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The Stability of Location Quotients*

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Abstract: Although location quotients are widely used to analyze local industry specialization and identify industry clusters in regions of all size, past studies have noted issues related to the accuracy of location quotients in small places. This paper examines the stability of location quotients in response to a marginal (i.e., one-unit) increase in the number of business establishments, with a focus on small regions. The analysis considers location quotients calculated for cities and towns in Maine, as well as all U.S. counties, and uses a range of industry classifications (e.g., 1-digit and 3-digit NAICS categories). Results show that the stability of location quotients increases with the population size of regions, but they do not uncover a single, universal population size cutoff for the reliable use of location quotients. Rather, the analysis shows that population size, the level of industry aggregation (e.g., 1-digit versus 3-digit NAICS) and even how the data are collected matter in determining the stability of location quotients.

Keywords: clusters, industry specialization, small regions, location quotients

JEL Codes: R10, R11, R12

1. INTRODUCTION

Location quotients are one of the oldest and most popular measures of state and local industry structure used in the study and practice of regional analysis and policy (Haig, 1926). As an indicator of the extent to which a region specializes in the production of a particular good or service, location quotients are used to identify sectors that are clustered in a given place (Carroll et al., 2008; Porter, 1990; O'Donoghue and Gleave, 2004; Tian, 2013). When using them to uncover clusters and "pick winners," the emphasis is often on calling out the exact sectors with high values of the location quotient (Crawley and Hallowell, 2021). Since regional industry specialization can result in cost savings to firms,

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location quotients are also used to represent localization economies and places that provide a thick labor market, a ready supply of specialized inputs and machinery, and facilitate the flow of knowledge spillovers (De Propris, 2005; Kemeny and Storper, 2015; Marshall, 1920). When used as a measure of industry specialization, researchers often examine the effect of location quotients on other regional indicators such as industry employment change or new business startups (Artz et al., 2016; Bagchi-Sen et al., 2020; Fracasso and Vittucci Marzetti, 2018; Gabe, 2003, 2017; Glaeser et al., 1992).

The location quotient is a point estimate, which provides evidence on the level of industry specialization in a region, but it is traditionally not reported with a measure of statistical confidence (Crawley et al., 2013). Calculated as the ratio of an industry's percentage of employment (or establishments) in the region of interest relative to the industry's percentage of employment (or establishments) in a benchmark economy, location quotients are sensitive to the level of industry aggregation, how regions are defined, and the choice of the benchmark. For example, the analysis of location quotients at a highly aggregated industry level (e.g., Manufacturing, Financial Services) may not provide evidence of industry agglomeration (i.e., the industry location quotient may be less than or equal to 1.0), even though the region may specialize in a narrowly defined sector. Likewise, the analysis of location quotients in small cities and towns is often complicated by relatively low populations and thus may provide evidence of industry specialization (i.e., location quotient greater than 1.0) with only one or a few businesses operating in the region-industry pair.

This paper examines the stability of location quotients across the population size spectrum of U.S. regions. Stability is measured as the extent to which location quotients are influenced by a marginal (i.e., one-unit) change in the count of establishments in the region-industry[1]. Our results provide evidence of how the stability of location quotients increases with the population size of regions, but they do not uncover a single, universal population size cutoff for the reliable use of location quotients. Rather, the analysis shows that population size, the level of industry aggregation (e.g., 1-digit versus 3-digit NAICS) and even how the data are collected matter in determining the stability of location quotients. For example, analysis of 3-digit NAICS sectors across U.S. counties shows that location quotients are highly stable in places with one million or more people, and moderately stable in counties with between 100,000 and one million residents. In the county-level analysis of 1-digit NAICS categories, location quotients are moderately stable in places with 500 to 24,999 residents (and highly stable in counties with 25,000 or more people).

2. BACKGROUND AND MOTIVATION

The widespread use of location quotients in the empirical analysis of regional economies is due to their limited data requirements and ease of interpretation(Isserman, 1977; Tian,

[1]Although it is unlikely that a very small region would experience a one-business increase in certain types of sectors (e.g., transportation equipment manufacturing, alternative energy and turbines), our analysis highlights the limitations of using location quotients in regions with a small base of establishments and sectors that account for a small share of the benchmark economy. In addition, a one-unit change in the number of establishments could happen—even in small regions—as a result of an administrative miscounting or misclassification of businesses.

2013). In addition to location quotients, other indicators such as spatial statistics (Carroll et al., 2008; Goetz et al., 2009), the Ellison-Glaeser index (Ellison and Glaeser, 1997) and measures of industry linkages (Delgado et al., 2016; Feser and Bergman, 2000) have been employed in the analysis of industry concentration and regional industry specialization. A key limitation of location quotients, which is the focus of this paper, is their difficulty in identifying industry clusters and accurately measuring industry specialization (Woodward and Guimarães, 2009), particularly in very small regions (Tian et al., 2020). For example, Carroll, Reid and Smith note that "a few auto plants in a rural Indiana county may generate a higher location quotient than the large automobile employment concentration in Wayne County, Michigan." This issue of "a few" establishments generating a misleadingly high location quotient in a small region is very much at the heart of our analysis.

Other often cited limitations of using simple location quotients in empirical research—and these are closely related to (and exasperated by) the "small region problem" described above—are that they are based on a single industry and a single location. It may be incomplete to use location quotients that focus on a single industry because the benefits of clusters and industry localization are due to the presence of a good or service's entire supply chain along with supporting infrastructure and institutions, and a pooled labor force (Porter, 2000). As a way to overcome this limitation and incorporate an industry's supply chain, studies by Feser and Bergman (2000), Feser et al. (2008) and Yang and Stough (2005) identified clusters based on linkages across multiple sectors of the economy.

An issue related to the use of location quotients that focus on a single region (e.g., county, town, etc.) is that clusters often straddle administratively defined borders (Duranton and Overman, 2005). In other words, there is no reason why a group of firms that produce a similar good, and businesses that supply related products and services, needs to line up with the geographic boundaries of towns, counties or even states. Related to this issue, Crawley and Pickernell (2012) examined how different sizes of regions masked the number of clusters identified by the European Cluster Observatory. To address this limitation of location quotients, Carroll et al. (2008) used the Geti-Ord measure of spatial autocorrelation to identify multi-county indicators of industry clusters, and Tian et al. (2020) employed a spatial input-output location quotient (SI-LQ) that accounts for linkages across county borders.

Another challenge related to the use of location quotients, which is relevant regardless of how sectors or regions are defined, is coming up with an appropriate cutoff to identify industry clusters (i.e., a sufficiently high level of regional industry specialization). By construction, a location quotient value of greater than 1.0 means that an industry's share of total employment (or establishments) in the region of interest exceeds this percentage in the benchmark economy. Following this general guideline, research by De Propris (2005) and Delgado et al. (2014) used location quotient cutoffs of 1.25 or higher to identify clusters. In other studies, Crawley et al. (2013), O'Donoghue and Gleave (2004), and Tian (2013) exploit information on the distribution of location quotient values across regions to determine appropriate cutoffs (e.g., upper five percent of the distribution) for identifying high levels of industry specialization.

Building from the existing literature on the pitfalls and limitations of using location quotients to identify clusters and measure industry specialization, we focus on the stability of location quotients in response to a one-unit increase in the number of establishments in a region-industry pair. This could happen if a new business begins operations in a region, or because of an administrative misclassification or miscounting of businesses. Whatever the source, a large change in the location quotient due to a marginal increase in the number of establishments is characterized as instability in the location quotient. Our results show that, especially when conducting analysis at a disaggregated industry level, location quotients are often highly unstable in small regions. This means that the main concern regarding the use of location quotients in very small places is not just related to the appropriate cutoff to identify industry clusters. Instead, the tool may be an unreliable measure of industry specialization in small regions at any cutoff level of the location quotient, even when extremely high values are observed.

The paper's main contribution to the literature is to provide a practical demonstration of how location quotients are influenced by a marginal change in region-industry size. Although we are primarily interested in the connection between the stability of location quotients and a region's population size, which contributes to the literature on the challenges of using location quotients in small areas (Carroll et al., 2008; Tian et al., 2020), the paper also examines the stability of location quotients across different levels of industry aggregation (e.g., 1-digit and 3-digit NAICS sectors). This information, along with some guidelines and suggestions for using location quotients presented at the end of the paper, will help researchers and practitioners in the study of regional industry specialization and industry cluster analysis.

3. MEASURING THE STABILITY OF LOCATION QUOTIENTS

A common use of location quotients is to measure industry agglomeration and identify regions with a high specialization in a given industry. Although there are differences in the exact cutoffs used to define clusters (Akgüngör et al., 2003; Carroll et al., 2008; Delgado et al., 2016; Manzini and Luiz, 2019; Mendoza-Velazquez, 2017), location quotients that exceed 2.0 indicate that an industry's percentage of regional employment (or establishments) is more than twice as high as the industry's percentage of employment (or establishments) in the benchmark. A location quotient of, say, 2.5 in a big metropolitan area might signify a reasonably large group of businesses that function as a distinct industry cluster, whereas a similar (or even much larger) value of the location quotient in a small town might represent a single, isolated establishment (Carroll et al., 2008).

To illustrate the method used to examine the stability of location quotients, we start by calculating location quotients for 6,136 region-industry pairs in Maine. The dataset covers 472 cities and towns—ranging in size from fewer than 100 residents to more than 60,000 people—and 13 industry groups[2]. The industry groups, which do not cover all sectors of the economy, are based on classifications used by the Battelle Institute and Maine Technology Institute—referred to as "Battelle clusters" throughout the paper—to study industry clusters in Maine. The industry groups (e.g. Environmental Services, Forestry-Related Products,

[2]The five largest cities in Maine are Portland (66,715 people), Lewiston (36,211 people), Bangor (32,237 people), South Portland (25,431 people) and Auburn (22,941 people).

and Medical Devices) consist of as few as three, and as many as 50, six-digit NAICS codes[3]. They vary in size from industry groups that are a small part (e.g., Boatbuilding and Related Industries) of the benchmark region (i.e., the United States), to groups that are relatively large contributors (Finance and Business Support Services) to the U.S. economy. The number of establishments in the 6,136 region-industry pairs is counted using Dun and Bradstreet records from 2017[4].

