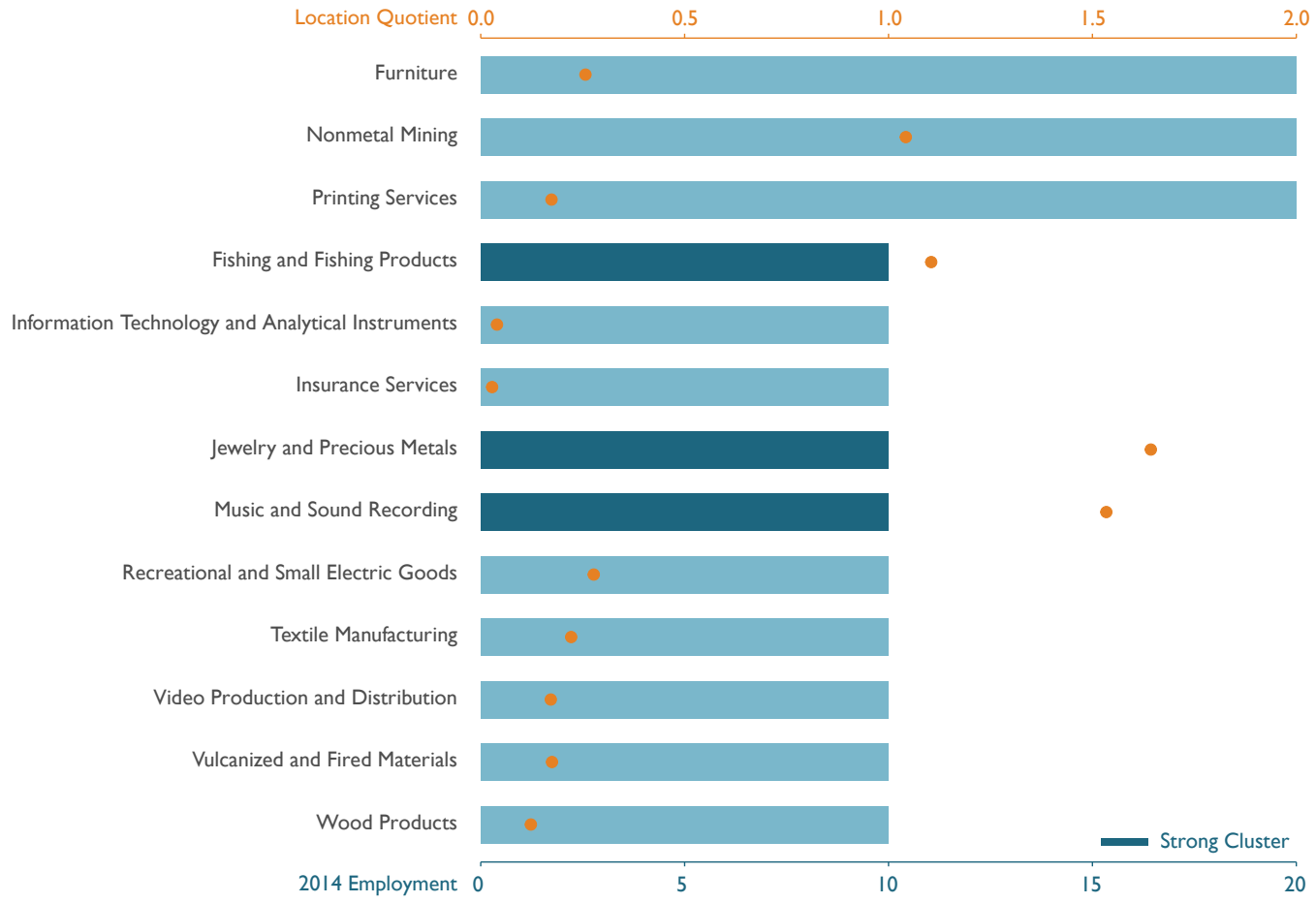
SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 9A: KAUAI LARGE TRADED CLUSTERS, 2014 TOTAL EMPLOYMENT AND CLUSTER STRENGTH



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 9B: KAUAI SMALL TRADED CLUSTERS, 2014 TOTAL EMPLOYMENT AND CLUSTER STRENGTH



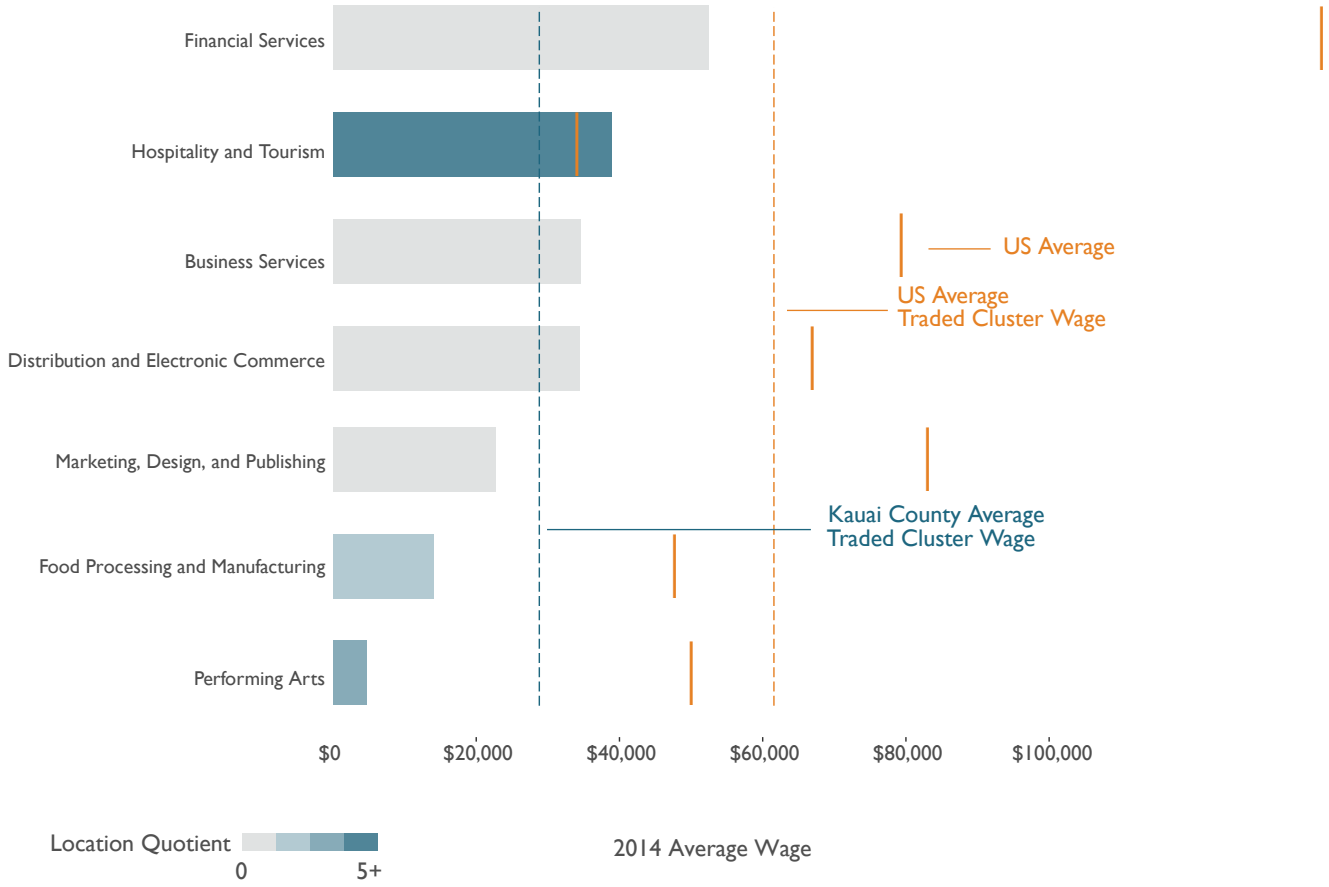
SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

and 2014, Kauai's EKCC was its fastest growing traded cluster, adding 245 jobs at an annual rate of 18%. Its fastest growing strong traded cluster, the Performing Arts cluster, added 135 jobs, an annual growth rate of 9%, while the HTC grew at an annual rate of 3% adding more than 2,000 jobs.

The bar charts in Figures 9a and 9b above show a similar picture to that of Maui County. Business Services and Distribution and Electronic Commerce are the second and third largest clusters by employment with close to 1,000 employees each. Yet both of these clusters have LQ less than 0.7. Similar to Maui County, Transportation and Logistics, Performing Arts, and Food Processing and Manufacturing all have LQ greater than one with job counts ranging from 180 to almost 500 employees. More of Kauai's smaller clusters are strong or have LQ close to 1.0. Water Transportation, Apparel, Nonmetal Mining, Fishing and Fishing Products, Jewelry and Precious Metals, and Music and Sound Recording all have LQ greater than one.

The average Kauai County traded cluster wage of $28,809, is more than $30,000 less than the US average traded cluster wage of $61,568. Only the HTC pay wages that are higher than the US average for that cluster. Outside of tourism, the traded clusters for which we have wage data for Kauai tend to be relatively high wage clusters nationally, such as financial services. That is, the average wage paid in each traded cluster is higher than the national average traded cluster wage. Yet on Kauai, these non-hospitality traded clusters pay well below US wages. As in the case of

FIGURE 10: KAUAI COUNTY TRADED CLUSTER WAGES, 2014 AVERAGE WAGE AND LOCATION QUOTIENT VS US WAGE



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

Maui and Honolulu, many of Kauai's traded clusters have relatively small LQ. Recall that the average wage reported in Figure 10 is calculated in a way that may overstate the degree to which wages on Kauai are lower than US average wages. For example, if the performing arts cluster has a large number of part-time employees on Kauai and relatively few part-time employees nationally, then wages reported for Kauai will automatically be lower than the national average.

HAWAII COUNTY CLUSTER OVERVIEW

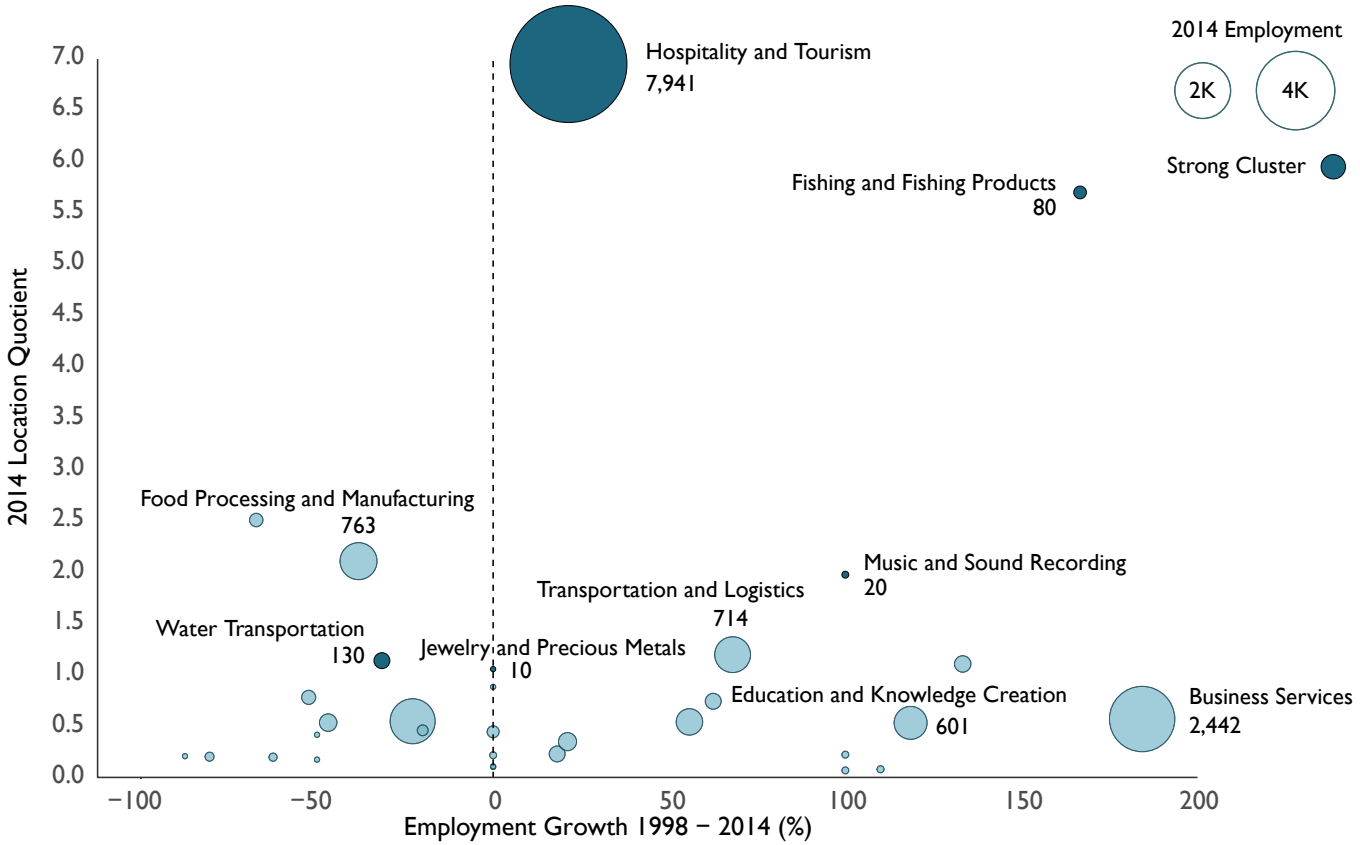
The HTC in Hawaii County employs almost 8,000 people, while the remaining strong traded clusters have a total of less than 250 workers. The relative dominance of Hospitality and Tourism is evident in Figure 11, yet with a location quotient of almost 7, Hawaii County's cluster is the least concentrated of all counties with the exception of Honolulu. The Fishing and Fishing Products cluster is also a strong cluster with a LQ of 5.7, but with only 80 employees in 2014. The remaining strong traded clusters are Music and Sound Recording and Water Transportation. Because of the large size of the HTC, a large fraction, 54.2%, of total traded employment occurs in strong traded clusters ranking Hawaii County 83rd out of 3,147 counties nationwide for overall cluster strength. Between 1998 and 2014, the fastest growing traded cluster was Business Services, adding 481 jobs with an annual growth rate of 9%. The HTC grew at an annual rate of 1% adding more than 900 jobs, and the Education and Knowledge Creation cluster grew by 5%, adding more than 300 jobs.

The bar charts in Figures 12a and 12b again show a similar picture to that of Maui and Kauai Counties. The Business Services and Distribution and Electronic Commerce are the second and third largest clusters by employment with more than 3,500 employees combined. Yet both of these clusters have LQ less than 0.7 implying that these clusters primarily serve the local community as opposed to competing nationally or globally. Other strong traded clusters include Water Transportation, Fishing and Fishing Products, Jewelry and Precious Metals, and Music and Sound Recording, combined accounting for 850 jobs in the county.

The Agriculture Inputs and Services cluster has a LQ greater than two, but is not classified as a strong traded cluster because of its relatively small size—its share of national cluster employment falls below the 25th percentile.