Table 1 shows the top 20 location quotients from the 6,136 region-industry pairs considered in the analysis. Seven region-industry pairs have location quotients that exceed 200, suggesting that an industry's share of establishments in a place is more than 200-times larger than the industry's share of U.S. establishments, and another 13 region-industry pairs in the table have location quotients of between 100 and 200. Although places with a population of 500 or fewer people represent about one-quarter of the towns in the dataset, they account for over one-third of the region-industry pairs with the highest location quotients.

Atkinson, Maine, which has a population of 322 people and a total of 12 business establishments, is home to the "largest" industry cluster in Maine. The Boatbuilding and Related Industries sector's share of Atkinson's establishments is 573-times larger than the industry's share of U.S. businesses. In reality, the cluster consists of two establishments in the five NAICS categories that make up the cluster (see footnote 3). In fact, almost all (17 of 20) of the most highly specialized industry sectors highlighted in Table 1 consist of one or two establishments. If a single company in the cluster were to disappear, the location quotient would fall by a very large amount. Likewise, the location quotient would change dramatically if the industry sector were to grow by one establishment or if a few other businesses (in different sectors) were to begin operations in the region.

To examine the stability of industry location quotients, we performed an experiment — involving the calculation of "adjusted" location quotients — that added one hypothetical establishment to each of the 13 industry sectors in all 472 regions. A comparison of the actual and adjusted location quotients shows the extent to which the measure of regional industry agglomeration is impacted by a marginal change in the region-industry's size. Such a change in region-industry size could happen if a new business located in the area, or even due to an administrative misclassification of an establishment's industry sector and/or a miscounting of businesses located in a region. Crawley et al. (2013) note that, in some applications of location quotients, publicly available employment figures and establishment counts may be imputed estimates rather than direct figures. In a small rural area, where data are more often to be suppressed, an estimated figure that varies from the region-industry's actual size (by even a small amount) can have a sizable impact on the location quotient.

For example, equations 1 and 2 show the calculations for the actual and adjusted location quotients, focusing on Atkinson's Boatbuilding and Related sector:

[3]For example, the Boatbuilding and Related Industries sector is made up of the Plastics material and resin manufacturing (NAICS: 325211), Synthetic rubber manufacturing (NAICS: 325212), Cellulosic organic fiber manufacturing (NAICS: 325221), Noncellulosic organic fiber manufacturing (NAICS: 325222), and Boat building (NAICS: 336612) industries.

[4]The other data sources used to calculate the region-industry location quotients are described later in the paper.

Table 1: Top 20 Location Quotients in Maine Region-Industry (Battelle Cluster) Pairs

Town	Industry Sector	Town Population	Number of Establishments	Location Quotient
Atkinson	Boatbuilding and Related Industries	322	2	573
Isle au Haut	Alternative Energy and Turbines	27	1	548
Brooklin	Boatbuilding and Related Industries	857	7	463
Atkinson	Alternative Energy and Turbines	322	1	411
Cranberry Isles	Boatbuilding and Related Industries	143	1	344
Beals	Boatbuilding and Related Industries	405	1	246
North Haven	Boatbuilding and Related Industries	540	2	208
Carroll Plantation	Forestry-Related Products	136	1	180
Arundel	Alternative Energy and Turbines	4,186	8	168
Long Island	Boatbuilding and Related Industries	257	1	164
Athens	Alternative Energy and Turbines	972	1	154
Garland	Alternative Energy and Turbines	1,237	1	145
Parsonsfield	Alternative Energy and Turbines	1,958	1	137
Southwest Harbor	Boatbuilding and Related Industries	1,684	7	132
Sedgwick	Boatbuilding and Related Industries	1,180	2	123
Exeter	Alternative Energy and Turbines	1,061	1	117
Perry	Alternative Energy and Turbines	655	1	117
Steuben	Boatbuilding and Related Industries	1,228	2	117
Surry	Boatbuilding and Related Industries	1,605	2	107
South Bristol	Boatbuilding and Related Industries	1,000	1	107

Notes: Town population figures are from the U.S. Census Bureau for the year 2017. Dun and Bradstreet records from 2017 are used to count the number of establishments in Maine cities and towns. When calculating the location quotient, the numbers of establishments in the benchmark (i.e., United States) industry and region are counted using County Business Patterns data.

$$LQ = \frac{(X_{ir}/X_r)}{(X_{iN}/X_N)} = \frac{(2/12)}{(2,286/7,860,674)} = 573 \tag{1}$$

$$LQ_{adj} = \frac{(X_{ir}+1)/(X_r+13)}{(X_{iN}+1)/(X_N+13)} = \frac{(3/25)}{(2,287/7,860,687)} = 413 \tag{2}$$

where, X represents the number of business establishments, the subscript "i" indexes the industry sector (e.g., Boatbuilding and Related Industries), the subscript "r" indexes the region (e.g., Atkinson, Maine) and the subscript "N" represents the benchmark economy (e.g., the United States).

The adjusted location quotient (413) is approximately 28 percent lower than the actual location quotient (573)[5]. This large difference calls into question whether location quotients

[5]Tian et al. (2020) found even larger differences when they compared maximum values of simple location quotients and their adjusted spatial input-output location quotients (SI-LQ). For example, Patrick County, Virginia, has a simple location quotient value of 738 for the Fishing, Hunting and Trapping sector (NAICS 114), whereas—after accounting for input-output relationships and linkages across county borders—the maximum SI-LQ for the Fishing, Hunting and Trapping sector falls to 9.66 in St. Bernard Parish, Louisiana.

can convey reliable information about industry agglomeration at this level of sectoral aggregation for a small town such as Atkinson, Maine. Table 2 shows the actual and adjusted location quotients for all 13 of the Battelle clusters in Atkinson, where the difference between the two measures is squared to exaggerate larger differences and translate negative differences into positive values. The average squared difference between the actual and adjusted location quotients is 3,073 in Atkinson, when we performed the experiment of adding one establishment to each of the 13 industry sectors. Finally, we take the square root of the average squared difference of the actual and adjusted location quotients to arrive at a standardized difference of actual and adjusted location quotients (e.g., 55 in Atkinson), which is the measure of regional location quotient stability used in the paper[6].

Table 2: Actual and Adjusted Town-Industry Location Quotients in Atkinson, Maine

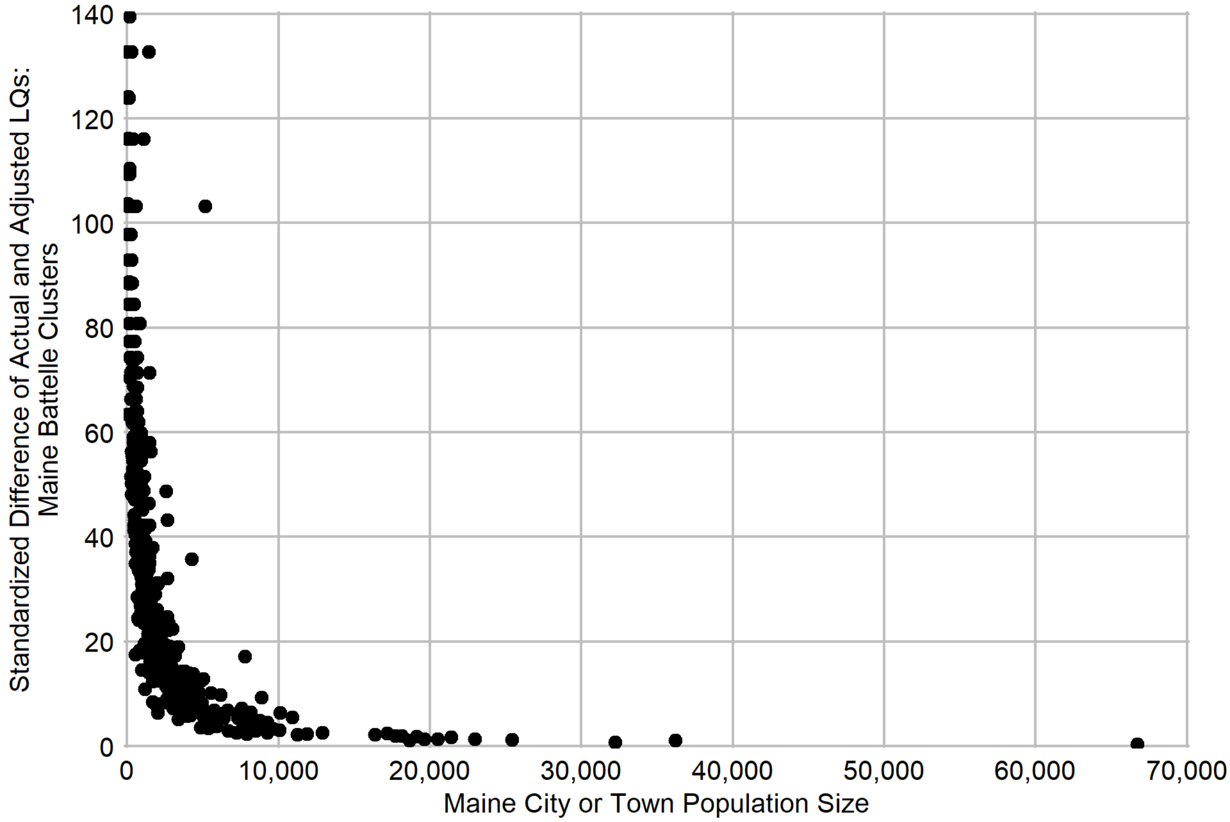
Industry Sector	Location Quotient	Adjusted LQ	Difference Squared
Boatbuilding and Related Industries	573	413	25,750
Alternative Energy and Turbines	411	395	271
Agriculture, Aquaculture, Fisheries and Food Production	0	6	38
Biopharmaceuticals	0	24	595
Defense	0	90	8,038
Electronics and Semiconductors	0	42	1,739
Engineering and Scientific/Technical Services	0	3	12
Environmental Services	0	11	117
Finance and Business Support Services	0	1	0
Forestry-Related Products	0	7	52
Information Technology Services	0	2	3
Materials for Textiles, Apparel, Leather and Footwear	0	22	463
Medical Devices	0	54	2,876
Average Difference Squared			3,073
Square Root of Average Difference Squared (i.e., Standardized Difference of Actual and Adjusted LQs)			55

Notes: Location quotients are calculated using 2017 Dun and Bradstreet business records for Maine, and the numbers of establishments in the benchmark (i.e., United States) industry and region are counted using County Business Patterns data.