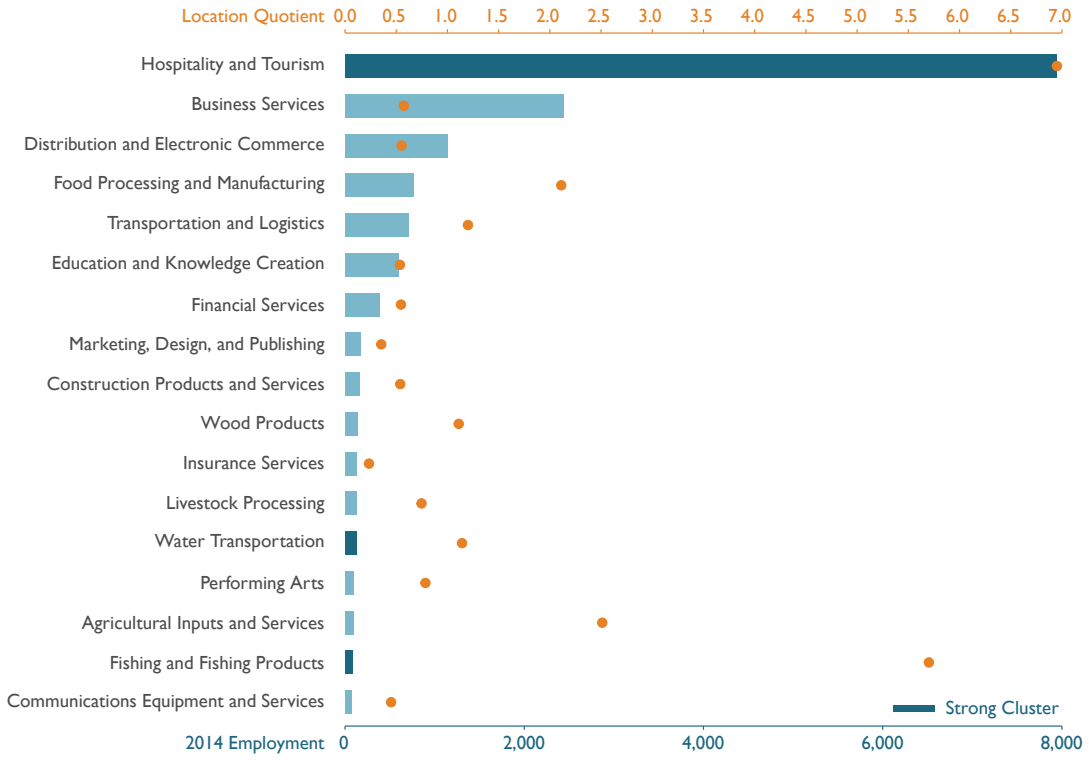
The average Hawaii County traded cluster wage of $39,383 is more than $20,000 below the US average traded cluster wage of $61,568. Three Hawaii County clusters pay wages above the US Average wage for that cluster, Education and Knowledge Creation, Hospitality and Tourism, and the Furniture cluster. Note that the latter only represents 56 jobs. Of the eleven traded clusters for which we have wage data for Hawaii County, only four would be considered high wage clusters nationally in the sense that the average wage paid in each traded cluster is higher than the national average traded cluster wage. Yet on Hawaii Island these traded clusters pay well below US wages. As in the case of Maui and Kauai, many of Hawaii's traded clusters have relatively small LQ.

FIGURE 11: HAWAII COUNTY TRADED CLUSTERS ONE LARGE, STRONG TRADED CLUSTER



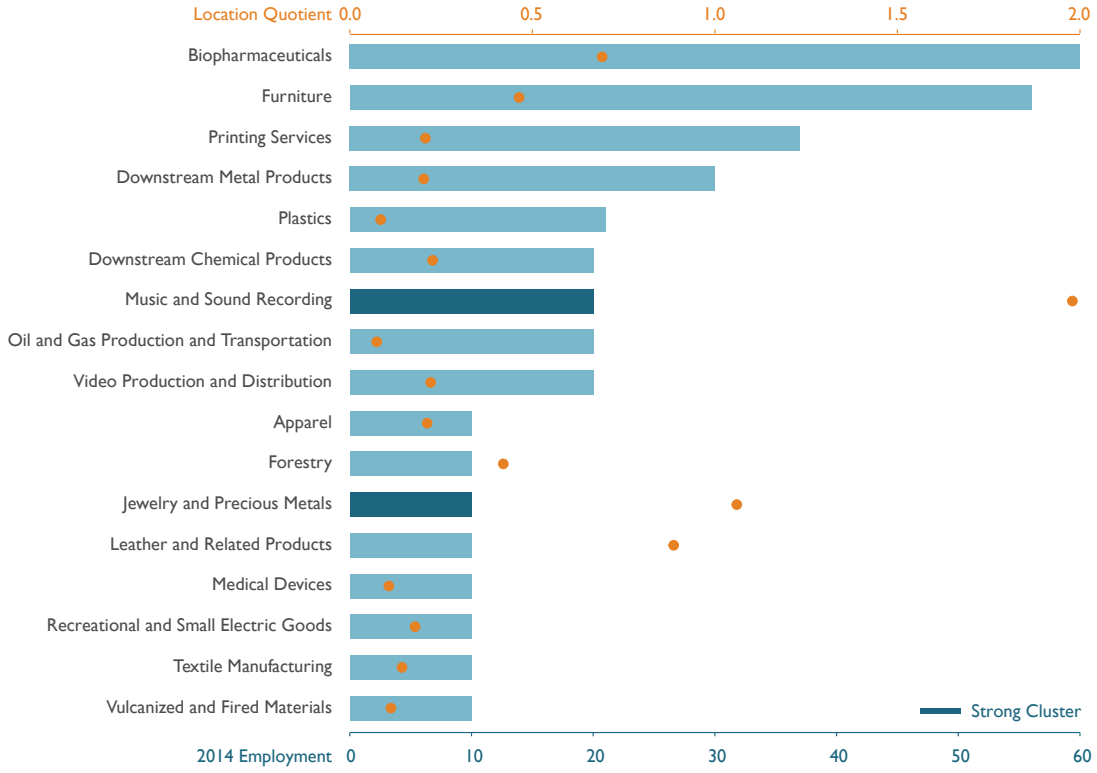
SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 12A: HAWAII COUNTY LARGE TRADED CLUSTERS, 2014 EMPLOYMENT AND CLUSTER STRENGTH



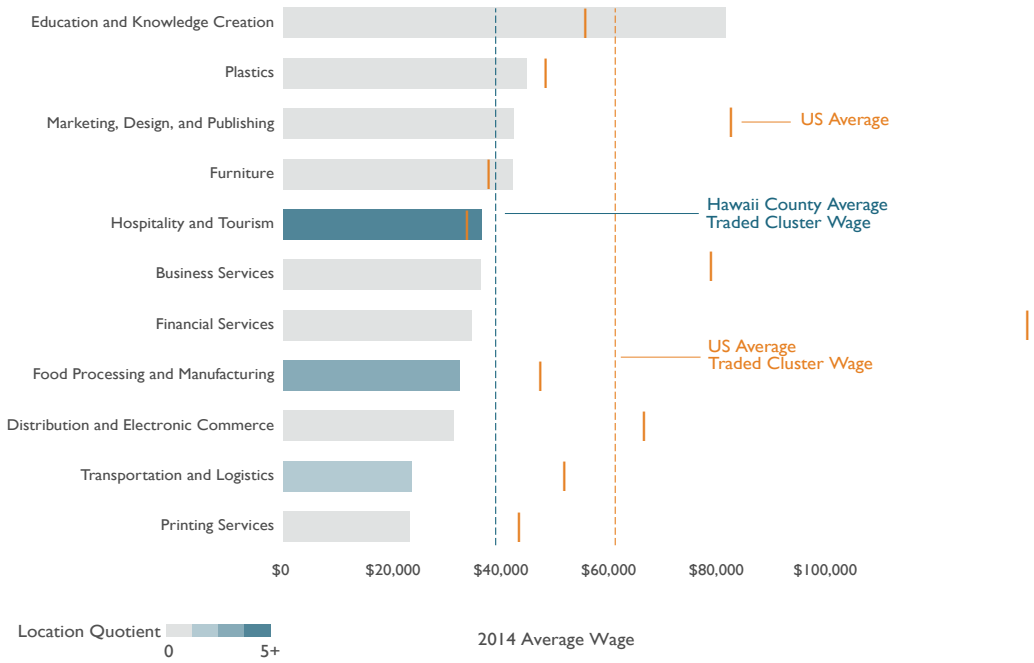
SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 12B: HAWAII COUNTY SMALL TRADED CLUSTERS, 2014 TOTAL EMPLOYMENT AND CLUSTER STRENGTH



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 13: HAWAII COUNTY TRADED CLUSTER WAGES, 2014 AVERAGE WAGE AND LOCATION QUOTIENT VS US WAGE



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

IV. COUNTY COMPARISONS: TOURISM AND MILITARY

Here we compare the strength and mix of traded clusters in Honolulu and Maui counties with those in other counties across the country. To do this, we choose counties that are as similar as possible in size and either strength of the HTC or the concentration of federal military personnel and spending.

Tourism focused county comparisons

Maui County has the strongest HTC of any county in Hawaii with a LQ of 9.3. Only 29 of 3,221 US counties have HTCs that are more concentrated. We compare Maui County clusters and overall economic performance to five counties with similar 1) HTC strength, 2) employment size and 3) population size. Summary statistics are presented in Table 1.

The county closest in size to Maui County is Santa Fe, New Mexico, with a population of close to 150,000 people. The next closest in size is El Dorado, California with more than 180,000. Despite being close in size, with 9% fewer and 12% more residents respectively, both Santa Fe and El Dorado have many fewer private non-farm jobs. Both El Dorado and Santa Fe have close to 45,000 jobs, while Maui County has more than 60,000. These differences are at least in part due to the demographic makeup of the counties. Both Santa Fe and El Dorado have large numbers of older adult residents (ages 65 and older) making up between 18 and 20% of the total population. In contrast, only 15% of Maui County population is aged 65 and older. Also, the tendency for Hawaii workers to hold more than one (often part-time) job would contribute to a relatively larger non-farm employment. Osceola County has a lower share of older adult population than Maui County, its total population is almost twice as large as Maui's, but its non-farm job count is only 10% greater than Maui. Finally, the closest comparisons in terms of the concentration of the HTC are Atlantic County, New Jersey and Harrison County, Mississippi with LQ of 10.2 and 8.1 (versus 9.3 for Maui County).

TABLE 1: SUMMARY OF COUNTY CHARACTERISTICS COMPARING MAUI TO US COUNTIES WITH STRONG HOSPITALITY AND TOURISM CLUSTERS

	Maui, HI	Santa Fe, NM	El Dorado, CA	Harrison, MS	Atlantic City, NJ	Osceola, FL
2014 Employment	63,429	45,219	42,457	70,791	110,726	69,236
Employment vs Maui	100%	71%	67%	112%	175%	109%
2014 Total Population	163,019	148,164	183,087	199,058	275,209	310,211
Pop vs Maui	100%	91%	112%	122%	169%	190%
2014 HTC Employment	15,969	4,621	5,322	11,748	31,506	8,868
2014 HTC LQ	9.26	5.65	5.12	8.14	10.2	6.44

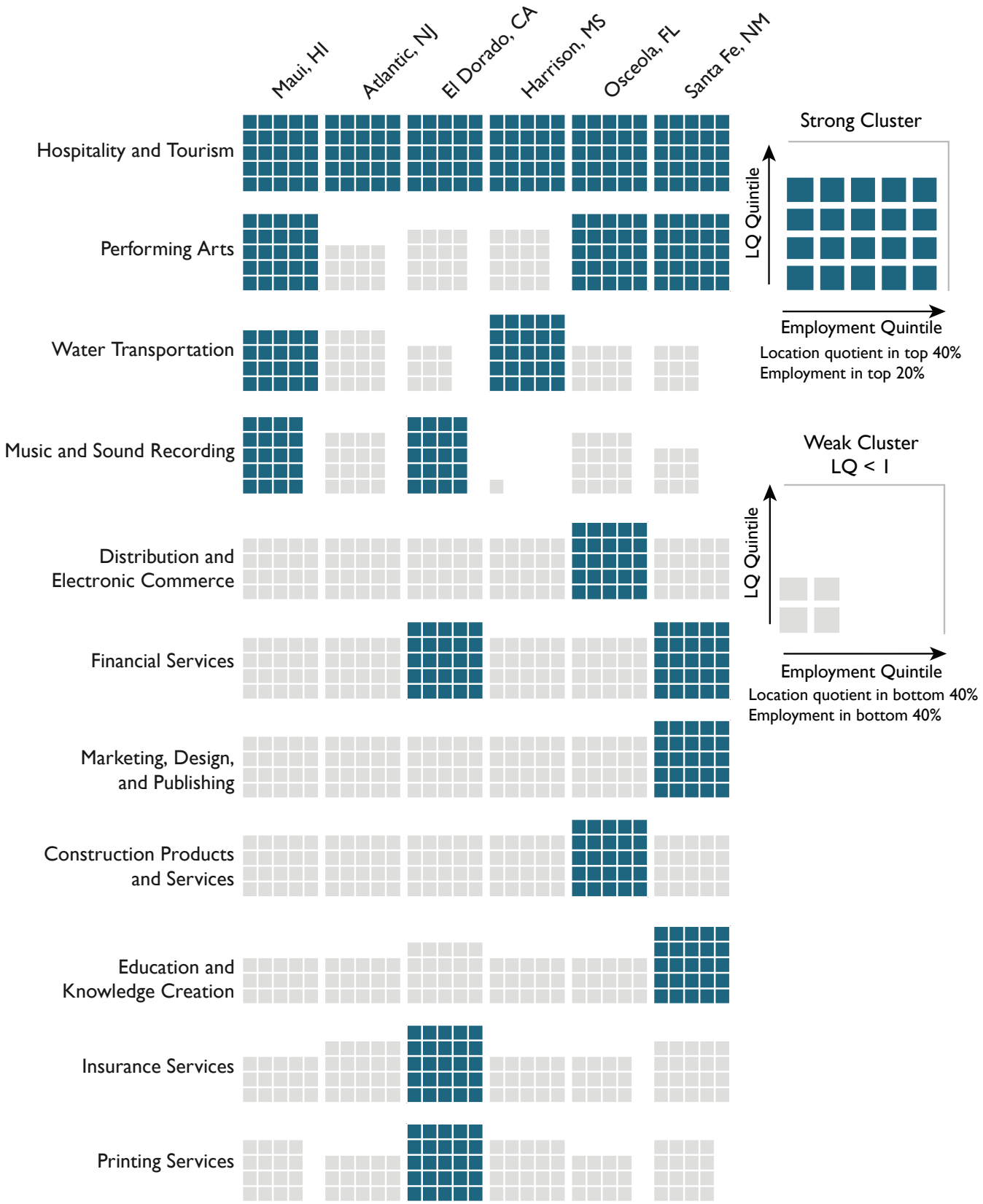
SOURCE: US CLUSTER MAPPING PROJECT.

What stands out in the Tourism Comparison chart below is the relatively small number of both strong traded clusters and clusters with LQ greater than one in Maui County. Of the six counties compared in Figure 14, two (Maui and Osceola) have four strong traded clusters and eighteen clusters with LQ less than one. Atlantic County has only two strong traded clusters, while El Dorado, and Santa Fe have nine, and Harrison has five strong traded clusters. For Maui County, outside of Hospitality and Tourism, the next largest strong traded cluster is Performing Arts followed by Water Transportation and Music and Sound Recording.

All of Maui County's strong traded clusters are related to either Hospitality and Tourism, or to the necessity of providing local water transportation services. For example, of the 200 jobs in Maui's strong Water Transportation cluster, 120 jobs are in the freight transportation and marine cargo handling industries. In contrast, the water transportation cluster in Harrison County, Mississippi is home to more than one thousand jobs in ship building and repair businesses that are truly traded industries. If we treat Maui's water transportation cluster as a local cluster, then Maui looks much more like Osceola, Florida, but without the manufacturers of Motor Homes and Construction Products clusters.

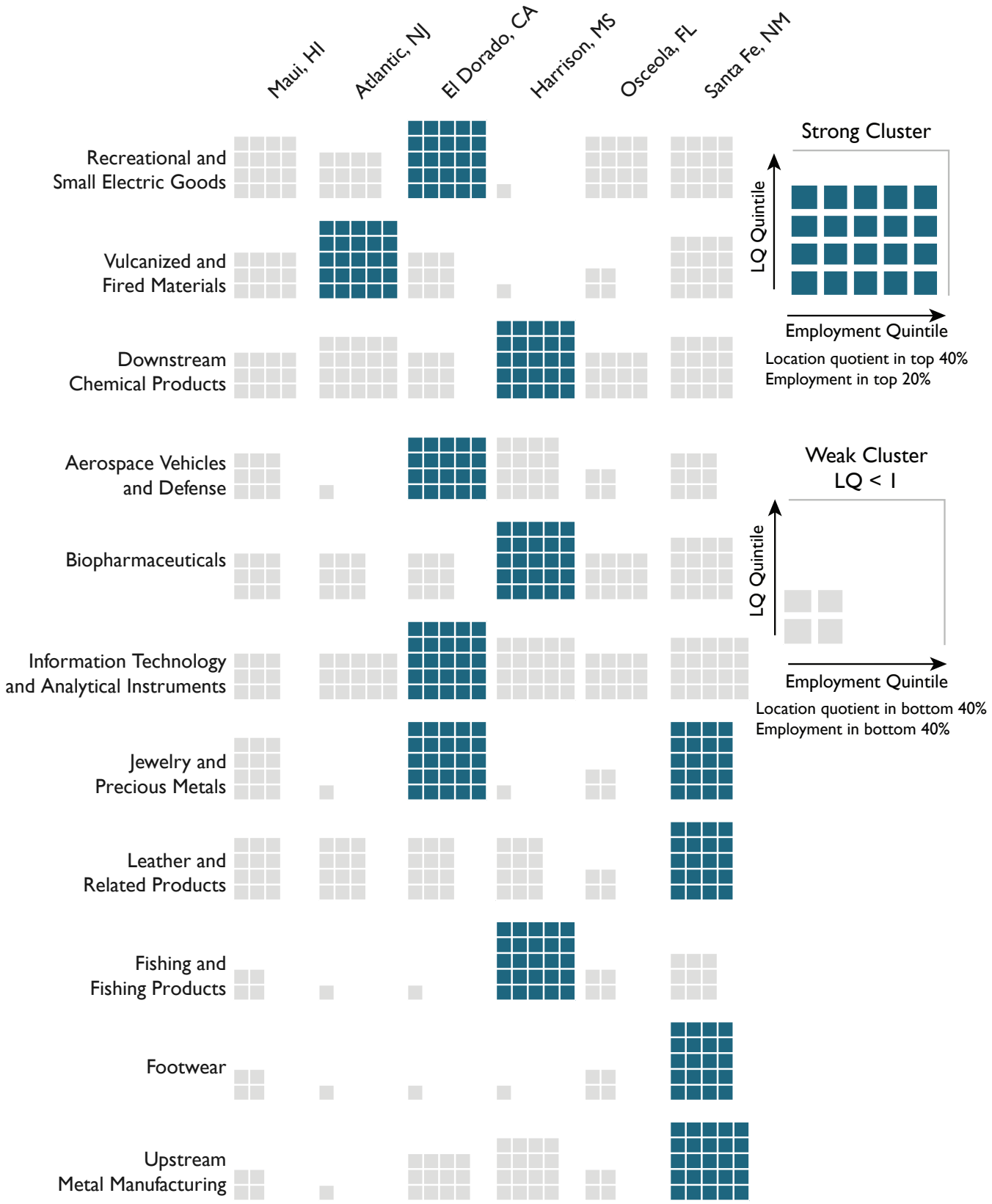
Note that the comparisons we are making focus on the mix and strength of traded clusters within each county. Unlike counties in the lower 48, Hawaii counties are not near anything except each other. Just as the HTC on Maui, Hawaii Island and Kauai benefit from the strength of the HTC and related clusters on Oahu, clusters on the continent benefit from strong clusters in their close proximity. But they are much closer to potentially many more strong clusters. For example, Gulf Coast Shipyards Group in Gulfport Mississippi (Harrison County) is about eighty miles east of the port of New Orleans, one of the busiest ports in the country. About forty miles in the other direction, a little less than half the distance from Honolulu to Kahului, is Pascagula, home of Ingalls Shipbuilding. Drive one hundred miles in any direction from Gulfport, and you are surrounded by relevant customers, suppliers, and competitors. Clearly, the relatively small size of Maui, Hawaii and Kauai Counties, but more importantly their distance from other markets, contributes to the underdevelopment of strong traded clusters outside of the HTC.

FIGURE 14A: MAUI VS US COUNTIES WITH SIMILAR HOSPITALITY & TOURISM CONCENTRATION, 2014



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 14B: MAUI VS US COUNTIES WITH SIMILAR HOSPITALITY & TOURISM CONCENTRATION, 2014



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

Military-Based County Comparisons

The concentration and mix of industries in Honolulu County is quite different from that of the other islands. This is due in part to Honolulu being the most populous county, the center of state government and the homeport for transportation and logistics operations. Another characteristic of Honolulu County that distinguishes it from Hawaii's three other counties and most other US regions, is the dominant role of Federal Department of Defense spending in the county economy. In FY2014, Honolulu County was home to 67,354 military personnel compared to roughly 600 personnel in Hawaii and Maui Counties, and 250 personnel for Kauai County. The $6.7 billion in defense spending in FY2014 represented 9.9% of state GDP, and 14% of the 2013 estimate of county GDP in the UCMP database. In Table 2, we draw comparisons with counties across the country. We selected counties where defense spending was a similar proportion of county GDP, and the number of military personnel represented a similar share of county population. It is important to control for both personnel and spending to capture differences in the makeup of defense spending by region. For example, while defense spending in Pima County, Arizona represents 14% of county GDP, approximately the same as in Honolulu County, there were less than 12,000 personnel stationed in Pima (1.2% of total population) versus more than 67,000 on Oahu (6.8% of total population). Clearly the defense spending in Pima is different than that in Honolulu, and this should show up in the mix and strength of clusters. Pierce County, Washington and El Paso County, Colorado appear most similar to Honolulu County based on the defense spending share of county GDP, the share of total population that are military personnel, and the size of the region as measured by total population. Yet the mix and cluster strength of these counties remain quite different.

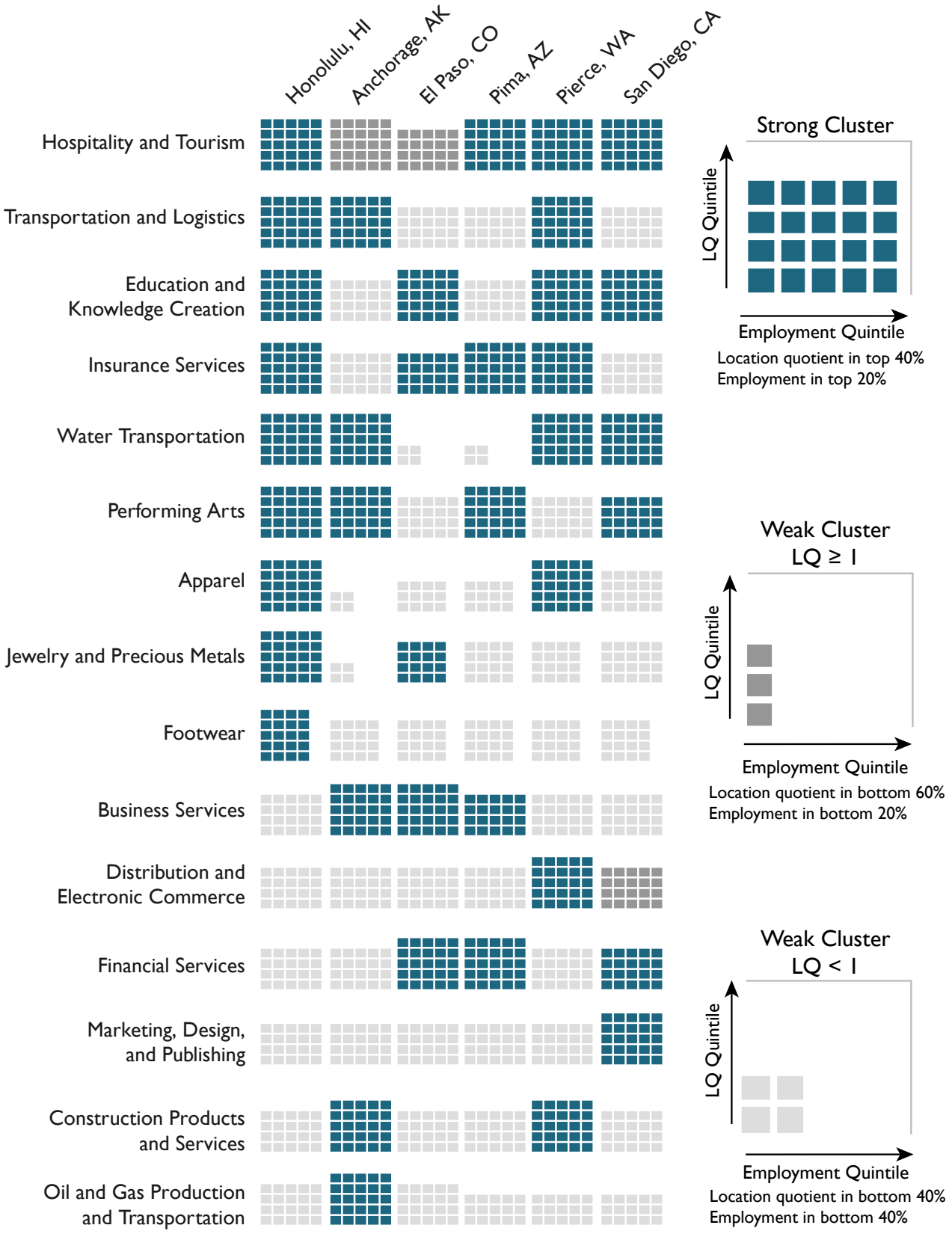
Figure 15 below shows the mix of each county's clusters along with measures of LQ and cluster employment share quintiles. As we have already seen, Honolulu County has strong and relatively large clusters in Hospitality and Tourism, Insurance, Transportation and Logistics, Water Transport, and Education and Knowledge Creation (see figure 15a). These clusters, with the exception of Insurance and to some extent Education and Knowledge Creation are related to Hawaii's location both as a world-class tourism destination and the most isolated archipelago in the world. The latter results in a higher concentration of Transportation and Logistics and Water Transport clusters. For example, the Honolulu County Water Transportation cluster is more concentrated than the same cluster in San Diego County, with a location quotient of 4.1 versus 2.8 for San Diego. (Both have LQ and cluster employment shares in the top quintile nationally.) Almost a quarter of the employment in the Water Transportation cluster in Honolulu is

TABLE 2: SUMMARY OF COUNTY CHARACTERISTICS COMPARING HONOLULU TO US COUNTIES WITH SIMILAR US DEPARTMENT OF DEFENSE SPENDING

	Honolulu, HI	Anchorage, AK	El Paso, CO	Pierce, WA	Pima, AZ	San Diego, CA
2013 GDP ($B)	47.9	19.9	24.9	28.3	33.9	164.4
FY14 Mil. Spending ($B)	6.7	2.1	4.1	3.6	4.6	15.1
Mil. Share of GDP	14%	11%	16%	13%	14%	9%
Total Pop	983,429	300,950	655,044	819,743	996,554	3,211,252
Mil. Personnel	67,534	17,850	36,752	50,886	11,896	108,729
Personnel/Pop	6.8%	5.9%	5.6%	6.2%	1.2%	3.4%
Pop vs Hon	105%	32%	70%	87%	106%	342%

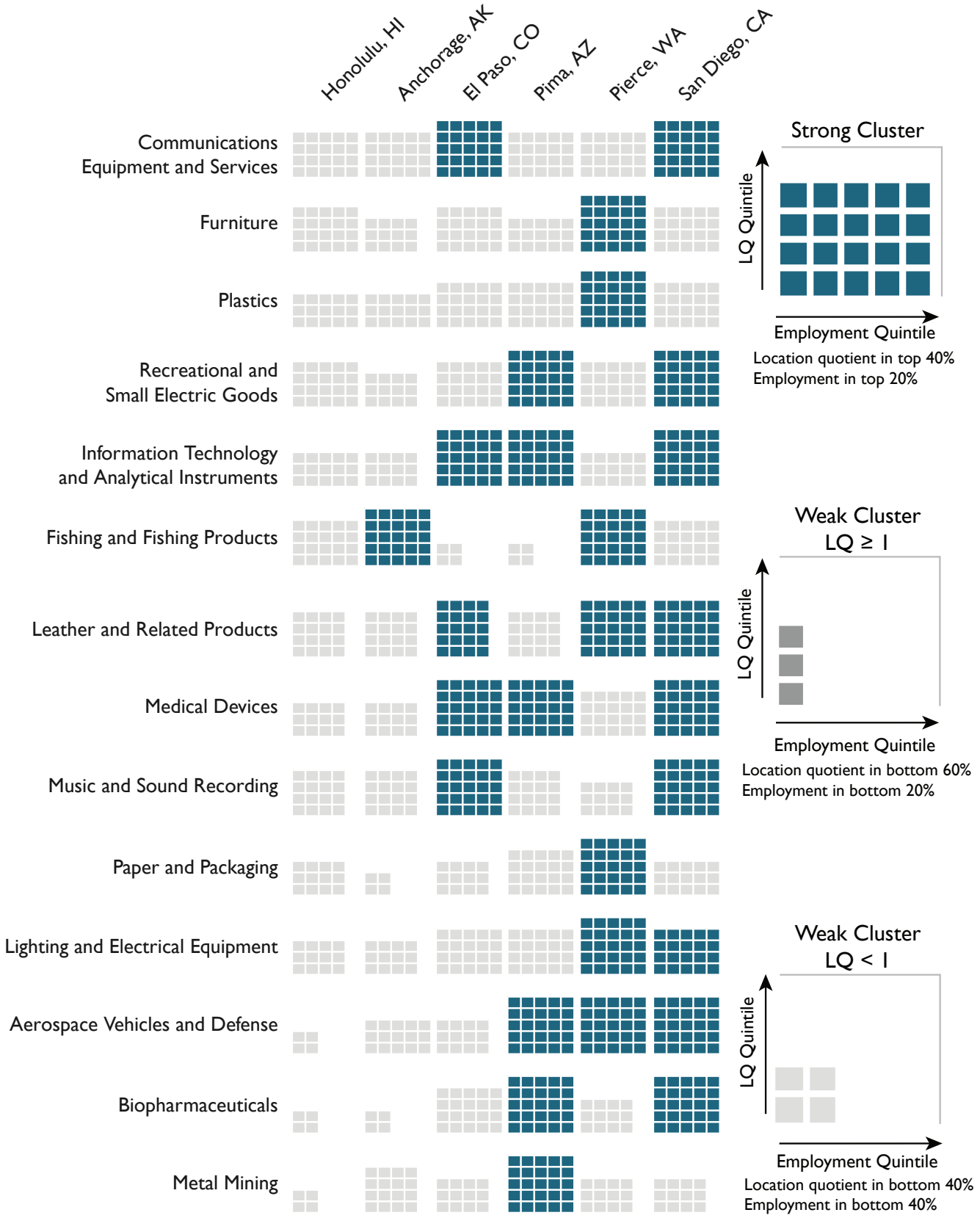
SOURCE: DEFENSE SPENDING BY STATE, FISCAL YEAR 2014, US DEPARTMENT OF DEFENSE OFFICE OF ECONOMIC ADJUSTMENT; US BUREAU OF CENSUS.