To expand the analysis across a wider range of places, we compare the actual and adjusted

[6] Our hypothetical experiment involved adding one establishment to each sector and, because there are 13 Battelle clusters, 13 establishments to the total count of businesses. A different approach could have added one establishment to each sector and then one establishment to the total count of businesses. Although the approach we used of adding 13 establishments to the total count of businesses is a more extreme change to the local economy, this method yields a considerably lower value of the stability measure (compared with an approach of adding one establishment to the total count of businesses) in the analysis of small cities and towns (see Appendix A). The specific approach used—either adding 1 or 13 establishments—would have very little impact, however, on the stability measure in larger regions. For example, the difference between the stability measures—from the approaches of adding 1 or 13 establishments—is less than 1.0 in 56 of the 61 cities and towns (92 percent) with over 5,000 residents.

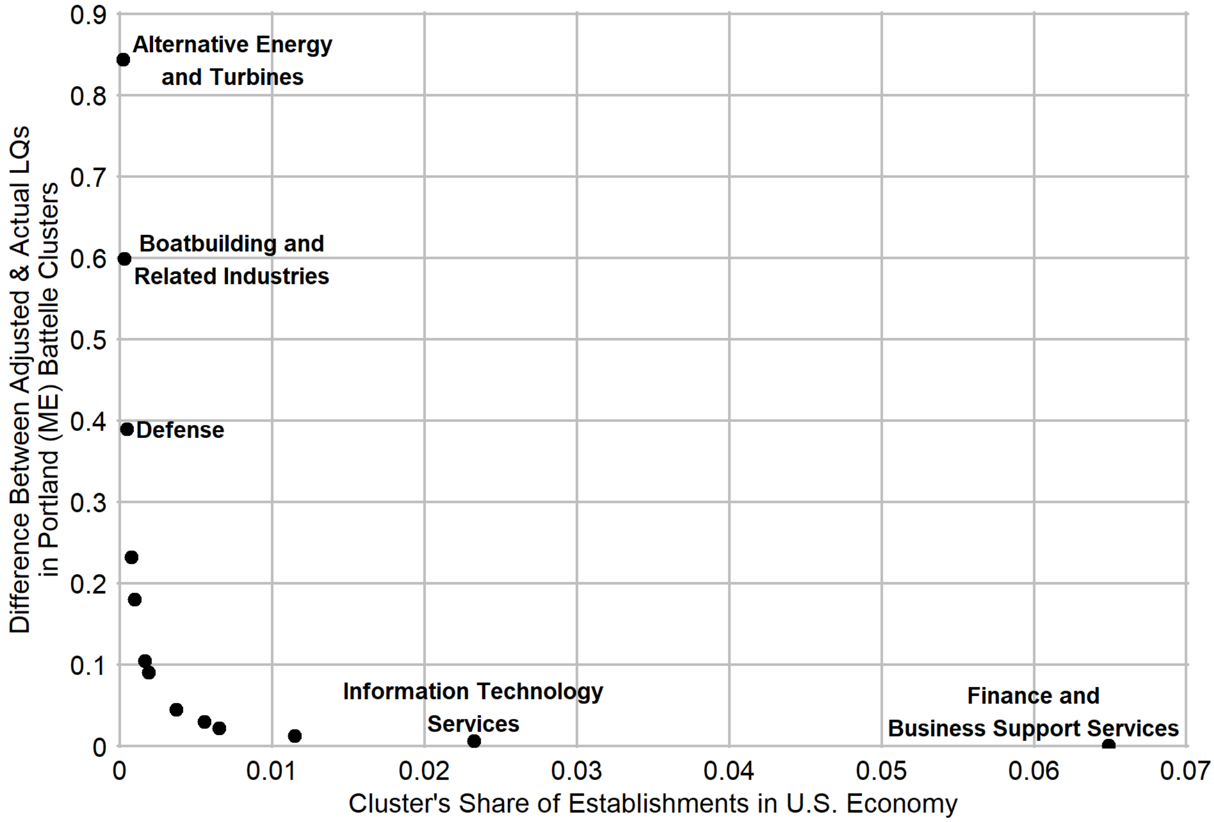
Figure 1: Stability of Battelle Cluster Location Quotients in Maine Cities and Towns



Notes: Location quotients are calculated using 2017 Dun and Bradstreet business records for Maine, and the numbers of establishments in the benchmark (i.e., United States) industry and region are counted using County Business Patterns data. Town population data are from the U.S. Census Bureau for the year 2017.

location quotients for all 6,136 region-industry pairs in Maine. The city- and town-level data used to calculate the location quotients are from 2017 Dun and Bradstreet establishment records in Maine, and the numbers of establishments in the benchmark (i.e., United States) industry and region are counted using County Business Patterns data. Figure 1 shows how the city- and town-level standardized difference between actual and adjusted location quotients varies with population size. The results show that our experiment of adding one hypothetical establishment to each region-industry pair leads to very large differences between the actual and adjusted location quotients in places with fewer than 1,000 people, with especially large differences in towns with fewer than 500 residents. For example, in the 115 Maine towns with 500 or fewer people, the standardized difference between actual and adjusted location quotients has a mean value of 90, compared with a mean value of 25 in the 357 cities and towns with more than 500 people. In the 198 places with fewer than 1,000 people, the standardized difference has a mean value of 71, compared with 19 in Maine's cities and towns with 1,000 or more residents.

Figure 2: Difference between Actual and Adjusted Location Quotients for Battelle Clusters in Portland, Maine



Notes: Authors' calculations using 2017 Dun and Bradstreet records for Maine businesses and U.S. County Business Patterns data.

Analysis of the Battelle clusters in Maine cities and towns shows a standardized difference between actual and adjusted location quotients of less than 1.0 in Portland (population of 66,715) and Bangor (population of 32,237), and between 1.0 and 2.0 in nine other cities and towns. In Portland, the difference between the actual and adjusted location quotients is quite small in several of the Battelle clusters. For example, Portland's actual location quotient for Finance and Business Support Services is 0.87, similar to an adjusted location quotient of 0.87. Likewise, Portland's actual and adjusted location quotients for Information Technology Services are 0.66 and 0.67, respectively. Even though the difference between the actual and adjusted location quotients is generally small for the 13 Battelle clusters in Portland, a marginal change in city-industry size increases the location quotient from less than 1.0 to above 1.0 in 3 of the 13 clusters. For example, a one-establishment increase in the number of businesses in the Boatbuilding and Related Industries cluster changes the location quotient from an actual value of 0.60 to an adjusted value of 1.20. Likewise, a marginal increase of the establishment count in the Defense cluster changes the location quotient from an actual value of 0.78 to an adjusted value of 1.17.

By construction of the location quotient, which has as its denominator the industry's share of total establishments in the benchmark (i.e., United States) economy, the difference between the actual and adjusted location quotients is inversely related to the cluster's share of all U.S. establishments. For example, Figure 2 shows that the Finance and Business Support Services cluster, which accounts for about seven percent of all U.S. businesses, has the most stable location quotient in response to a marginal change in the number of establishments. At the other end of the spectrum, the Battelle cluster of Alternative Energy and Turbines only accounts for 0.02 percent of U.S. establishments—and its adjusted and actual location quotients differ by 0.8 in Portland.

Whereas the Alternative Energy and Turbines cluster has adjusted (8.62) and actual (7.77) location quotients that well exceed 1.0 in Portland, which suggests a high specialization of industry, the Battelle clusters of Boatbuilding and Related Industries, and Defense have actual and adjusted location quotients that change from less than 1.0 to greater than 1.0.

4. ADDITIONAL EVIDENCE ON THE STABILITY OF LOCATION QUOTIENTS

Analysis of the Battelle clusters in Maine shows that a marginal change in the number of establishments in a region-industry results in a large difference between the actual and adjusted location quotients in small cities and towns, and the stability of location quotients generally increases with population size. Within an individual region, however, the stability of location quotients in response to a marginal change in the number of establishments is also related to the industry's share of establishments in the benchmark economy. This idea that the location quotient's stability is connected to the industry's size relative to the overall benchmark economy suggests that the level of industry aggregation used in a study will influence the stability of location quotients. Specifically, analysis of highly disaggregated industries (that make up small shares of the benchmark economy) will have greater instability in location quotients than analysis of broad, aggregated sectors.

To illustrate this point, we conduct analysis of location quotients at the 3-digit NAICS and 1-digit NAICS levels of aggregation for U.S. counties, and cities and towns in Maine. Table 3 shows the top 20 location quotients from U.S. county-industry (3-digit NAICS) pairs. The location quotients exceed 200 in 15 county-industry pairs, suggesting very high levels of industry specialization, although the county-industry pairs have fewer than ten establishments in 9 of the 20 pairs shown in the table. Alaska is home to 12 of the 20 highest location quotients and these sectors (along with others in the table) are related to natural resource-based harvesting (e.g., hunting and fishing) and transportation. Similar to what we found in the analysis of the Battelle clusters in Maine, the highest location quotients are generally found in very small regions. Whereas, although counties with fewer than 10,000 residents account for 22 percent of all U.S. counties, they are home to 17 of the 20 highest location quotients in Table 3.