FIGURE 15A: HONOLULU VS US COUNTIES WITH SIMILAR US DEPARTMENT OF DEFENSE SPENDING, 2014



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

FIGURE 15B: HONOLULU VS US COUNTIES WITH SIMILAR US DEPARTMENT OF DEFENSE SPENDING, 2014



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT.

passenger transportation due to tourism activity. Honolulu also has strong traded clusters in Performing Arts, Jewelry and Precious Metals, Apparel, and Footwear. Each of these clusters benefits from the strength of the HTC, and these clusters are much less concentrated in the other five counties, with the exception of Performing Arts in Anchorage and Pima and Apparel in Pierce County.

TABLE 3: TOP HAWAII DEFENSE CONTRACTORS FY2014 AWARDS, INDUSTRY AND CLUSTER DESIGNATIONS

Contractor	Cluster: Subcluster	NAICS	FY14 Awards
BAE Systems	**Commercial Services: Miscellaneous Repair Services**	811310 — Commercial and Industrial Machinery and Equipment Repair and Maintenance	$136.7 M
Tesoro	Distribution & E-Commerce: Wholesale of Petroleum and Petroleum Products	424720 — Petroleum and Petroleum Products Merchant Wholesalers (except Bulk Stations and Terminals)	$66.8 M
Nan, Inc.	**Local Real Estate, Construction, and Development: General Contractors**	236220 — Commercial and Institutional Building Construction	$62.5 M
Manu Kai	Business Services: Consulting Services	541690 — Other Scientific and Technical Consulting Services	$58.8 M
J & J Maintenance	**Local Real Estate, Construction, and Development: Speciality Contractors**	238990 — All Other Specialty Trade Contractors	$36.3 M
Pelatron	Education and Knowledge Creation: Research Organizations	541712 — Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology)	$35.9 H
dck-ecc pacific	**Local Real Estate, Construction, and Development: General Contractors**	236220 — Commercial and Institutional Building Construction	$35.7 M
Absher Construction	**Local Real Estate, Construction, and Development: General Contractors**	236220 — Commercial and Institutional Building Construction	$35.7 M
Performance Systems Inc.	**Local Real Estate, Construction, and Development: General Contractors**	236220 — Commercial and Institutional Building Construction	$35.3 M
Y. Hata	**Local Food and Beverage Processing and Distribution: Food Wholesaling**	424410 — General Line Grocery Merchant Wholesalers	$26.2 M

SOURCE: DOD OFFICE OF ECONOMIC ADJUSTMENT FY 2014 REPORT. NAICS CODES ARE FROM MERGENT ONLINE, 2016. CLUSTER: SUBCLUSTER IS FROM UCMP. BOLD CLUSTERS ARE LOCAL CLUSTERS.

Unlike Honolulu County, Pima, Pierce, and San Diego counties have Aerospace Vehicle and Defense clusters that are both relatively large in terms of employment and highly concentrated with LQ greater than four (see figure 15b). In contrast, Honolulu, El Paso, and Anchorage Municipality have no significant Aerospace Vehicle and Defense concentration (each have clusters with LQ less than one and in the bottom 60% nationally). This cluster consists of industries manufacturing airplanes, engines and parts as well as missiles and navigation, guidance, detection and aeronautical and nautical systems. Honolulu and Anchorage with their remoteness and high transportation and electricity costs have little in the way of manufacturing clusters and this helps to explain the lack of such defense related clusters. Finally, note that the Aerospace cluster often occurs side by side with Information Tech and Analytical Instruments as well as Medical Device clusters. This is the case in Pima County, which is also home to concentrated clusters in Metal Mining, Medical Devices, Information Technology and Analytical Instruments, and Biopharmaceuticals. In contrast to Pierce, Pima and San Diego, defense spending outside of basic support for personnel and base operations in Honolulu tends to show up in the Research and Development subclusters of the Education and Knowledge Creation cluster, or even in local service clusters. Table 3 above reports NAICS codes and UCMP clusters for the top Department of Defense contractors in Hawaii. The top defense contractor in FY2014, BAE Systems Hawaii, operating the Pearl Harbor Shipyard, is self-classified as operating in NAICS 811310— Commercial and Industrial Machinery and Equipment Repair and Maintenance. In the UCMP cluster definitions, that industry is part of the local cluster in Commercial Services. Similarly, BAE Spectral Solutions and Pelatron are classified as part of NAICS 541712—Research and Development in the Physical, Engineering, and Life Sciences. That industry is part of the Research Organizations subcluster of the EKCC discussed in more detail in Section V below. Unlike San Diego and other counties that are more concentrated in defense related Research and Development (R&D) and manufacturing, Honolulu tends to see most defense spending concentrated in base operations and maintenance. This is clear from looking at the top contractors in the Table 3. The majority of the contracts are for construction firms, and all but three contracts are to firms that are classified in the UCMP as part of local, not traded clusters.

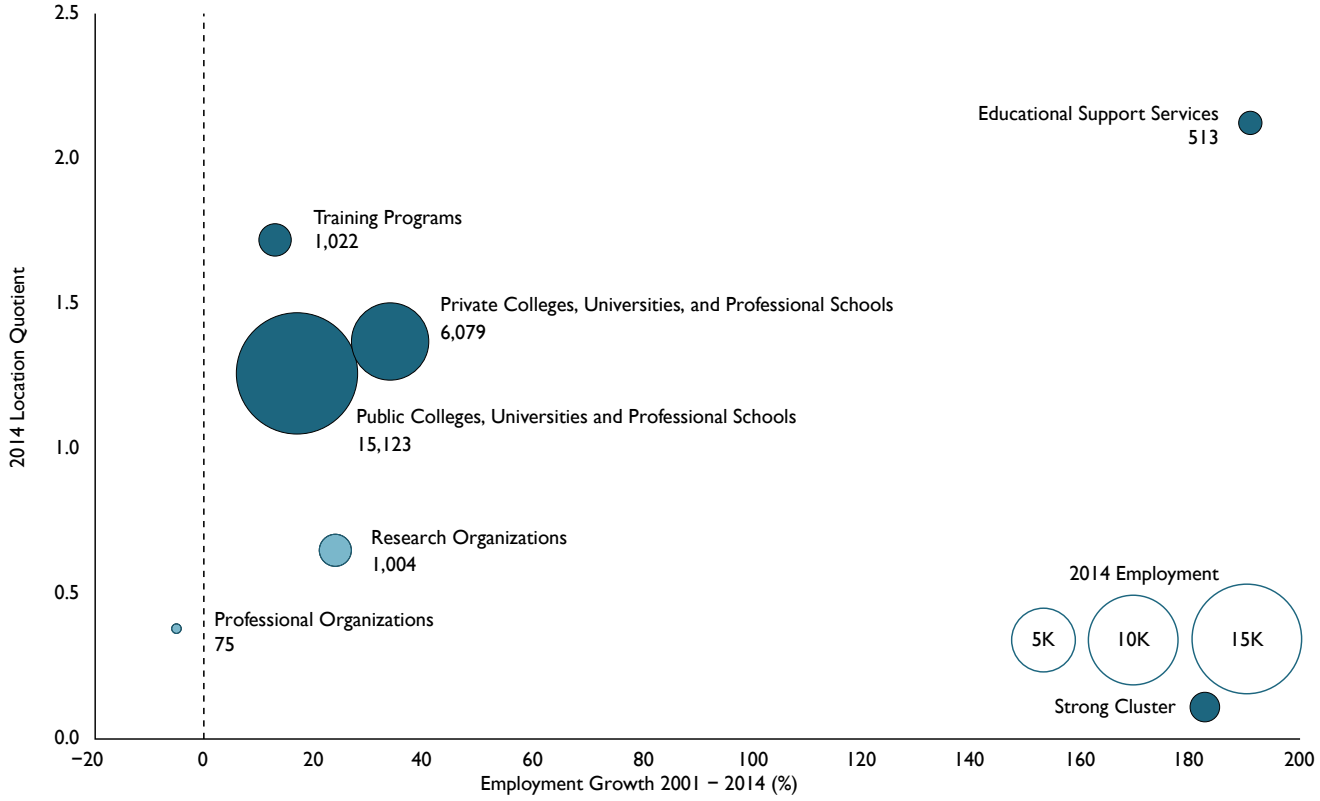
V. HAWAII'S EDUCATION AND KNOWLEDGE CREATION CLUSTER

The Education and Knowledge Creation cluster (EKCC) was one of the fastest growing clusters in Hawaii from 1998 to 2014, ranking third for total job creation. While it is not classified as a strong traded cluster at the state level, and paid below average cluster wages in 2014, this is due to its mix of subclusters and the large size of the relatively low wage Private Colleges, Universities and Professional Schools subcluster (Private CUPS). At the county level, the EKCC is in the top tier of job creating clusters and its Research Organizations subcluster is typically one of the highest wage subclusters. Below, we present charts of the EKCC for each county and discuss its performance by county. Because the UCMP clusters are defined for private sector jobs, their EKCC does not include any information on the public University of Hawaii. Here we augment the UCMP data with data from Economic Modeling Specialists[12] (EMSI) to include Public CUPS in the EKCC.

Figure 16 plots the 2014 LQ for the subclusters of the Honolulu EKCC against their job growth over the 2001-2014 period. The sample used here does not include data starting in 1998 as we did in Sections III-IV because the data for the Public CUPS subcluster is only available from EMSI beginning in 2001. The EKCC as defined by the UCMP is made up of five subclusters: Private CUPS, Research Organizations, Educational Support Services, Training Programs and Professional Organizations. We add the data on the Public CUPS separately from Private CUPS for illustration purposes. For Honolulu, four of the five subclusters are strong, and all but Professional Organizations grew at double digit rates from 2001 to 2014. The fastest growing subcluster, Educational Support Services grew

12 See http://www.economicmodeling.com/data/.

FIGURE 16: HONOLULU COUNTY EDUCATION AND KNOWLEDGE CREATION CLUSTER, 2014

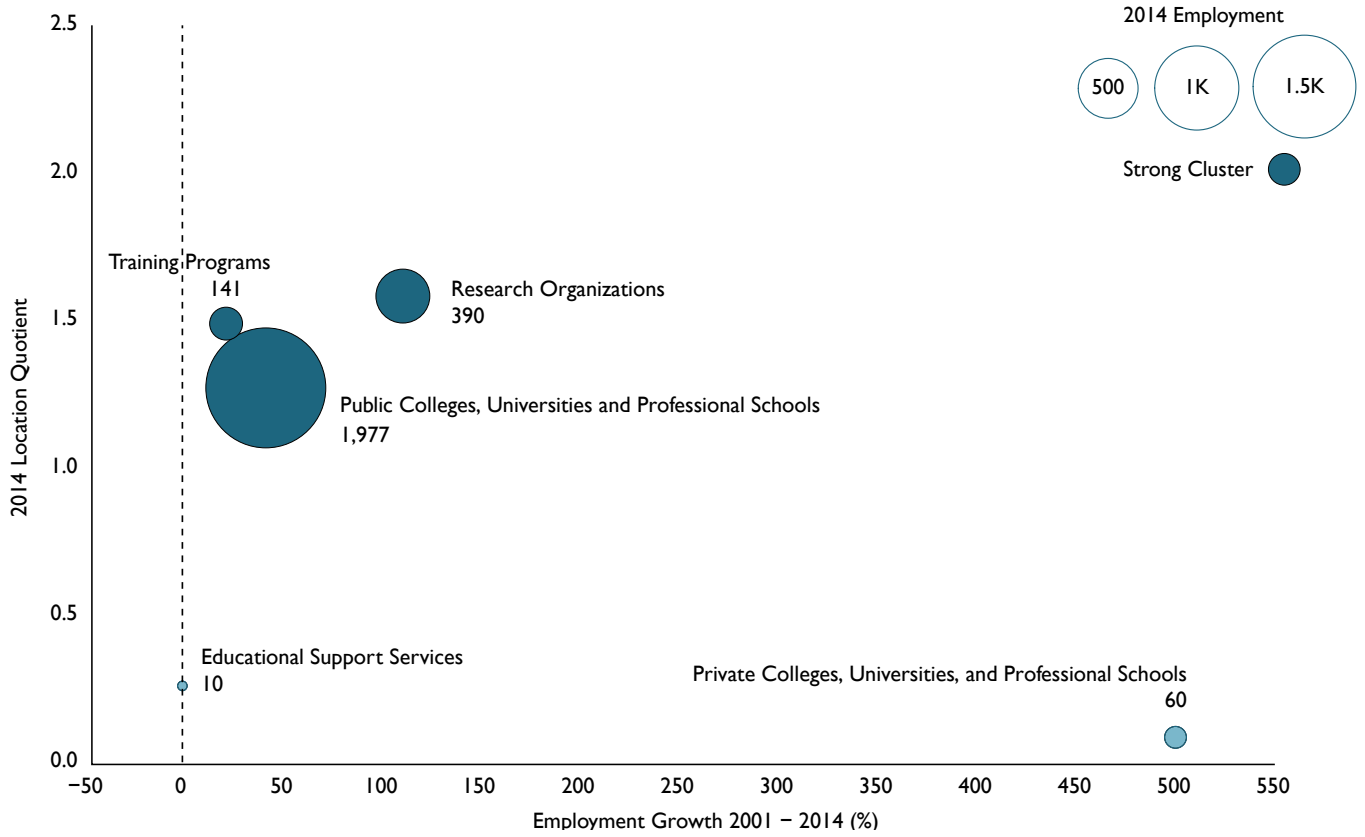


SOURCE: DATA FROM US CLUSTER MAPPING PROJECT, PUBLIC CUPS DATA FROM ECONOMIC MODELING SPECIALISTS.

by 191% from less than 200 jobs in 2001 to more than 500 in 2014. This subcluster is made up of a single industry with businesses providing non-instructional services that support educational systems such as educational guidance counseling services and testing and evaluation services. Both of the CUPS subclusters grew significantly, with public sector colleges adding more than 2,200 jobs and private sector colleges adding close to 1,600 jobs. Of the strong subclusters, Training Programs grew the least, adding 118 jobs, and paid an average wage of less than $21,000 in 2014, well below the EKCC average wage of almost $40,000. The Training Programs subcluster is made up of 8 distinct industries ranging from Language Schools (NAICS 611630) to Computer Training (NAICS 611420) and Exam Prep and Tutoring (NAICS 611691). Exam Prep and Language Schools make up about 80% of the employment in this subcluster. These are likely serving the local community, though there may be some export related activities related to Training Programs.