The highest county-industry location quotients, which are primarily in rural areas, are also considerably larger than the location quotients that characterize some of the United States' best known industry clusters. For example, the transportation equipment (e.g., automobile) manufacturing (NAICS 366) industry has a location quotient of 2.6 in the Detroit area (Wayne County, Michigan); computer and electronic product manufacturing (NAICS

Table 3: Top 20 Location Quotients in U.S. County-Industry (3-Digit NAICS) Pairs

Town	3-DIG NAICS Sector	County Population Population	Number of Establishments	Location Quotient
Kodiak Island Borough, Alaska	Fishing, hunting and trapping	13,773	87	491
Wrangell City and Borough, Alaska	Fishing, hunting and trapping	2,475	14	385
Valdez-Cordova Census Area, Alaska	Fishing, hunting and trapping	9,439	66	353
Petersburg Borough, Alaska	Fishing, hunting and trapping	3,275	20	343
McMullen County, Texas	Pipeline transportation	600	6	289
Wheeler County, Georgia	Forestry and logging	7,952	19	270
Glasscock County, Texas	Pipeline transportation	1,420	4	242
Aleutians East Borough, Alaska	Fishing, hunting and trapping	3,338	5	232
Hoonah-Angoon Census Area, Alaska	Scenic and sightseeing transportation	2,146	7	226
Lake and Peninsula Borough, Alaska	Fishing, hunting and trapping	1,301	4	211
Hoonah-Angoon Census Area, Alaska	Air transportation	2,146	10	211
Aleutians West Census Area, Alaska	Water transportation	5,784	5	209
Plaquemines Parish, Louisiana	Water transportation	23,394	29	207
Sitka City and Borough, Alaska	Fishing, hunting and trapping	8,810	29	207
Knox County, Maine	Fishing, hunting and trapping	39,700	135	203
Cameron Parish, Louisiana	Pipeline transportation	6,806	12	184
Winkler County, Texas	Pipeline transportation	7,777	16	184
Bristol Bay Borough, Alaska	Air transportation	917	8	167
Eureka County, Nevada	Mining (except oil and gas)	1,728	4	165
Dillingham Census Area, Alaska	Air transportation	4,974	9	163

Notes: Location quotients and establishment counts are calculated using 2017 County Business Patterns data. County population data are from 2017 U.S. Census Bureau.

334) has a location quotient of 7.2 in Silicon Valley (Santa Clara County, California); financial services (NAICS 525) and apparel manufacturing (NAICS 315) have location quotients of 3.8 and 6.7 in New York City (New York County, New York); and two textiles manufacturing sectors (NAICS 313 and 314) have location quotients of 48.5 and 36.0, respectively, in Dalton (Whitfield County), Georgia. The fact that the location quotients in Table 3 are an order of magnitude larger than many of those that describe some of the most established and best-known U.S. industry clusters muddles the interpretation of very high location quotients in small places.

4.1. Stability of U.S. County-Level, 3-Digit NAICS Location Quotients

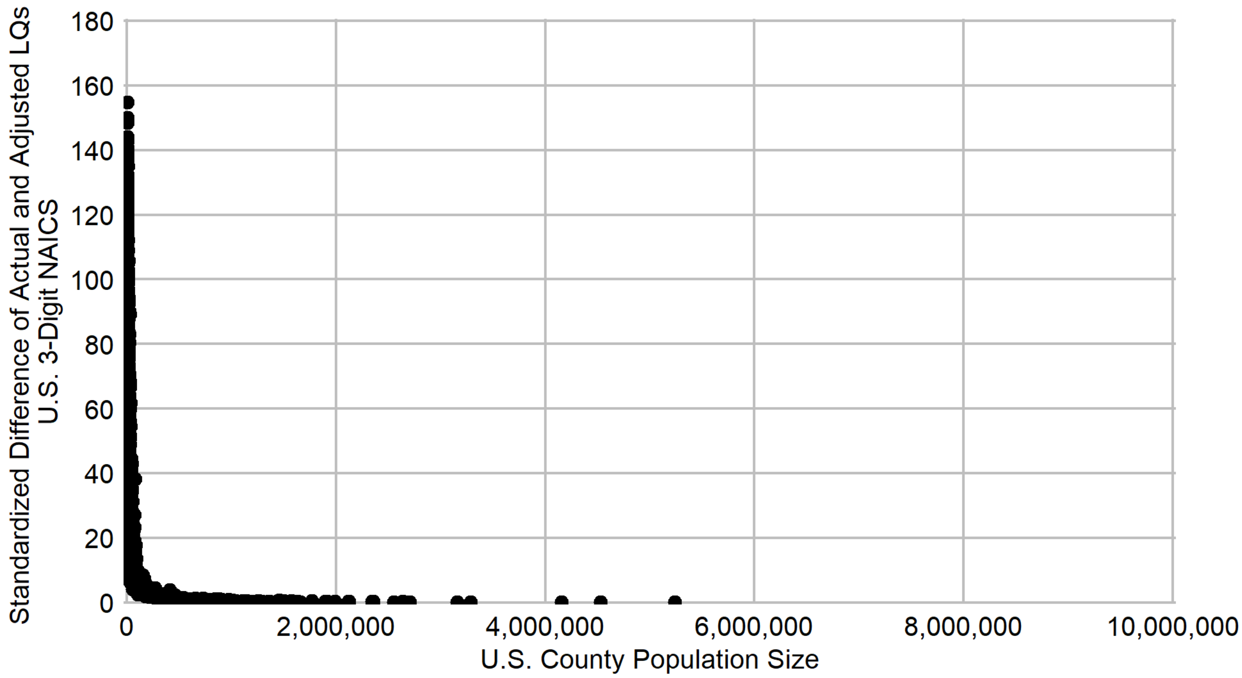
To extend our scope beyond the stability of the location quotients for the Battelle industry clusters in Maine, we conducted a similar experiment of comparing actual and adjusted location quotients after adding a marginal establishment to the 3-digit NAICS industries of U.S. counties. Figure 3 shows the relationship between a county's standardized difference of actual and adjusted location quotients and its population size.

As we found in the analysis of cities and towns in Maine, location quotients are unstable in the most sparsely populated areas. The difference between the actual and adjusted location quotients, however, is very small in the largest U.S. counties. To focus in on smaller regions, Figure 3b is a reproduction of Figure 3a that is limited to counties with 70,000 or fewer residents.

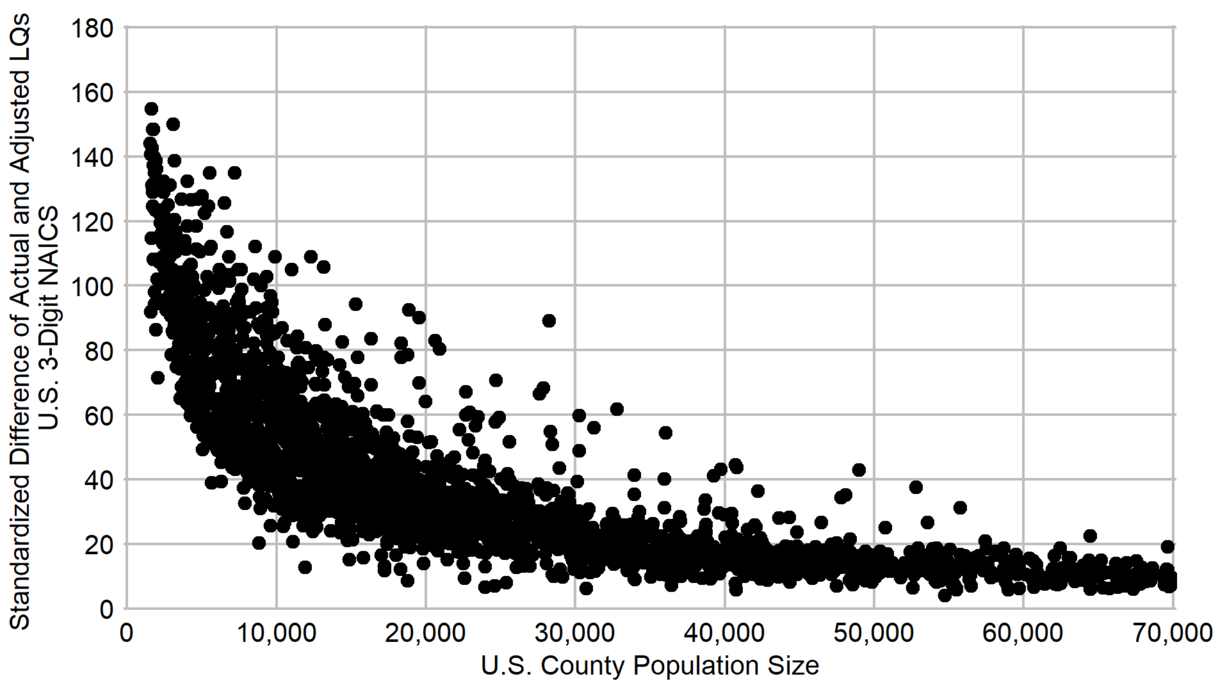
In the 25 U.S. counties with fewer than 1,000 people, the standardized difference between

Figure 3: Stability of 3-Digit NAICS Location Quotients in U.S. Counties

(a) All U.S. Counties

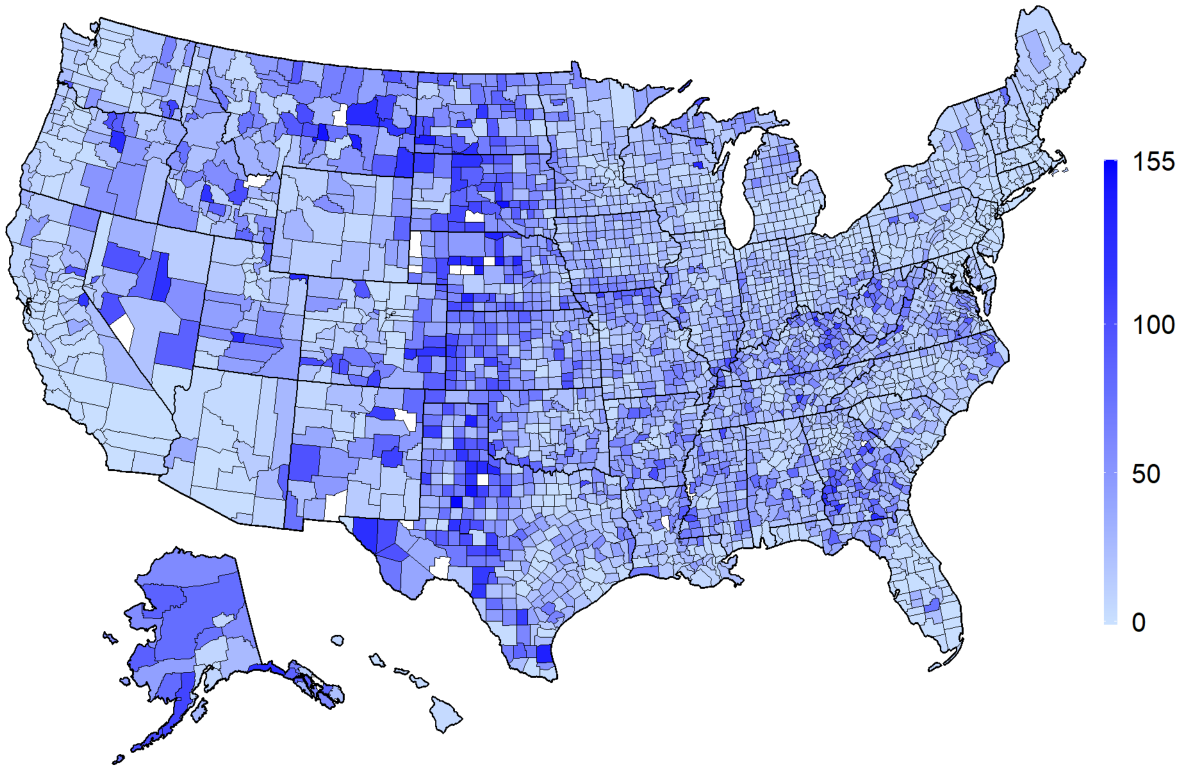


(b) U.S. Counties with 70,000 or Fewer Residents



Notes: Location quotients are calculated using 2017 County Business Patterns data. County population data are from 2017 U.S. Census Bureau.

Figure 4: Map of Standardized Difference of Actual and Adjusted Location Quotients, 3-Digit NAICS



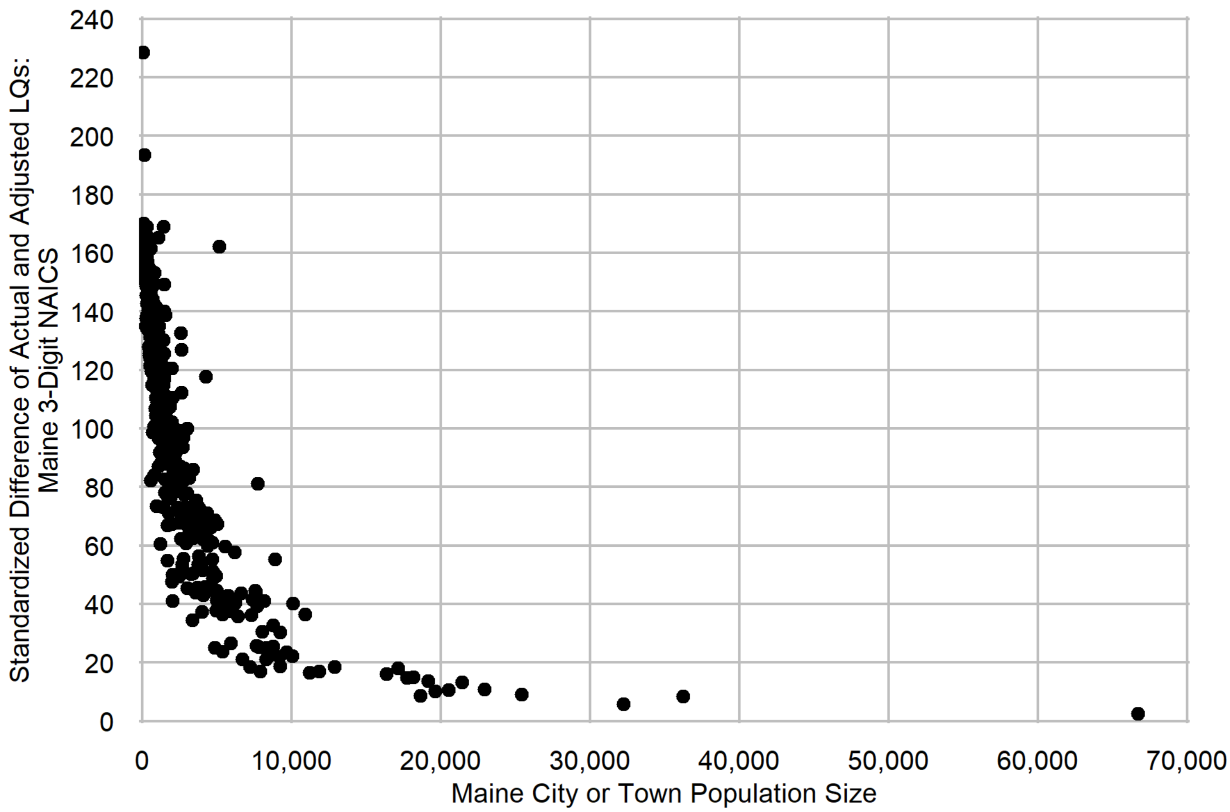
Notes: Location quotients are calculated using 2017 County Business Patterns data.

actual and adjusted location quotients (across 3-digit NAICS sectors) has a mean value of 127, compared with a mean value of 31 in the 3,101 counties with 1,000 or more people. In the 2,145 counties with fewer than 50,000 residents, the standardized difference has a mean value of 44, compared with 5.9 in the 981 counties with 50,000 or more people. Figure 4 is a map of the geographic distribution of the standardized difference of actual and adjusted location quotients across U.S. counties. It shows that location quotients calculated for 3-digit NAICS sectors are particularly unstable in large sections of the central United States, areas of the Southeast, and Alaska.

4.2. Stability of 3- and 1-Digit NAICS Location Quotients Calculated for Maine Cities and Towns

Figure 5 shows the relationship between the standardized difference of actual and adjusted location quotients, calculated for 3-digit NAICS sectors, and the population size of Maine cities and towns. In the 115 towns with fewer than 500 people, the standardized difference between actual and adjusted location quotients has a mean value of 156, compared with a mean value of 87 in regions with 500 or more residents. The standardized difference between actual and adjusted location quotients, calculated for 3-digit NAICS sectors, is 104 across

Figure 5: Stability of 3-Digit NAICS Location Quotients in Maine Cities and Towns

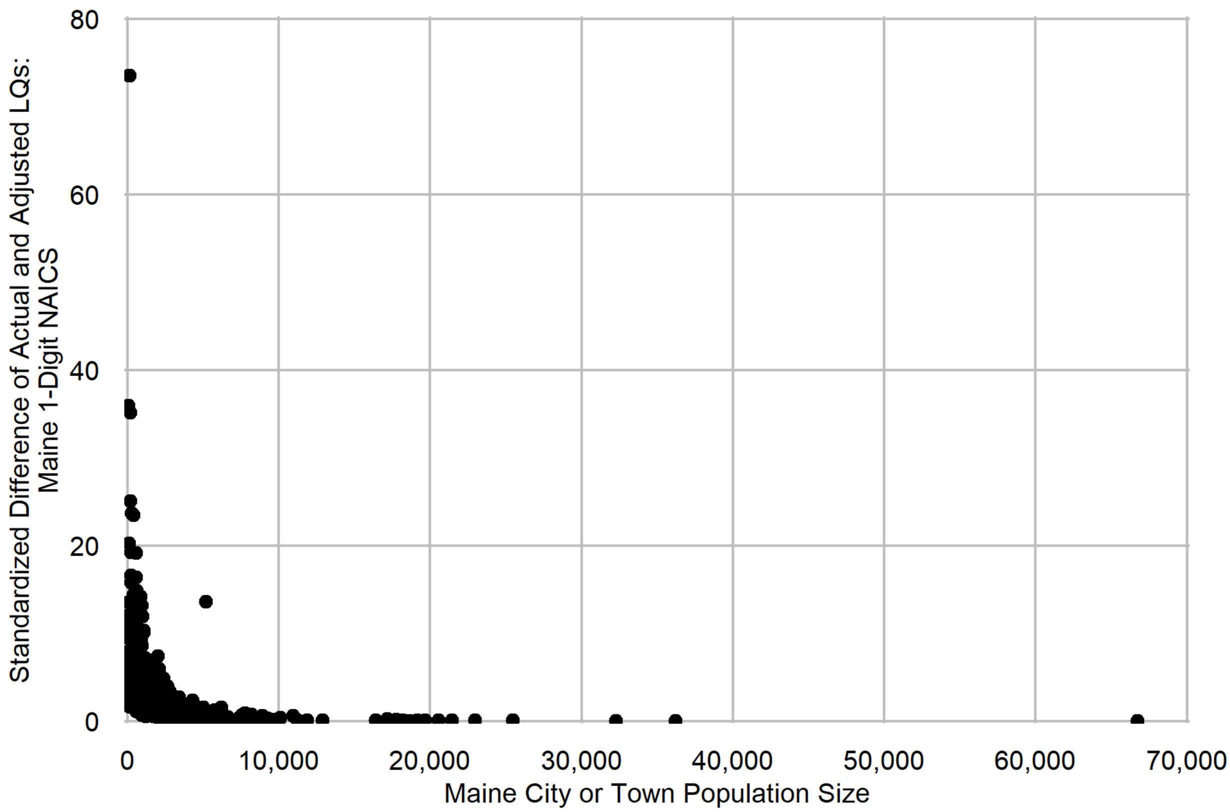


Notes: Location quotients are calculated using 2017 Dun and Bradstreet business records for Maine, and the numbers of establishments in the benchmark (i.e., United States) industry and region are counted using County Business Patterns data. Town population data are from the U.S. Census Bureau for the year 2017.

all 472 Maine cities and towns.