By far the highest private wage in the EKCC, $75,000, is paid in the Research Organizations subcluster. Even so, that is substantially less than the $112,000 national average wage for this subcluster. Research Organizations grew by 24% during our sample period, adding almost 200 jobs. The industries in the Research Organizations subcluster comprise private sector R&D in Biotech (NAICS 541711), R&D in Physical Engineering and Life Sciences except Biotech (NAICS 541712) and R&D in Social Sciences and Humanities (NAICS 541720). Examples of businesses that are part of the Research Organizations subcluster include businesses at the fore of Honolulu's R&D activities, including Oceanit, Pelatron, Trex Enterprises, BAE Spectral Solutions, the Oceanic Institute, and Hawaii Biotech to name a few. Hawaii Biotech, for example, conducts R&D on vaccines for established and emerging infectious diseases such as the West Nile Ebola virus in partnership with the University of Hawaii John A. Burns School of Medicine.

FIGURE 17: HAWAII COUNTY EDUCATION AND KNOWLEDGE CREATION CLUSTER, 2014



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT, PUBLIC CUPS DATA FROM ECONOMIC MODELING SPECIALISTS.

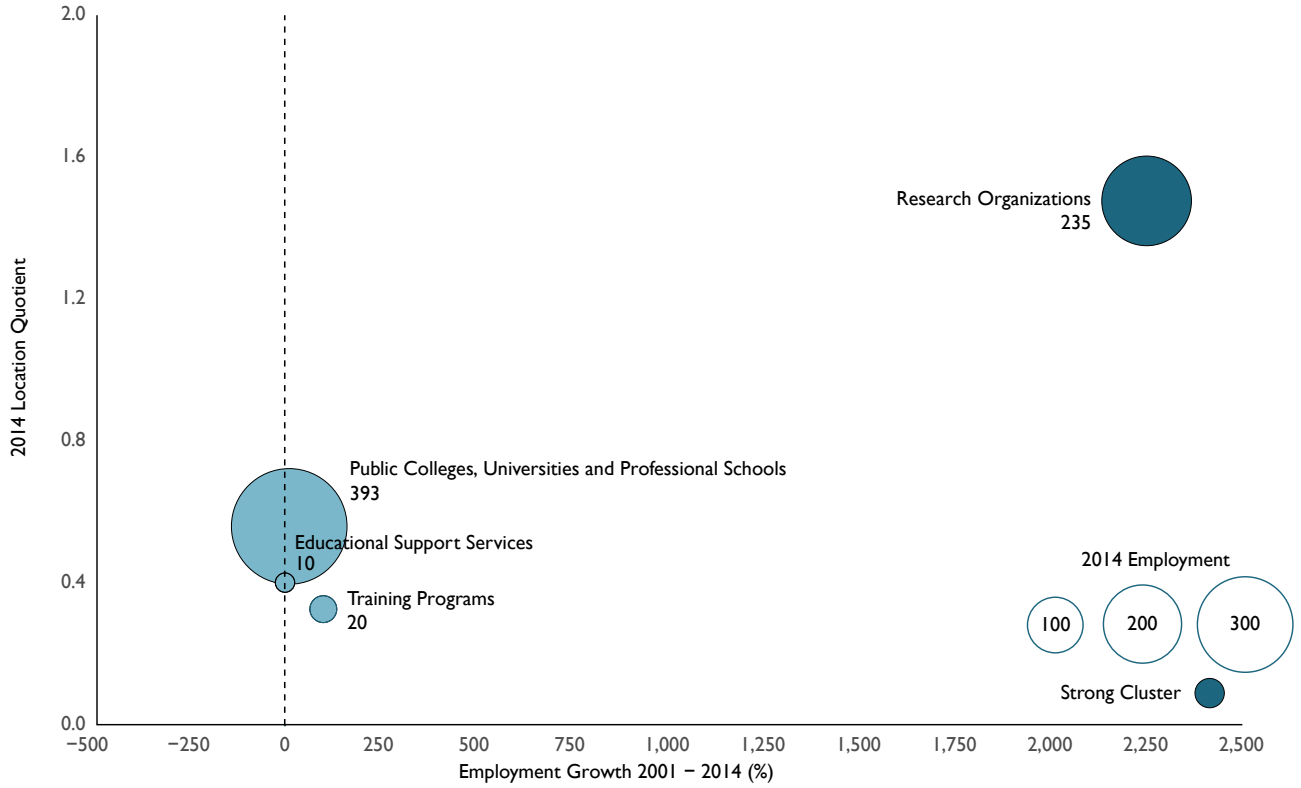
Several of the other companies listed above have worked on Department of Defense R&D and/or projects related to astronomy activity and have offices on multiple islands in the state. Oceanic Institute is affiliated with the Hawaii Pacific University.

Though the Research Organizations subcluster is not currently a strong subcluster for Honolulu County, with a LQ of only .65, it is growing. With the growth of accelerators and other efforts statewide, there is reason to believe that this trend should continue (see Bonham, Burnett, and Rosen, 2016).

Hawaii County

The Hawaii County EKCC has three strong traded subclusters—Training Programs, Research Organizations, and the Public CUPS subclusters all meet the UCMP definition for strong clusters and have grown rapidly over our 2001-14 sample. Research Organizations, with 390 employees on the Big Island, more than doubled over this period, and as was true for Honolulu, pays the highest wage in the cluster. In fact, the Research Organization subcluster in Hawaii County paid an average wage of more than $84,000 in 2014, almost $10,000 higher than on Oahu. The relative size and high wage of the Research Organizations subcluster helps to explain the high average wage of the EKCC. The majority of the jobs in the Research Organizations subcluster are in the R&D in Physical Engineering and Life Sciences industry and includes employees working at the WM KECH Observatory, the Canada-France-Hawaii Telescope corporation, and Makai Ocean Engineering among others. State and local policies that support and facilitate collaboration among researchers, and investment in shared infrastructure at locations such as the Natural Energy Laboratory Hawaii in Kona can all contribute to continued growth and strengthening of the Hawaii County EKCC.

FIGURE 18: KAUAI COUNTY EDUCATION AND KNOWLEDGE CREATION CLUSTER, 2014



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT, PUBLIC CUPS DATA FROM ECONOMIC MODELING SPECIALISTS.

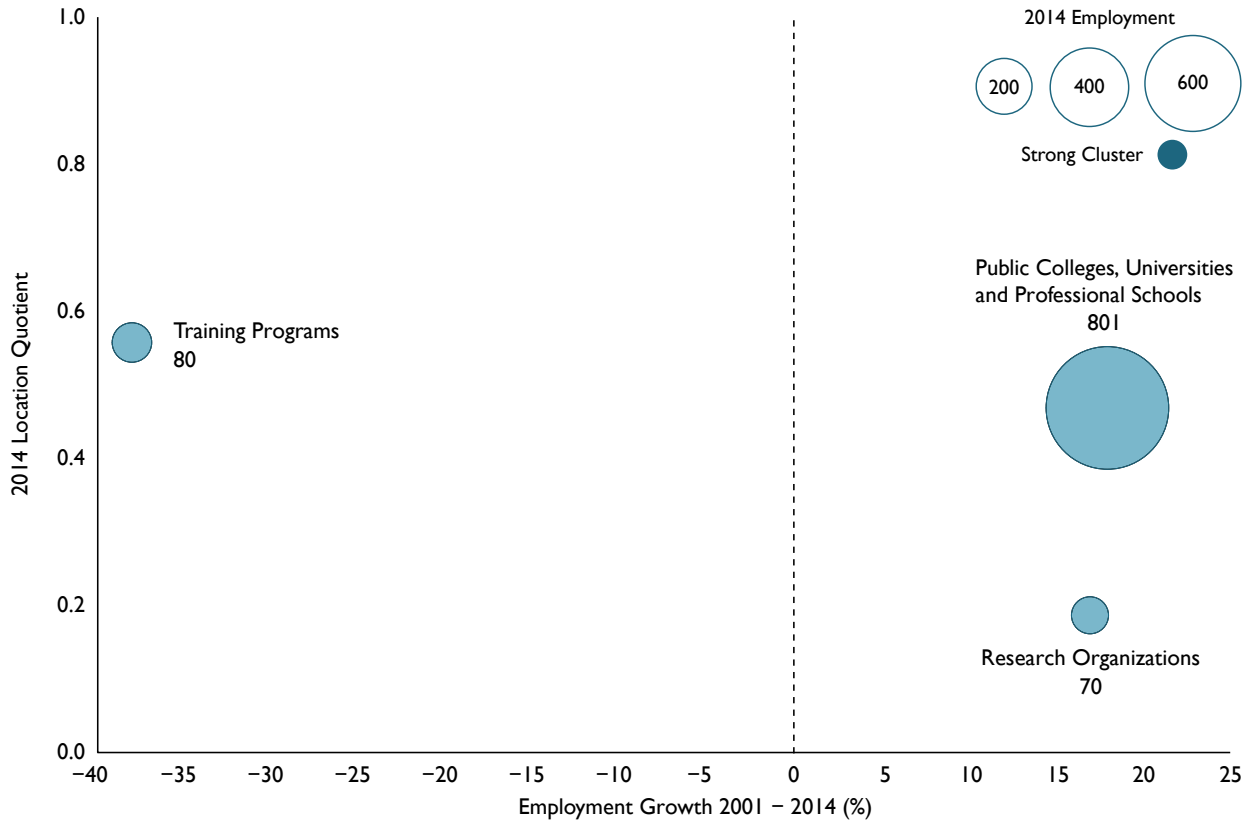
Kauai County

The EKCC in Kauai County is dominated by Public CUPS and the Research Organizations subcluster. While the former is larger, with almost 400 employees in 2014 (adding 38 jobs between 2001 and 2014), it is not a strong cluster. Kauai County does not have any Private CUPS activity, and its Educational Support and Training Program subclusters are extremely small with LQ of 0.4 or lower. The strong Research Organizations subcluster grew from around 10 employees in 2001 to more than 200 in 2014. Approximately two-thirds of the jobs are in R&D in Biotech, and the remaining third in R&D in Physical Engineering and Life Sciences where the average wage in 2014 was more than $100,000. The primary Biotech R&D on Kauai is related to seed corn research by firms such as Dow Agroscience, Syngenta, DuPont, and Pioneer. Given the recent controversy surrounding genetically modified crops and pesticide use, including passage, veto, override, and eventually a decision by a federal judge to strike down Kauai County Council ordinance 960 that would have required more disclosure from biotech companies about pesticide use and genetic engineered farming practices, it is unclear whether public policy and public opinion will support further growth and clustering of biotech-based research activities on Kauai.

Maui County

Surprisingly, the Maui County EKCC has no strong subclusters. In fact, the entire EKCC shrank by more than 20% over the 2001-14 period, losing 50 jobs, mostly in the Training Programs subcluster. The Research Organizations subcluster on Maui is dominated by R&D in Physical Engineering and Life Sciences. But given the astronomy activity on Haleakala, the presence of the Maui High Performance Computing Center, and companies such as Boeing,

FIGURE 18: MAUI COUNTY EDUCATION AND KNOWLEDGE CREATION CLUSTER, 2014



SOURCE: DATA FROM US CLUSTER MAPPING PROJECT, PUBLIC CUPS DATA FROM ECONOMIC MODELING SPECIALISTS.

Oceanit, Trex enterprises, Pelatron, and Pacific Defense Solutions among others, we posit that some of the lack of activity may be the result of misreporting or business classifications that are counterintuitive, similar to DoD related activities in Honolulu. Another possibility is that Maui is more concentrated in areas such as computing services and advanced IT services. The Computer Services subcluster is part of the broader Business Services cluster shown in Figure 5 above. On Maui that cluster is large, growing rapidly with companies such as Akimeka LLC, operating in the Computer Systems Design Services Industry (NAICS 541512). While Maui's Computer Services subcluster grew at a 7% annual rate from 1998-2014, it has not yet reached even average levels of concentration, with a LQ of only 0.22. Deciphering why Maui's relatively clear research activities are not showing up in the UCMP metrics would require surveying companies operating on the island and is beyond the scope of this report.

VI. AN EMERGING ENERGY INNOVATION CLUSTER?

The UCMP benchmark clusters include an Electric Power Generation and Transmission cluster (EPGTC) with subclusters in Fossil Fuel Electric Power, Alternative Electric Power, and Electric Power Transmission. The Alternative Electric Power subcluster in Hawaii consists of businesses generating electricity using geothermal, biomass, solar, wind, and other non-fossil fuels. Between 1998 and 2014, Hawaii added 80 jobs in the Alternative Electric Power subcluster, with the majority of those jobs added in Hawaii County. In fact, only Hawaii County has a high LQ, with a concentration of employment in renewable power generation that is 3.6 times greater than the average county nationwide. Growth of the Alternative Electric Power subcluster is at least partly due to state policy and the push for renewable energy. For the continental U.S., the power and transmission services produced by the EPGTC are traded

across state and county borders. But in Hawaii, the EPGTC is by definition a local cluster. While the state economy could benefit significantly if a switch in energy technologies leads to lower costs for electricity, once the transition is complete, the EPGTC will grow just like any other local cluster — at roughly the rate of the overall economy. To derive longer-term benefit from the EPGTC requires that the State's renewable energy goals serve as a catalyst for R&D and innovation that is traded — what we are here calling the Hawaii Energy Innovation Cluster (EIC).[13]

R&D and innovation around renewable energy in Hawaii is occurring across a number of industries that are part of both the EKCC and the large Business Services cluster. For example, R&D in the Physical, Engineering, and Life Sciences (NAICS 541712) and Custom Computer Programming Services (NAICS 541511) are both industries engaged in activities that are part of the EIC. The industries' 2014 LQ are 0.52 and 0.32, respectively. Combined they account for just 2,300 jobs, a large number presumably working outside of the area of renewable energy R&D. Therefore, even if we could compare Hawaii's EIC with others nationally, it is unlikely that it would be a strong cluster based on the UCMP definition (see footnote 7).