By comparison, the standardized difference between actual and adjusted location quotients, calculated for 1-digit NAICS sectors (Figure 6), has a mean value of 4.07 across all 472 Maine cities and towns. The standardized difference between actual and adjusted location quotients (1-digit NAICS) in 115 regions with fewer than 500 people has a mean value of 8.09, and the standardized difference in the 357 regions with 500 or more people has a mean value of 2.77. For the entire sample of cities and towns in Maine—and the subsamples of places with less than 500 people and 500 or more residents—the standardized difference between actual and adjusted location quotients is considerably smaller in the analysis of 1-digit NAICS categories (mean values of 4.07, 8.09, and 2.77) than in the analysis of 3-digit NAICS sectors (mean values of 104, 156 and 87). In the analysis of the Battelle industry clusters, which include a mix of aggregated (e.g., Finance and Business Support Services) and highly disaggregated (Alternative Energy and Turbines) sectors, the corresponding mean values of the standardized difference for the entire sample (41), towns with fewer than 500 people (90) and 500 or more residents (25) fall in the middle of the mean values calculated

Figure 6: Stability of 1-Digit NAICS Location Quotients in Maine Cities and Towns

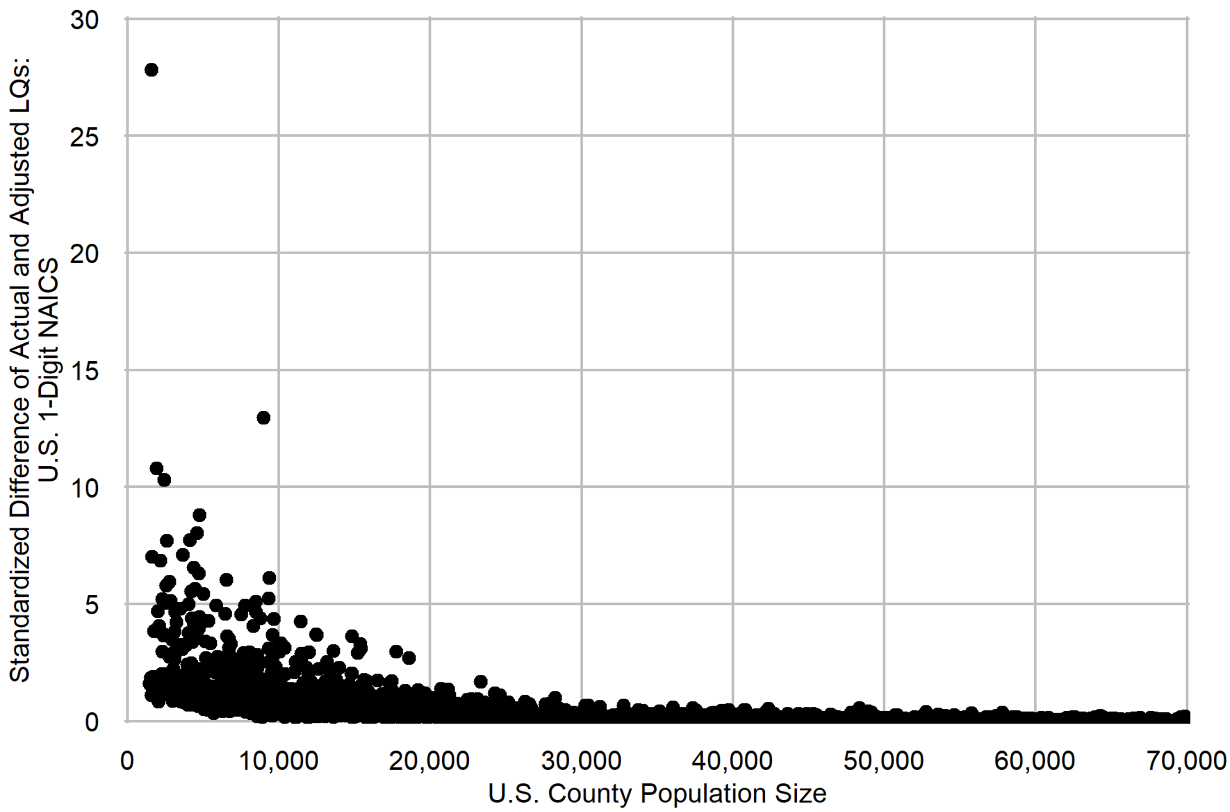


Notes: Location quotients are calculated using 2017 Dun and Bradstreet business records for Maine, and the numbers of establishments in the benchmark (i.e., United States) industry and region are counted using County Business Patterns data. Town population data are from the U.S. Census Bureau for the year 2017.

in the analysis of the highly aggregated 1-digit NAICS and disaggregated 3-digit NAICS sectors. These results illustrate how the stability of location quotients to a marginal change in region-industry size is influenced by the level of sectoral aggregation used in the analysis.

The results for cities and towns in Maine, compared with those for U.S. counties, also demonstrate how the stability of location quotients is influenced by the way in which data are collected. That is, location quotients in Maine cities and towns are generally more stable than those in similar-sized counties. For example, the average standardized difference between actual and adjusted location quotients (3-digit NAICS) is 18 in Maine cities and towns with between 10,000 and 24,999 people, compared with an average of 39 in U.S. counties that fall in the same population size range. Likewise, the average standardized difference (3-digit NAICS) is 39 in Maine regions with between 5,000 and 9,999 people, compared with 62 in U.S. counties. A reason for these differences is that the establishment counts for Maine are from the Dun and Bradstreet data files, which include sole proprietors and non-employers, whereas the data for U.S. counties are from County Business Patterns, which has a more limited scope of businesses with at least one employee. The broader coverage of businesses

Figure 7: Stability of 1-Digit NAICS Location Quotients in U.S. Counties with 70,000 or Fewer Residents



Notes: Location quotients are calculated using 2017 County Business Patterns data. County population data are from 2017 U.S. Census Bureau.

in the Dun and Bradstreet files gives a higher number of business establishments per capita, compared with an analysis using County Business Patterns, which make the stability of location quotients in Maine cities and towns comparable to the stability found in counties of a larger population size.

4.3. Stability of U.S. County-Level, 1-Digit NAICS Location Quotients

The level of industry aggregation also strongly influences the stability of location quotients measured in U.S. counties. For the 1-digit NAICS location quotients shown in Figure 7, the standardized difference of actual and adjusted location quotients has a mean value of 0.75 across the 2,145 counties with fewer than 50,000 residents. By comparison, the standardized difference based on 3-digit NAICS sectors and shown in Figures 3 and 4, has a much higher mean value of 44 in the 2,145 counties with fewer than 50,000 people. There's also a much smaller standardized difference between the actual and adjusted location quotients when using the more aggregated industrial sectors (i.e., 1-digit versus 3-digit NAICS) in the analysis of U.S. counties with 50,000 or more U.S. residents—0.05 versus 5.9—and in the analysis of all 3,132 U.S. counties—0.53 versus 32.

5. SUMMARY

Our analysis of location quotients calculated for five different combinations of regions and levels of industry aggregation shows that the stability of location quotients increases with population size and when using a higher level of industry aggregation. The main results of the study are summarized in Table 4, which shows mean values of the standardized difference between actual and adjusted location quotients calculated for 12 population size intervals. The cells with values that round to zero have combinations of population size and level of industry aggregation that result in highly stable location quotients. The table shows that a population of 10,000 or more people is needed for highly stable location quotients in the analysis of 1-digit NAICS sectors in Maine cities and towns, 25,000 or more residents is the cutoff for analysis at the 1-digit NAICS level in U.S. counties, 50,000 or more people is the cutoff for the analysis of the Battelle clusters in Maine, and one million or more people is the cutoff for analysis at the 3-digit NAICS level in U.S. counties. This means that, when conducting analysis of disaggregated sectors, a very large population is needed to ensure that location quotients are not influenced very much by a marginal change in region-industry size.

Table 4: Summary of Standardized Difference of Actual and Adjusted LQs, by Population Size

Population	3-Digit NAICS U.S. Counties	3-Digit NAICS Maine Cities & Towns	Battelle Maine Cities & Towns	1-Digit NAICS U.S. Counties	1-Digit NAICS Maine Cities & Towns
Less than 100	NA	165	110	NA	9
100 to 499	NA	152	81	NA	8
500 to 999	127	126	46	3	5
1,000 to 4,999	89	88	22	2	2
5,000 to 9,999	62	39	8	1	1
10,000 to 24,999	39	18	2	1	0
25,000 to 49,999	20	8	1	0	0
50,000 to 99,999	11	3	0	0	0
100,000 to 249,999	5	NA	NA	0	NA
250,000 to 499,999	2	NA	NA	0	NA
500,000 to 999,999	1	NA	NA	0	NA
1,000,000 or more	0	NA	NA	0	NA

Notes: Authors' calculations.

For example, in Broward County, Florida (population of 1.9 million people), the absolute value of the difference between actual and adjusted location quotients has a mean value of 0.04, and only 1 of 86 3-digit NAICS sectors has a difference of more than 0.15. This outlier, which is the Monetary Authorities—Central Bank sector (NAICS 521) has an actual location quotient of zero in Broward County and an adjusted location quotient—with an increase in businesses from zero to one—of 2.22. Across all 3,784 county (with one million or more people) and 3-digit NAICS pairs, the actual and adjusted location quotients change from less than 1.0 to above 1.0 in only about two percent of the cases.

In the analysis of more aggregated sectors, the location quotients are highly stable in much smaller regions. For example, across 12,559 county (25,000 to 49,999 people) and

1-digit NAICS pairs, the actual and adjusted location quotients change from less than 1.0 to greater than 1.0 in fewer than one percent of the cases. Furthermore, in the 96 out of 12,559 county (population between 25,000 and 49,999 people) and 1-digit NAICS industry pairs where a marginal increase in establishments changes the location quotient from below 1.0 to above 1.0, the county and industry pair has zero establishments in 43 of the 96 cases.

Moving to the other end of the spectrum, we characterize combinations of population size and level of industry aggregation with standardized differences of 10 or above as having unstable location quotients. Table 4 shows that U.S. counties with fewer than 100,000 people and Maine cities and towns with fewer than 25,000 people have unstable location quotients when measured at the 3-digit NAICS level of industry aggregation. For example, in Coryell County, Texas, which has a population of about 75,000 people and is part of the Killeen-Temple metropolitan area, the absolute value of the difference between actual and adjusted location quotients exceeds 0.20 in 46 of the 86 3-digit NAICS sectors. In addition, the experiment of adding one establishment to the county-industry pair increases the location quotients in Coryell County from less than 1.0 to greater than 1.0 in 24 of the 86 3-digit NAICS sectors.

Finally, we move to the population size and level of industry aggregation combinations with standardized differences of between 1 and 9, which are characterized as having location quotients that are moderately stable. Pasco County, Florida, with a population of about 500,000 residents, has a standardized difference between actual and adjusted location quotients—measured at the 3-digit NAICS level of aggregation—of 1.5. The 3-digit NAICS location quotients are reasonably stable in Pasco County, with the absolute value of the difference between the actual and adjusted location quotients having an average value of 0.24 across the 86 sectors. Furthermore, the actual and adjusted location quotients increase from below 1.0 to above 1.0 in 4 of the 86 3-digit NAICS sectors.

Yuma County, Arizona (population of about 200,000 residents), has a standardized difference between actual and adjusted location quotients (3-digit NAICS) of 4.71, and the absolute value of the difference between actual and adjusted location quotients has a mean value of 0.75. Despite this fairly large mean value for the absolute value of the difference between the actual and adjusted location quotients across the 86 3-digit NAICS categories, this difference is less than 0.10 in 52 of 86 sectors and less than 0.20 in 60 of the 86 3-digit NAICS categories. Furthermore, the actual and adjusted location quotients increase from less than 1.0 to greater than 1.0 in 8 of 86 sectors. These results suggest that, with some exceptions, location quotients can provide a reasonably accurate picture of regional industry specialization in a county with an overall standardized difference of around 5.0.

As shown in Table 4, the location quotients calculated at a more aggregated industry level of 1-digit NAICS sectors are moderately stable in even very small U.S. counties. For example, Rooks County, Kansas (population of 5,148 people) has a standardized difference between actual and adjusted location quotients (1-digit NAICS) of 1.33. Although the absolute value of the difference between actual and adjusted location quotients has a mean value of 0.56, this difference is less than 0.2 in 6 of the 19 1-digit NAICS sectors and less than 0.1 in 2 of 19 industries. In addition, the actual and adjusted location quotients do not change from less than 1.0 to greater than 1.0 in any of the 19 1-digit NAICS sectors.

6. CONCLUSIONS

Due in part to its modest data requirements, and straightforward and intuitive interpretation, the industry location quotient is used extensively in regional economic analysis. Despite this widespread use, researchers have noted several limitations of "simple" location quotients, including their weakness at identifying clusters that cross industry and geographic borders (Feser et al., 2008; Tian et al., 2020), and the difficulty in determining an appropriate cutoff of the location quotient for identifying industry clusters (Crawley et al., 2013; O'Donoghue and Gleave, 2004). Likewise, studies have noted the pitfalls and limitations of using location quotients to measure regional specialization in very small places (Carroll et al., 2008).

In this paper, we examined the use of location quotients across the population size spectrum of cities and towns in Maine and U.S. counties with a focus on the stability of location quotients in small regions. Our analysis demonstrates that the stability of location quotients—i.e., change in response to a marginal change in region-industry size—depends both on the size of region studied and the level of industry aggregation. At the highly aggregated industry level of 1-digit NAICS sectors, location quotients are highly stable down to a county population size of about 25,000 people and, in the analysis of cities and towns in Maine, about 10,000 residents. In addition, location quotients are moderately stable in smaller regions (e.g., U.S. counties with fewer than 25,000 residents) when the analysis is conducted at the 1-digit NAICS level.

On the other hand, a very large population size is needed for location quotients to remain virtually unaffected in response to a marginal change in region-industry size when the analysis is conducted at the more disaggregated industry level of 3-digit NAICS sectors. At this industry level, location quotients are highly stable in U.S. counties with one million or more people, and they are moderately stable in U.S. counties with between 100,000 and 1,000,000 people, and Maine cities and towns with 25,000 or more people. In small regions, however, location quotients are unstable when calculated at a highly disaggregated (i.e., 3-digit NAICS) level of industry aggregation.

With these general trends in mind, we suggest the following five guidelines for using location quotients. First, researchers and practitioners should use a combination of location quotients and (minimum) establishment counts to identify industry clusters. Although some region-industry pairs can have location quotients in excess of 100 (see Tables 1 and 3), which suggests high levels of regional industry specialization, many of these extraordinarily high location quotients are the result of one (or just a few) business establishments in very small regions. A region-industry with a few establishments, despite a high location quotient, is unlikely to function as an industry cluster and/or provide the benefits of industry localization. Using a combination of location quotients and a minimum number of establishments is more likely to identify actual industry clusters.

A second guideline for using location quotients is to use employment figures along with establishment counts to measure industry specialization when such data are available. The analysis in this paper uses establishment counts as the indicator of region-industry size due to its ready availability and fact that employment figures are often suppressed for narrowly defined industries in small regions. It's an unfortunate irony, however, that the types of region and industry pairs with the least stable location quotients—i.e., small regions and disaggregated sectors—are the very same ones where employment data are most likely to be suppressed. There are some commercially available products that provide (estimated) employment data for narrowly defined industries in small regions and it's also possible to use disclosure "flags" in data series such as County Business Patterns to estimate employment figures. The combination of location quotients calculated from establishment and employment data might provide a more accurate picture of regional industry specialization and industry clusters. More generally, our results highlight the importance of using the highest-quality data—whether establishment counts or employment figures—that are available for the region(s) and sector(s) of interest. This is especially important in small, rural areas.

A third guideline for using location quotients is to take care when setting the level of industry aggregation that is needed and appropriate for the analysis. In the introduction to this paper, we note that using location quotients at a highly aggregated industry level (e.g., manufacturing) may not uncover industry specialization when a cluster exists in a narrowly defined sector (e.g., primary metal manufacturing). The results of our analysis, however, show the high instability of location quotients, measured at the detailed 3-digit NAICS level, in even reasonably large regions. Our analysis of the Battelle industry clusters shows that it's possible to achieve higher stability in location quotients (compared with analysis of 3-digit NAICS categories) using a "custom" level of aggregation to match sectors that are targeted in the region.

A fourth guideline for using location quotients, which is closely related to the third, is to carefully consider the level of geography used when analyzing location quotients. Given the high instability of location quotients in small places, an approach to studying industry clusters and regional specialization in these areas is to combine nearby places into larger regions. For example, studies by Carroll et al. (2008) and Tian et al. (2020) outline approaches to identify multi-region indicators of industry clusters. Although the analysis of multi-county and city regions limits a researcher or practitioner's ability to describe the industry structure of a specific (small) place, the fact that clusters cross administratively defined borders suggests that a small town—if part of a multi-place region with a high specialization of industry—can contribute to (and capture the benefits of) an industry cluster.

Our fifth and final recommendation for using location quotients is to combine their results with local knowledge about a region's specialization of industry, and to ground truth very high location quotients when possible. If a region truly has a specialization of industry and the benefits that accrue from localization economies, local economic development practitioners and industry officials will likely be aware of it. In addition, a reasonably large industry cluster will have signs of supporting infrastructure such as government programs that are connected to the industry, a cohesive and shared marketing plan and materials, educational and training programs to help industry workers, and connections to other organizations such as university and industry groups. In other words, although some of the benefits of industry localization such as knowledge spillovers do not always leave a paper trail (Krugman, 1991), the presence of an industry cluster usually has some sort of a footprint.

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APPENDIX

A. AN ALTERNATIVE APPROACH OF ADDING ONE ESTABLISHMENT, INSTEAD OF THIRTEEN, TO THE TOTAL COUNT OF BUSINESSES IN THE ANALYSIS OF THE BATTELLE CLUSTERS IN MAINE

In the analysis of the Battelle clusters in Maine, our experiment to demonstrate the stability of location quotients involved adding one hypothetical establishment to each sector and, because there are 13 Battelle clusters, 13 establishments to the total count of businesses. A different approach could have been to add one establishment to each sector and then add one establishment to the total count of businesses. In this short appendix, we show how the stability measure calculated for Maine cities and towns would have differed if we had used this alternative approach of adding only one establishment to the total count of businesses.