Nevertheless, Hawaii's Physical Engineering and Life Sciences industry grew by 39% from 2001 to 2014, significantly faster than the national growth rate of 25%. Over that same period, the Custom Computer Programing industry grew by 23% compared to a national growth rate of 38%. Some of this growth can likely be attributed to growth in energy-related R&D and innovation. So, there is evidence of market (and policy) driven economic activity. And, Hawaii does have many of the necessary resource attributes for regional "competitive advantage" and the conditions necessary for growth of both the Research Organizations and Computer Services subclusters, including Energy R&D and innovation. Below we discuss Hawaii's EIC from the perspective of Porter's four "Determinants of Competitive Advantage"—factor conditions, related and supporting industries, demand conditions, and firm strategy, structure and rivalry (see Figure 19).[14] Porter (1990, 2003) describes the many factors that contribute to becoming more productive. Among them, access to high quality factor inputs, availability of suppliers and supporting industries, existence of local rules and incentives that encourage investment, and sufficient demand conditions including strict quality, safety and environmental standards. Overall there must be vigorous competition in the creation of high quality goods and services, from local, national and global sources.

Factor Conditions

Hawaii has an environment rich in renewable resources, primarily wind and sun, but also ocean. For example, many locations in Hawaii have strong wind regimes with annual capacity factors in the range of 50-60% (Corbus et al., 2010). These conditions along with some of the world's most-costly electricity make Hawaii an ideal place for innovation in renewable energy generation and deployment. This abundance of physical resources along with the selective factor disadvantage of high priced petroleum based generation and physical remoteness have led to significant investment and accumulation of knowledge and human resources. Specifically, the Hawaii Natural Energy Institute (HNEI) at the University of Hawaii at Manoa is a critical component of the EIC. HNEI employees about 70 people, but these and other researchers at the University are not counted in the private non-farm employment data used by the UCMP.

An example of an HNEI-related energy R&D project is the Maui Smart Grid, which demonstrates how a "smart grid" can improve the function and efficiency of a local power grid (HNEI, 2014). The project involves cooperation

13 In addition, if the switch in technology used by the EPGTC reduces the high energy-cost factor disadvantage, other traded clusters will benefit. To the extent that other traded clusters are able to take advantage of the relative cost change, they may become more productive and expand more rapidly than they would have otherwise.

14 See section II and references in footnote 4 for a critique and interpretation of Porter's use of terms "competitiveness" and "competitive advantage".

between utilities (Maui Electric Company and parent company), government entities (County of Maui, U.S. Department of Energy, for-profit companies (including Hitachi, Alstom Grid, Corix, HNU-Energy, Silver Spring Networks and SRA International), advocacy and support organizations (including the Maui Economic Development Board) and additional University partners (Sustainable Living Institute of Maui at University of Hawaii Maui College). The smart meter technology is relatively straight-forward, but the impact on energy efficiency and grid modernization is potentially quite large when scaled up to a full size grid. The advanced metering infrastructure includes software platforms, advanced inverters and controllers that will enable more effective dynamic pricing and support grid services. The knowledge creation on Maui of how these systems can better leverage renewable energy resources could have profound implications for how economies across the world generate and use power.

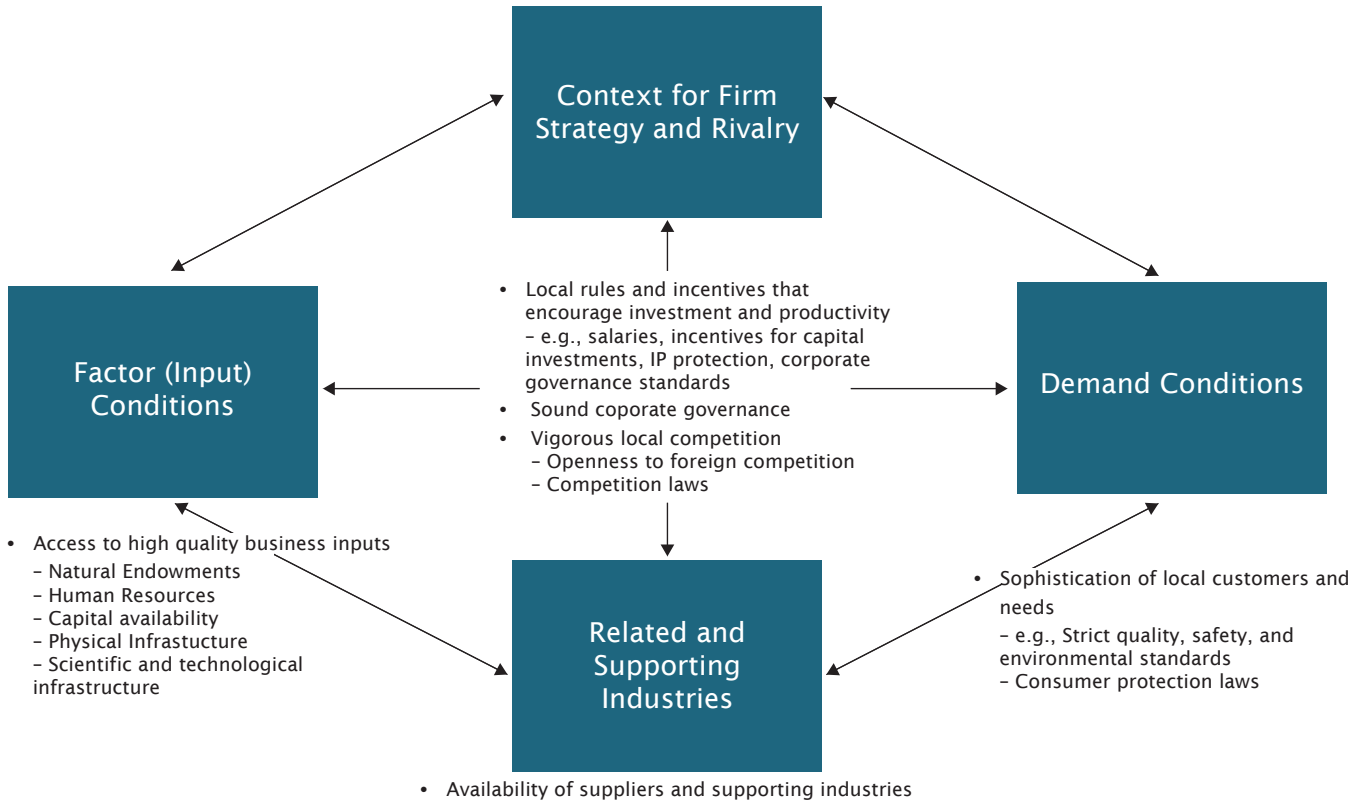
Beyond University of Hawaii research facilities, the state of Hawaii has invested in infrastructure that supports the EIC. For example, the Natural Energy Laboratory of Hawaii (NELHA) provides physical space for 31 clients to conduct R&D not only in energy but also more broadly in Ocean Sciences. It was at NELHA where the world's first grid-connected ocean thermal energy conversion (OTEC) plant was developed (Lockheed Martin, 2011). NELHA administers a research facility, the Hawaii Ocean Science & Technology (HOST) Park, funded in part by the State of Hawaii. Many client companies use the HOST Park to conduct research, including renewable energy projects such as OTEC, biofuels, and concentrated solar power.

A major factor disadvantage for Hawaii is the relative dearth of capital. According to data from the Money Tree Report from Price Waterhouse Coopers and CB Insights,[15] there was just under $200 million in venture capital investment in seventy-seven deals in Hawaii from 2003 to 2016. Twenty-two of the deals and $55 million in investment were made in Energy & Utilities. It is important to note that at least part of the explanation for the limited investment in Hawaii is the limited opportunities for investment associated with the very small clusters of activity described above. And Hawaii's remoteness certainly does not help. Both private sector and public efforts are underway to try and address Hawaii's limited deal flow and venture funding. New private venture firms are forming in Hawaii. A particularly interesting example is Sultan Ventures which manages the new XLR8UH venture accelerator focused on University of Hawaii startups. In 2011, the Hawaii Strategic Development Corporation launched the HI Growth Initiative with a $13 million grant from the U.S. Department of the Treasury's State Small Business Credit Initiative. After facilitating the creation of Blue Startups and GVS Transmedia, these two accelerator programs graduated over 40 startups. Over $60 million in funding has been generated, along with over 150 Hawaii-based jobs. The accelerators and their associated companies have spent approximately $10.8 million in the state of Hawaii (see Bonham, Burnett, and Rosen, 2016). The Elemental Excelerator, previously the Energy Excelerator, provides another example of a primarily federal investment, with some state and private monies, in this case directly focused on the Hawaii EIC. The Elemental Excelerator typically funds seed to series C stage start-ups, post R&D, to help demonstrate and launch their technologies. It currently funds 24 companies that are either headquartered in the state, demonstrating technology in the state, or a mainland-based company with an employee based in Hawaii (Elemental Excelerator, 2016). The Elemental Excelerator has reached not only on Hawaii but also the Asia-Pacific Region.

In sum, Hawaii's factor advantages include having a plethora of renewable energy resources, strong human capital in the area of energy development and innovation, and several important public investments in physical infrastructure. However, Hawaii also has major factor disadvantages in limited access to capital and the high cost of fossil fuel, land and other inputs. In addition, Hawaii's geographic location means that transportation costs are higher than most other places, and those costs are aggravated by lack of competition. Porter (1990) argues that it is the other parts of "the diamond" (see Figure 19) that influence whether firms can innovate around selective disadvantages.

15 Accessed online at https://www.pwc.com/us/en/technology/moneytree.html, January 31, 2017.

FIGURE 19: MICROECONOMIC COMPETITIVENESS: QUALITY OF BUSINESS ENVIRONMENT



SOURCE: RECREATED FROM PORTER (1990, 2009)

Demand Conditions

Hawaii's small size and distance from other markets make it difficult to develop traded industries characterized by significant economies of scale or that require large initial investments (that don't rely on a dominant natural resource advantage). On the other hand, consumers in Hawaii have long dealt with high energy costs. This likely leads to relatively sophisticated demand for alternative energy resources. Examples of such sophisticated demand include the DoD recognition of the importance of diversifying energy supplies and energy efficiency (2016 Operational Energy Strategy) as well as the high adoption of distributed solar PV. Nearly 17% of homes on Oahu have PV (Trabish, 2016). But the impact of even a savvy local demand, created in part through government intervention and subsidies, depends crucially on other parts of Porter's "diamond" discussed below.

Related and Supporting Industries

The presence of nationally or internationally competitive supplier industries creates advantages in downstream industries (Porter, 1990). And, international success in one industry generates pull through demand for complementary products and services. The best examples in Hawaii are in the tourism industry where internationally competitive accommodations and travel companies help create demand for various services from tour and excursion operators to restaurants and retail shopping experiences. One area where there is some evidence for the role of related industries in the EIC is the overlap between firms conducting R&D for the Department of Defense or in areas where Hawaii has a natural resource advantage such as Astronomy.[16] For example, HNU Energy conducts research, designs and

16 See Burnett, Cintina, and Wada (2014) for a discussion of the impact of Astronomy activities on Hawaii's economy.

builds custom energy solutions in areas such as smart grid technology, concentrated PV panels and electric vehicle quick charging technology. HNU Energy's parent company is HNU Photonics, a Maui based company specializing in optics, defense photonics and medical imaging technology with a long history of working on military projects. Another example of the role of related industries is Referentia Systems, Inc. They have long been engaged in cybersecurity work for the federal government, Department of Defense, as well as private sector clients. Referentia describes themselves as an applied R&D company and their primary NAICS classification places them in the Custom Computer Programming Services industry (NAICS 541511). Referentia has also focused on big-data smart grid applications. In January 2016, Referentia Systems spun off "in2lytics" as a new company focused on big-data smart grid management systems that can help small and mid-sized utilities efficiently integrate distributed renewable energy in legacy grid environments.

Other businesses operating in related industries include Makai Ocean Engineering and Oceanit. Both companies are self-classified in NAICS 541712—Research and Development in the Physical, Engineering, and Life Sciences –which employed 810 people in 2014 and grew at a rate of over 50% between 2001 and 2014. Makai Ocean Engineering is a diversified ocean engineering company working on everything from underwater pipelines and software for managing submarine cables to ocean based renewable energy R&D. Oceanit describes themselves as bringing disruptive thinking, science and engineering to create new knowledge and technology for humans and society. Their products include Advanced Materials (including fuel cell membranes), Sensor and Communication Systems, and Software. Together these companies employ about 250 people (Mergent Online, 2016), but only a fraction, if any, of these employees are likely focused full time on energy R&D.

Many of the examples given above are examples of companies that are operating across multiple industries, developing expertise and international competitiveness in areas where Hawaii has factor advantages or sophisticated demand from federal or DoD sources and then applying their developed expertise and human capital to specific problems in Energy R&D and innovation. As the Hawaii based accelerators continue to support new start-ups, many working on software and app development, we expect the EIC will continue to grow with possibly more growth in the Custom Computer Programing Services industry. Examples of such startups from the 2016 Excelerator Cohort include Carbon Lighthouse, PlottWatt, and Geli to name a few.

As we noted above, the industries where innovation for energy is most likely occurring in Hawaii have grown rapidly over the past decade, and there is evidence that factor conditions, home demand conditions, and the presences of competitive related industries all support growth of a Hawaii EIC. Yet, the EIC is still a very small collection of researchers, firms, university research centers and supporting state and county agencies. And, each of the "determinants of competitiveness" discussed above depend importantly on each other and on firm strategy, structure, and rivalry (Porter, 1990, 2003).

Firm Strategy, Structure, and Rivalry

"Among the strongest empirical findings from our research is the association between vigorous domestic rivalry and the creation and persistence of competitive advantage in an industry" (Porter, 1990, page 117). By competing vigorously with local rivals, firms are forced to constantly improve, innovate, and seek markets abroad to grow. But Hawaii is home to what appears to be a number of important industries with only limited competition, at least for the local market.[17] For Hawaii's energy production, examples of limited domestic (and national) rivalry include the difficulty electric utilities have in attracting competitive bids for projects such as wind farms that are small by national standards but large for Hawaii's market. By most measures, even as Hawaii's EIC continues to grow, it will likely remain

17 As with many of the other determinants discussed above, Hawaii's remoteness and very small market size contribute to limited competition for some industries.

small compared with EICs operating in much larger economies and ready markets for innovating renewable energy products and systems. California rises to the top of the clean-tech leaders overall according to Clean Edge, a research and advisory firm devoted to the clean-tech sector (2015a). Moreover, regions such as Oregon (Clean Edge, 2011) and New England (Meister Consultants Group, 2014) are positioning themselves to be national leaders in energy R&D.

While Hawaii's EIC may be much smaller than similar clusters in other regions, it may yet thrive due to a combination of factor advantages, selective disadvantages, and local policy context. State policy is pushing for dramatic integration of renewable sources for electricity—beyond what has occurred elsewhere—and therefore requiring innovative solutions. Hawaii's goal of meeting 100% of its net electricity sales from renewable sources by 2045 implies a massive shift from fossil fuels to solar, wind, and other renewable sources, along with integration of storage technology and demand side management. Beyond generation, which is by definition a local sector in Hawaii, government can help foster conditions for innovation; for example, by moving toward dynamic pricing for the power sector to create the market-incentives to test and launch transformative demand response and storage technologies. Our small and isolated grids, high penetration of renewables, and the high cost of fossil fuel generation stimulate grid and storage research and development (as they have in the Maui Smart Grid Project). The regulatory and policy environment must encourage local utilities and private distributed energy resource providers to experiment with new operating models and technologies.

Though Hawaii does not yet have a strong EIC, it does have many promising characteristics for growth. The EIC is supported by favorable factor conditions including natural resource advantages, a strong policy context and savvy but limited local demand conditions. On the other hand, Hawaii has major factor disadvantages related to small market size and distance from suppliers and global markets – likely affecting the renewable energy sector much like Hawaii's overall economy. A better understanding of the precise size and growth potential of Hawaii's EIC, requires company-level surveys that are currently out of scope.

VII. CONCLUSION

To better understand Hawaii's economy and prospects for growth, we document Hawaii's economic clusters at the state and county level and make comparisons to other US counties with similar characteristics. We focus on traded clusters, because the economic development literature has found important connections between the strength of a region's traded clusters and the growth of establishments, employment, patents, and wages.

In 2014, 37% of Hawaii's traded employment was in strong traded clusters ranking it 25th among all states. The typical state has ten strong traded clusters. In contrast, Hawaii has only three. The HTC, is by far the largest and strongest of Hawaii's traded clusters, with more than 55,000 jobs in 2014. Outside of the HTC, the remaining two strong traded clusters employ fewer than 4,000 workers. Furthermore, the average traded cluster wage for each of Hawaii's four counties is $20,000 to $30,000 less than the US average traded cluster wage. These relatively low wages are due to the mix of clusters, i.e. the dominance of the relatively low wage HTC, as well as the tendency of Hawaii's traded clusters to be relatively small and evidently focused more on the local market than would be expected nationally.

For each County, the basic picture is of a large, strong HTC and a handful of other small traded clusters. Over our study period, cluster employment growth differs markedly across counties, and some of the smaller traded clusters have grown much faster than the larger HTC. Honolulu has nine strong traded clusters employing 57% of total traded employment, ranking it 79th out of 3,147 counties nationwide. While Honolulu's HTC is clearly dominant in terms of employment (26,000), it lost more than 1,000 jobs between 1998 and 2014. Honolulu's fastest growing traded cluster

is the EKCC, with nearly 70% employment growth over the same period.[18] The EKCC is a strong traded cluster, with a LQ slightly larger than one. In contrast, many of Honolulu's other "traded clusters" such as Business Services, Distribution and Electronic Commerce, Financial Services, Marketing Design and Publishing, and Construction Product and Services have LQ well below one. This helps to explain why the 2014 average Honolulu County traded cluster wage was almost $20,000 lower than the average nationwide. Not only is Honolulu traded employment predominantly in clusters that are relatively low wage nationally, but the majority of the traded employment is in the HTC with an average wage of just over $38,000.

Compared to Oahu, the HTC is much more concentrated on Maui, Kauai, and Hawaii County, with LQs of 9.5, 8.5, and 7.0, respectively. And the HTC in all three counties grew employment over the 1998-2014 sample period. Outside of the HTC, the remaining strong clusters employed a total of 1,000 workers in Maui, 240 in Hawaii and 215 in Kauai County. Yet because of the strength of the HTC, all three counties rank in the top 3% nationwide on overall cluster strength— 43rd, 83rd, and 67th out of 3,147 counties respectively.

Comparing Maui and Honolulu County to US counties of similar size and either similar HTC concentration, or similar share of Federal DoD spending in county GDP, provides some insight into the importance of location and the size of Hawaii's counties. No US county is as isolated from other markets as those in Hawaii. Just as the HTC on Maui, Hawaii Island and Kauai benefit from the strength of the HTC and related clusters on Oahu, clusters on the continent benefit from strong clusters in their close proximity. But they are much closer to potentially many more strong clusters. The relatively small size of Maui, Hawaii and Kauai Counties, and their extreme remoteness contributes to the underdevelopment of strong traded clusters outside of tourism. Focusing on the importance of DoD spending, of the five counties we compare to Honolulu County, three have large Aerospace Vehicle and Defense clusters with LQ greater than four. In contrast, Honolulu, El Paso, and Anchorage Municipality have no significant Aerospace Vehicle and Defense concentration (each have clusters with LQ less than one and in the bottom 60% nationally). Honolulu and Anchorage with their distance from other markets, high transportation and energy costs have little in the way of manufacturing activity, and this helps to explain the lack of such defense related clusters. Unlike San Diego and other counties that are more concentrated in defense related R&D and manufacturing, Honolulu tends to see most defense spending concentrated in base operations and maintenance. Because such spending is closely tied to the size of the military presence in the state, many of the largest DoD contracts go to firms that are classified in the UCMP as part of local, not traded clusters.

Our interest in clusters is driven by research that finds that regional agglomeration effects drive economic activity and growth (Delgado, Porter, and Stern, 2012). That leads us to focus attention on the EKCC, a strong cluster on Oahu, and one of the fastest growing clusters across all but Maui County. From 1998 to 2014, the EKCC was the fastest growing traded cluster in Kauai and Honolulu counties, and the second fastest growing traded cluster in Hawaii County. The EKCC also pays the highest wage of all clusters in Hawaii County, and its Research Organizations subcluster generally pays wages near the very top of traded cluster wages statewide. We also explore the nascent Hawaii EIC, a cluster we describe but cannot compare nationally because it is not part of the UCMP benchmark definitions. Innovation around renewable energy in Hawaii is occurring across a number of industries that are part of both the EKCC and the large Business Services cluster. Though Hawaii does not yet have a strong EIC, it does have many promising characteristics that contribute to "competitiveness."

Though the literature on cluster development offers few salient policy recommendations, perhaps the most important is that policy should not aim to choose among clusters or individual industries but should support the

18 To facilitate comparisons with other clusters over the full sample from 1998 to 2014, throughout this section, we will rely only on UMCP data. As a result, conclusions regarding the EKCC are based on data excluding public CUPS. See Section V for a detailed discussion of the EKCC including the public CUPS over the shorter 2001 - 2014 sample period.

upgrading of all clusters present in a region. For example, no county in Hawaii has even a weak Aerospace & Defense cluster. Efforts to launch such an industry in Hawaii would be speculative at best.

A more effective role for government is to act as a convener of cluster participants, and this is already happening in Hawaii. In the case of Hawaii's EKCC and nascent EIC, private and public sector groups such as the various accelerators, the Hawaii Venture Capital Association, the Hawaii Strategic Development Corporation and High Tech Development Corporation are already well developed. Continued facilitation, for example through the efforts of the state's Development Corporations, the University of Hawaii and other groups, is vitally important. Moreover, identifying common needs between existing clusters, for example related to shared infrastructure and services, is likely a fruitful next step. Finally, it is important to recognize that a policy of upgrading all clusters in a region is consistent with the government's role in providing high quality public goods and services. In a world where people, ideas, and capital flow freely—yet location matters more than ever—maintaining the highest quality transportation and communication infrastructure, among others, is critical.

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REFERENCES

Bonham, C., K. Burnett, and S Rosen, (2016). The Evolution of the Hawaii Growth Initiative. *UHERO Project Report*, February 2017. Accessed on February 5, 2017 at http://www.uhero.hawaii.edu/assets/Evolution_HIGrowth_Initiative.pdf

Burnett, K, Inna Cintina, and C. Wada, (2014). The Economic Impact of Astronomy in Hawaii. *UHERO Project Report*, August 2014. Accessed on February 5, 2017 at http://www.uhero.hawaii.edu/assets/ UHERO_Astronomy_Final.pdf

Chatterji, A., E. Glaeser, W. Kerr, (2013). Clusters of Entrepreneurship and Innovation. *National Bureau of Economic Research*, Working Paper 19013, May.

Delgado, M., Porter, M., and Stern, S., (2010). Clusters and Entrepreneurship. *Journal of Economic Geography* 10(4): 495-518.

Delgado, M., Bryden R., and Zyontz, S. (2014). Categorization of Traded and Local Industries in the US Economy. US Cluster Mapping Project. Accessed February 17, 2017 at http://clustermapping.us/sites/default/files/files/page/Categorization%20of%20Traded%20and%20Local%20Industries%20in%20the%20US%20Economy.pdf

Delgado, M., Porter, M., and Stern, S. (2014). Defining Clusters of Related Industries. *Research Policy*, 43, 1785-1799.

Delgado, M., Porter, M., and Stern, S. (2014a). Clusters, Convergence and Economic Performance. *Research Policy*, 43, 1785-1799.

Department of Defense (2016). 2016 Operational Energy Strategy. Accessed on February 17, 2017 at http://www.acq.osd.mil/eie/Downloads/OE/2016%20DoD%20Operational%20Energy%20Strategy%20WEBc.pdf

Duranton, G. (2011). California Dreamin': the feeble case for cluster policies. *Review of Economic Statistics* 3 (1), 3–45.

Ellison, G., and Glaeser, E. (1999). Geographic Concentration of Industry. *American Economic Review* 89(2): 311-316.

Glaeser, E., and Gottlieb, J. (2009). The Wealth of Cities: Agglomeration Economies and Spatial Equilibrium in the United States. *Journal of Economic Literature*, 47(4), 983-1028.

Jacobs, J. (1969). The Economy of Cities. New York: Vintage.

Jaffe, A., Manuel, T., and Henderson, R. (1993). Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *Quarterly Journal of Economics*, 108(3), 577-598.

Ketels, C., and Memedovic, O. (2008). From Clusters to Cluster-Based Economic Development. International Journal of Technological Learning. *Innovation and Development*, 1(3), 375-392.

Lerner, Josh (2013). The Boulevard of Broken Dreams: Innovation Policy and Entrepreneurship. *Innovation Policy and the Economy*, Vol. 13, No. 1 (2013), pp. 61-82

Markusen, A. (2004). Targeting Occupations in Regional and Community Economic Development. *Journal of the American Planning Association*, 70(3), 253-268.

Markusen, A., and Schrock, (2006). The Distinctive City: Divergent Patterns in Growth, Hierarchy and Specialization. *Urban Studies*, 43(8), 1301-1323.
Mergent Online (2016), http://mergentonline.com.

Corbus, D., Schuerger, M., Roose, L., Strickler, J., Surles, T., Manz, D., Burlingame, D., and Woodford, D. (2010). Oahu Wind Integration and Transmission Study. Available at: http://www.nrel.gov/docs/fy11osti/48632.pdf

Neffke, F., Henning, M., and Boschma, R. (2011). How Do Regions Diversity Over Time? Industry Relatedness and the Development of New Growth Paths in Regions. *Economic Geography*, 87(3), 237-265.

O'Sullivan, A (2011). Urban Economics, 8th Edition. McGraw-Hill Education.

Porter, M. (1990). The Competitive Advantage of Nations. Harvard Business Review, Available at: https://hbr.org/1990/03/the-competitive-advantage-of-nations

Porter, M. (2003). *Regional Studies* 37:6-7, 549-578.

Porter, M. (2009). Institute for Strategy and Competitiveness.

Porter, M. (2010). The Economic Performance of Regions. *Regional Studies*, 37:6-7, 545-546.

Rodriguez-Clare, A. (2005). Clusters and Comparative Advantage: Implications for Industrial Policy. Available at: http://eml.berkeley.edu//~arodeml/Papers/Clusters-Sept-2005.pdf.

Stiglitz, Joseph E. Making globalization work. New York: W.W. Norton & Co, 2006.

Trabish, Herman. (2016). 17% of Hawaiian Electric customers now have rooftop solar. Published 1 February 2016. Available at: http://www.utilitydive.com/news/17-of-hawaiian-electric-customers-now-have-rooftop-solar/413014/

APPENDIX I: LIST OF TRADED CLUSTERS

TABLE A1: LIST OF TRADED CLUSTERS

Code	Cluster Name	No. of Industries	% of Traded Employment (2009)
1	Aerospace Vehicles and Defense	7	0.013
2	Agricultural Inputs and Services	9	0.002
3	Apparel	21	0.004
4	Automotive	26	0.019
5	Biopharmaceuticals	4	0.006
6	Business Services	33	0.242
7	Coal Mining	4	0.002
8	Communications Equipment and Services	8	0.013
9	Construction Products and Services	20	0.018
10	Distribution and Electronic Commerce	62	0.130
11	Downstream Chemical Products	13	0.006
12	Downstream Metal Products	16	0.010
13	Education and Knowledge Creation	15	0.068
14	Electric Power Generation and Transmission	5	0.003
15	Environmental Services	7	0.002
16	Financial Services	26	0.049
17	Fishing and Fishing Products	5	0.001
18	Food Processing and Manufacturing	47	0.022
19	Footwear	6	0.000
20	Forestry	4	0.002
21	Furniture	12	0.009
22	Hospitality and Tourism	31	0.070
23	Information Technology and Analytical Instruments	27	0.026
24	Insurance Services	8	0.038
25	Jewelry and Precious Metals	4	0.001
26	Leather and Related Products	6	0.001
27	Lighting and Electrical Equipment	15	0.008
28	Livestock Processing	5	0.012
29	Marketing, Design, and Publishing	22	0.029
30	Medical Devices	5	0.007
31	Metal Mining	8	0.001
32	Metalworking Technology	17	0.012
33	Music and Sound Recording	5	0.001
34	Nonmetal Mining	13	0.002

SOURCE: DELGADO, PORTER, AND STERN (2014). DOWNLOADED AT HTTP://WWW.CLUSTERMAPPING.US/CONTENT/CLUSTER-MAPPING-METHODOLOGY.

TABLE A1: LIST OF TRADED CLUSTERS (CONTINUED)

Code	Cluster Name	No. of Industries	% of Traded Employment (2009)
35	Oil and Gas Production and Transportation	12	0.013
36	Paper and Packaging	20	0.009
37	Performing Arts	8	0.007
38	Plastics	15	0.016
39	Printing Services	13	0.013
40	Production Technology and Heavy Machinery	41	0.023
41	Recreational and Small Electric Goods	15	0.005
42	Textile Manufacturing	23	0.005
43	Tobacco	3	0.000
44	Trailers, Motor Homes, and Appliances	9	0.003
45	Transportation and Logistics	17	0.038
46	Upstream Chemical Products	12	0.004
47	Upstream Metal Manufacturing	26	0.009
48	Video Production and Distribution	6	0.005
49	Vulcanized and Fired Materials	17	0.006
50	Water Transportation	12	0.007
51	Wood Products	13	0.009

SOURCE: DELGADO, PORTER, AND STERN (2014). DOWNLOADED AT HTTP://WWW.CLUSTERMAPPING.US/CONTENT/CLUSTER-MAPPING-METHODOLOGY.

APPENDIX II DEFINING CLUSTERS OF INDUSTRIES

DPS use cluster analysis to classify related industries into groups so that the industries in a cluster are more similar to each other than to industries in outside of the cluster. Their cluster algorithm produces a cluster configuration, C, based on the choice of similarity matrix, M_{ij}, broad parameter choices, β, such the number of clusters and starting values, and choice of cluster function, F.

The similarity matrix plays a central role in their algorithm as it determines the relatedness between pairs of industries i and j based on the choice of indicator used and the measure of similarity. For indicators, they use employment, number of establishments, measures of buyer-supplier linkages, and measures of shared labor requirements. For similarity measures, DPS use Locational Correlation (LC) to measures both employment and establishment co-location of pairs of industries to capture various types of inter-industry linkages.[19] They find that the average LC-Employment of a pair of industries is 0.30, while that of establishments is 0.52. Other measures of similarity include Ellison, Glaeser, and Kerr's (2010) Coagglomeration Index (COI), Input-Output Links (IO), and labor occupation links (Occ). The COI captures whether two industries are more co-located than expected if their employment is distributed randomly, while IO is used to capture supplier and buyer flows between industries. Using the Benchmark IO Accounts of the US, they

19 The Locational Correlation of Employment is simply the correlation of employment in industry i and employment of industry j in region r, similarly for establishments. DPS use data on 179 Economic Areas as defined by the Bureau of Economic Analysis. EAs cover the entire continental US, and do not suffer from the high level of suppression for confidentiality reasons that occurs in county level data.

construct a symmetric IO link between any pair of industries i,j based on the maximum of all unidirectional input and output links, where the input link is the share of industry i's total value of inputs that comes from industry j, and the output link is the share of industry i's total value of outputs that goes to industry j. For labor occupation links(Occ), they rely on data from the 2009 Occupational Employment Statistics (OES) Survey of the Bureau of Labor Statistics to compute the pairwise correlation between the occupation composition of any two industries.[20]

Finally, in addition to similarity matrices based on single measures of interrelatedness, the DPS algorithm allows for use of multidimensional similarity matrices that for example combines the LC, IO, and Occ in a single M_{ij} that is an average of the four M_{ij} associated with these measure.

For each cluster configuration C generated for different choice of M_{ij}, β or cluster function F, DPS score the configuration based on the criterion that industries within a particular cluster should be more closely related to each other than to industries in other clusters. To assesses this criteria, they use alternative measures of inter-industry linkages than those used for defining the cluster configuration to create validation sub-scores. By combining the sub-scores from use of alternative measures of inter-industry relatedness, the derive an overall validation score, VS, for each cluster configuration. The configurations with the highest ranks go through a series of robustness checks further assessment.

DPS applies their clustering algorithm to generate 713 different cluster configurations that group 778 6-digit NAICS industries using 2009 U.S. data. These configurations are based on 13 different similarity matrices (M_{ij}) and the parameter and clustering function choices discussed in the prior section ($C=F(M_{ij}, \beta)$). They find that Cs generated with the multidimensional LC-IO-Occ_{ij} matrix have, on average, statistically significant higher VS scores than other Cs generated based on unidimensional matrices. And the final set of cluster definitions is based on this Multidimensional matrix which generates meaningful sets of cluster definitions that capture a broad set of industry interdependencies. The final set of cluster definitions is available at the UCMP website US Cluster Definitions. Table A2 below provides a summary of Traded Cluster Definitions.

20 The OES data provides 792 non-governmental occupations and information on the prevalence of these occupations for each industry (i.e., for each occupation (e.g., computer programmers); it provides the percentage of that occupation in the total occupational employment of the industry).

TABLE A2: SUMMARY OF TRADED CLUSTER DEFINITIONS

Code	Cluster Name	Description
1	Aerospace Vehicles and Defense	Establishments in this cluster manufacture aircraft, space vehicles, guided missiles, and related parts. This cluster also contains firms that manufacture the necessary search and navigation equipment used by these products.
2	Agricultural Inputs and Services	This cluster includes establishments primarily engaged in farming and related services. Farming includes soil preparation, planting, cultivatation, harvest, fertilizer creation, and post-harvest activities. It also includes services that supply farm labor, support for animal production, and additional operations management.
3	Apparel	The establishments in this cluster are focused on manufacturing clothing and fabric accessories (for example, hats, gloves, and neckties) for men, women, and children.
4	Automotive	This cluster includes establishments along the value chain that are necessary for manufacturing cars, trucks, and other motorized land-based transportation equipment (other than motorcycles). This includes metal mills and foundries, manufacturers of metal automotive parts, and manufacturers of completed automobiles.
5	Biopharmaceuticals	Establishments in this cluster produce complex chemical and biological substances used in medications, vaccines, diagnostic tests, and similar medical applications.
6	Business Services	Firms in this cluster include establishments and services primarily designed to support other aspects of a business or to assist unrelated companies. This includes corporate headquarters. Professional services such as consulting, legal services, facilities support services, computer services, engineering and architectural services, and placement services. All for-hire ground passenger transportation services are also present in this cluster.
7	Coal Mining	This cluster includes establishments that mine coal and provide services to support coal mining.
8	Communications Equipment and Services	This cluster involves goods and services used for communications. This includes cable, wireless, and satellite services, as well as telephone, broadcasting, and wireless communications equipment.
9	Construction Products and Services	The establishments in this cluster supply construction materials, components, products, and services. Construction materials and components include those made of sand, stone, gravel, asphalt, cement, concrete, and other earthen substances. Construction products include pipes and heat exchangers. Construction services include the construction of pipelines for water, sewers, oil and gas, power, and communication, as well as building services for homes and industrial buildings.

SOURCE: DELGADO, PORTER, AND STERN (2014). DOWNLOADED AT HTTP://WWW.CLUSTERMAPPING.US/CONTENT/CLUSTER-MAPPING-METHODOLOGY.

TABLE A2: SUMMARY OF TRADED CLUSTER DEFINITIONS

Code	Cluster Name	Description
10	Distribution and Electronic Commerce	This cluster consists primarily of traditional wholesalers as well as mail order houses and electronic merchants. The companies in this cluster mostly buy, hold, and distribute a wide range of products such as apparel, food, chemicals, gasses, minerals, farm materials, machinery, and other merchandise. The cluster also contains firms that support distribution and electronic commerce operations, including packaging, labeling, and equipment rental and leasing.
11	Downstream Chemical Products	Establishments in this cluster manufacture complex chemical products for end users. These products include adhesives, beauty products, soaps, cleaners, film processing chemicals, dyes, paints, explosives, and lubricating oils.
12	Downstream Metal Products	This cluster contains establishments that manufacture metal containers, prefabricated metal structures, and end user metal products. These end user products include ammunition, kitchenware, hardware, metal bathroom fixtures, and similar metal products used in home finishing such as doors, windows and ornamentation.
13	Education and Knowledge Creation	This cluster contains all educational and training institutions, as well as related supporting establishments. It also includes research and development institutions in biotechnology, physical sciences, engineering, life sciences, and social sciences.
14	Electric Power Generation and Transmission	This cluster contains establishments primarily engaged in generating and distributing electric power. This includes power generated from alternative energy sources such as hydroelectric power, nuclear electric power, and solar and wind generated electric power.
15	Environmental Services	This cluster contains establishments primarily engaged in collection, treatment, processing, and disposal of hazardous and non-hazardous waste.
16	Financial Services	This cluster contains establishments involved in aiding the transaction and growth of financial assets for businesses and individuals. These firms include securities brokers, dealers, and exchanges; credit institutions; and financial investment support. Insurance firms are located in a separate Insurance Services cluster.
17	Fishing and Fishing Products	Establishments in this cluster are engaged primarily in catching fish and other seafood and processing the catch for consumption.
18	Food Processing and Manufacturing	This cluster includes firms involved in the processing of raw food materials and the manufacturing of downstream food products for end users. This includes millers and refineries of rice, flour, corn, sugar, and oilseeds. These upstream products contribute in part to producing specialty foods, animal foods, baked goods, candies, teas, coffees, beers, wines, other beverages, meats, packaged fruits and vegetables, and processed dairy products.
19	Footwear	Establishments in this cluster are those that manufacture men's and women's shoes, boots, slippers, and other footwear (including athletic shoes). This cluster also contains the upstream finished leather used in making footwear.

SOURCE: DELGADO, PORTER, AND STERN (2014). DOWNLOADED AT HTTP://WWW.CLUSTERMAPPING.US/CONTENT/CLUSTER-MAPPING-METHODOLOGY.

TABLE A2: SUMMARY OF TRADED CLUSTER DEFINITIONS

Code	Cluster Name	Description
20	Forestry	Establishments in this cluster are those that involve growing and harvesting trees. It also includes support services for these activities.
21	Furniture	This cluster contains establishments that manufacture furniture, cabinets, and shelving for residential homes and offices. It also includes establishments that produce manufactured homes. The products in this cluster can be made of wood, metal, plastic, and/or textiles.
22	Hospitality and Tourism	This cluster contains establishments related to hospitality and tourism services and venues. This includes sport venues, casinos, museums, and other attractions. It also includes hotels and other accommodations, transportation, and services related to recreational travel such as reservation services and tour operators.
23	Information Technology and Analytical Instruments	This cluster consists of information technology and analytical products such as computers, software, audio visual equipment, laboratory instruments, and medical equipment. The cluster also includes the standard and precision electronics used by these products (for example, circuit boards and semiconductor devices).
24	Insurance Services	This cluster consists of firms providing a range of insurance types, as well as support services such as reinsurance and claims adjustment.
25	Jewelry and Precious Metals	Establishments in this cluster manufacture jewelry, silverware, and fine tableware. This cluster also includes the upstream manufacture of jewelry parts and the processing of gemstones.
26	Leather and Related Products	This cluster consists of manufacturers of luggage and handbags made of leather and fabric. It also includes producers of personal and assorted other leather goods, as well as mills that produce textile bags and related products made from canvas.
27	Lighting and Electrical Equipment	This cluster contains firms involved in the manufacture of electrical equipment and electronic components. The companies in this cluster manufacture wire for communications, wiring devices, fiber optic cables, switchboards, lighting fixtures, motors, transformers, and related products.
28	Livestock Processing	This cluster contains establishments engaged in processing meat from livestock and livestock wholesaling.
29	Marketing, Design, and Publishing	This cluster consists of establishments involved in design services (physical and graphical), marketing (including advertising creation, marketing research, media buying, and public relations), and publishing (both in hard copy and on the internet).
30	Medical Devices	Establishments in this cluster primarily manufacture surgical, medical, dental, optical, ophthalmic, and veterinary instruments and supplies.
31	Metal Mining	Establishments in this cluster mine various metals including iron, gold, silver, lead, copper, and uranium. It also includes firms involved in supporting metal mining activities.
32	Metalworking Technology	The establishments in this cluster manufacture machine tools and process metal for use in metal working. The cluster also contains the downstream manufacture of metal fasteners and hand tools.

SOURCE: DELGADO, PORTER, AND STERN (2014). DOWNLOADED AT HTTP://WWW.CLUSTERMAPPING.US/CONTENT/CLUSTER-MAPPING-METHODOLOGY.

TABLE A2: SUMMARY OF TRADED CLUSTER DEFINITIONS

Code	Cluster Name	Description
33	Music and Sound Recording	Establishments in this cluster are primarily involved in the production and distribution of music and other sound recordings.
34	Nonmetal Mining	Establishments in this cluster mine earthen materials other than metals. This includes stone, granite, sand, clay, borate, and other minerals. The cluster also includes support for the nonmetal mining activities.
35	Oil and Gas Production and Transportation	This cluster includes firms involved in locating, extracting, refining, and transporting oil and gas. This includes companies that manufacture the equipment necessary to extract oil and gas, as well as companies that provide support services for oil and gas operations and pipeline transport.
36	Paper and Packaging	This cluster contains the paper mills and manufacturers of paper products used for shipping, packaging, containers, office supplies, personal products, and similar products.
37	Performing Arts	This cluster contains services that produce, promote, and support live artistic performances. Live performances include those by theater companies, dance troupes, musicians, and independent artists.
38	Plastics	Establishments in this cluster manufacture plastic materials, components, and products. The plastics and foams are manufactured for packaging, pipes, floor coverings, and related plastic products. The cluster also includes the upstream manufacturing of plastic materials and resins, as well as the industrial machines used to manufacture plastics.
39	Printing Services	Establishments in this cluster are primarily engaged in commercial printing, digital printing, and binding. The cluster includes upstream products and services necessary for printing (for example, ink and prepress services). It also includes end products such as books, greeting cards, business forms, and related goods.
40	Production Technology and Heavy Machinery	Establishments in this cluster primarily manufacture machines designed to produce parts and devices used in the production of downstream products. This cluster also includes end use heavy machinery such as air and material handling equipment. The machines are used for industrial, agricultural, construction, commercial industry, and related purposes.
41	Recreational and Small Electric Goods	This cluster contains establishments that manufacture end use products for recreational and decorative purposes. These products include games, toys, bicycles, motorcycles, musical instruments, sporting goods, art supplies, office supplies, shades, and home accessories. This cluster also incorporates firms that produce small, simple electric goods like hairdryers, fans, and office machinery.
42	Textile Manufacturing	This cluster contains textile mills that primarily produce and finish fabrics for clothing, carpets, upholstery, and similar uses. The textiles include yarn, thread, fibers, hosiery, knits, and other specialty fabrics.
43	Tobacco	The establishments in this cluster manufacture cigarettes and other tobacco products. This also includes upstream tobacco leaf processing.

SOURCE: DELGADO, PORTER, AND STERN (2014). DOWNLOADED AT HTTP://WWW.CLUSTERMAPPING.US/CONTENT/CLUSTER-MAPPING-METHODOLOGY.

TABLE A2: SUMMARY OF TRADED CLUSTER DEFINITIONS

Code	Cluster Name	Description
44	Trailers, Motor Homes, and Appliances	This cluster includes establishments that manufacture trailers, campers, and motor homes, as well as major household appliances.
45	Transportation and Logistics	This cluster contains all air, rail, bus, and freight transportation services. It also includes related operation services and support activities such as inspections, maintenance, repairs, security, and loading/unloading.
46	Upstream Chemical Products	This cluster consists of firms that manufacture basic organic and inorganic chemicals and gases. The chemicals are usually separate elements that could be used as inputs for more complex downstream chemical products.
47	Upstream Metal Manufacturing	The establishments in this cluster manufacture upstream metal products such as pipes, tubes, metal closures, wires, springs, and related products. The cluster includes iron and steel mills and foundries, as well as related metal processing techniques.
48	Video Production and Distribution	The establishments in this cluster are primarily involved with the production and distribution of motion pictures and other video. This includes specialized viewing venues such as drive-in theaters.
49	Vulcanized and Fired Materials	This cluster contains firms that manufacture construction and other materials out of earthen substances such as clay, sand, and rubber at extremely high temperatures. The production processes create goods made of tile, brick, ceramic, glass, and rubber (including refractories and tires).
50	Water Transportation	This cluster contains all establishments involved in transporting people and goods over water. The cluster includes boat building, transportation, operations, and other support services.
51	Wood Products	The establishments in this cluster are primarily engaged in making upstream wood materials and manufacturing non-furniture wood products. Upstream establishments include sawmills, plywood and hardwood manufacturers, cut stock manufacturers, and wood preservation services. Downstream establishments produce windows, doors, flooring, wood containers, prefabricated wood buildings, and related products.

SOURCE: DELGADO, PORTER, AND STERN (2014). DOWNLOADED AT HTTP://WWW.CLUSTERMAPPING.US/CONTENT/CLUSTER-MAPPING-METHODOLOGY.

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