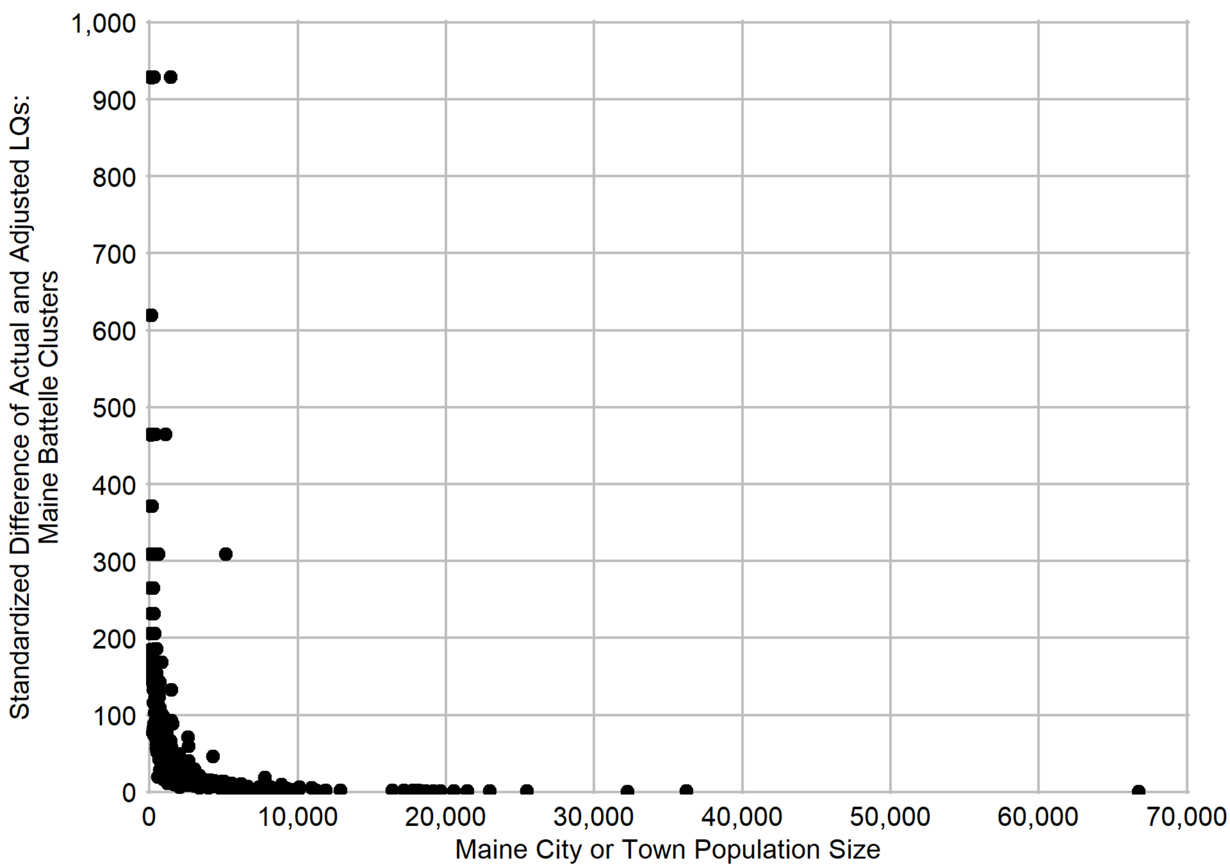
Table A1: Actual and Adjusted Town-Industry Location Quotients in Atkinson, Maine; Using an Approach of Adding 1 Business to the Total Number of Establishments (Instead of 13 Businesses)

Industry Sector	Location Quotient	Adjusted LQ	Difference Squared
Boatbuilding and Related Industries	573	794	48,587
Alternative Energy and Turbines	411	759	121,067
Agriculture, Aquaculture, Fisheries and Food Production	0	12	140
Biopharmaceuticals	0	47	2,200
Defense	0	172	29,728
Electronics and Semiconductors	0	80	6,431
Engineering and Scientific/Technical Services	0	7	45
Environmental Services	0	21	434
Finance and Business Support Services	0	1	1
Forestry-Related Products	0	14	192
Information Technology Services	0	3	11
Materials for Textiles, Apparel, Leather and Footwear	0	41	1,711
Medical Devices	0	103	10,636
Average Difference Squared			17,014
Square Root of Average Difference Squared (i.e., Standardized Difference of Actual and Adjusted LQs)			130

Notes: Location quotients are calculated using 2017 Dun and Bradstreet business records for Maine, and the numbers of establishments in the benchmark (i.e., United States) industry and region are counted using County Business Patterns data.

Table A1 (with a comparison to Table 2) shows how an approach of adding one establishment to the total count of businesses would have affected the adjusted location quotients in Atkinson, Maine. For example, adding one establishment to the Medical Devices cluster, along with one establishment to the total count of businesses in Atkinson, changes the location quotient from an actual value of 0 to an adjusted value of 103. However, the approach used in the paper, which added 13 establishments to the total count, raises the location quotient for the Medical Devices cluster to a lower adjusted value of 54 (Table 2). Likewise, adding one establishment to the Boatbuilding and Related Industries cluster and one establishment to the total count of businesses would change the location quotient from an actual value of 573, which is the highest in the state (see Table 1), to an adjusted value of 794. By comparison, the approach that we used of adding one business to the Boatbuilding and Related Industries cluster and 13 establishments to the total count lowered the location quotient from an actual value of 573 to an adjusted value of 413 (Table 2). Across all 13 clusters, an approach of adding one establishment to the total count of businesses would yield a standardized difference of actual and adjusted location quotients of 130, which is considerably higher than the value of 55 from the approach that we used of adding 13 establishments to the total count.

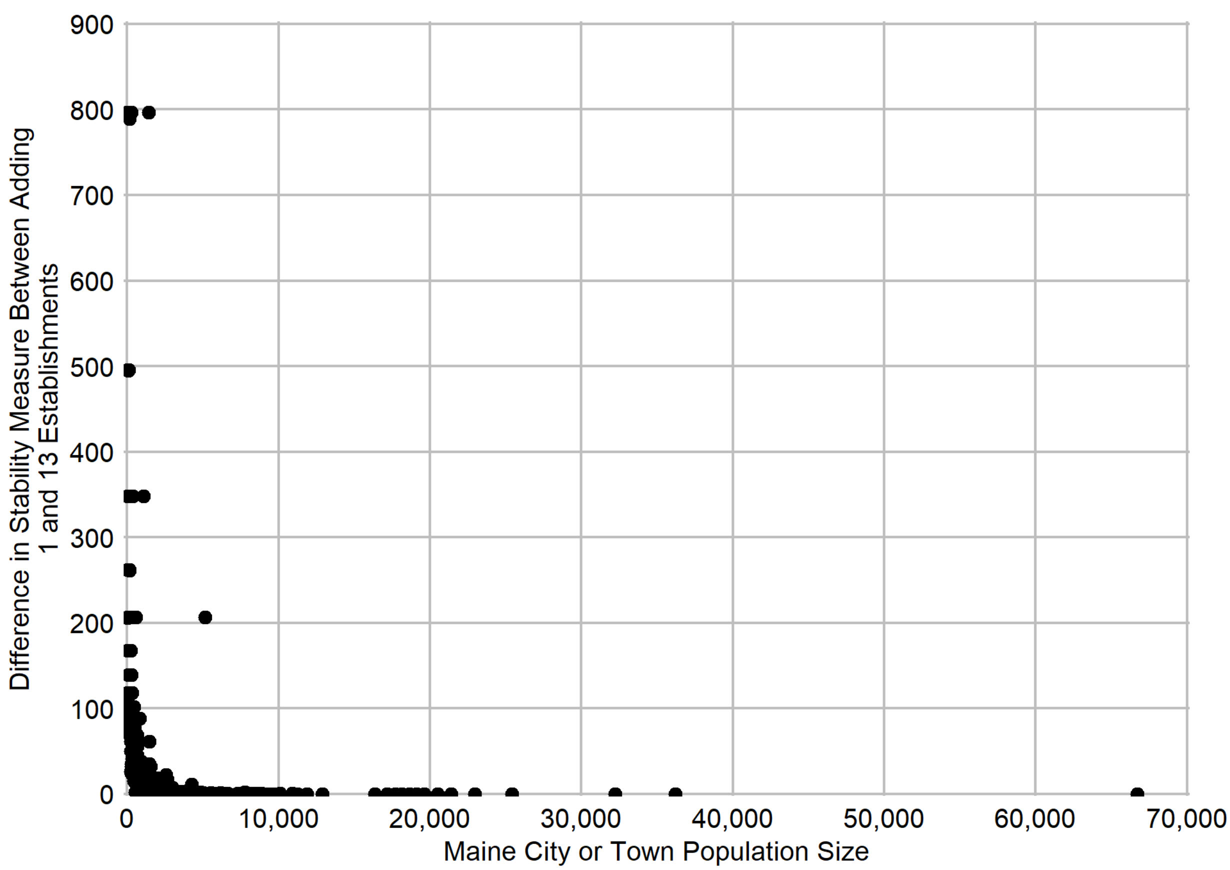
Figure A1: Stability of Battelle Cluster Location Quotients in Maine Cities and Towns (Using an Approach of Adding 1 Business to the Total Number of Establishments)



Notes: Location quotients are calculated using 2017 Dun and Bradstreet business records for Maine, and the numbers of establishments in the benchmark (i.e., United States) industry and region are counted using County Business Patterns data. Town population data are from the U.S. Census Bureau for the year 2017.

Figure A1 shows the relationship between the stability of the Battelle cluster location quotients, using an approach of adding one establishment to the total count of businesses, and population size. As in the analysis that uses an approach that added 13 establishments to the total count of businesses (see Figure 1), the location quotients are considerably more stable in larger regions. Figure A2 shows the difference in the stability of location quotients between an approach that adds one establishment to the total count of businesses (Figure A1) and the approach used in the paper that adds 13 businesses to the total count (Figure 1). The difference is less than 1.0 in 56 of the 61 cities and towns (92 percent) with over 5,000 people. This means that, although using an alternative approach of adding one establishment to the total count of businesses would affect the results about the stability of location quotients in very small regions, our findings would be largely unchanged in bigger places.

Figure A2: Difference in Stability Between an Approach that Adds 1 or 13 Establishments to the Total Count of Businesses



Notes: Location quotients are calculated using 2017 Dun and Bradstreet business records for Maine, and the numbers of establishments in the benchmark (i.e., United States) industry and region are counted using County Business Patterns data. Town population data are from the U.S. Census Bureau for the year 2017.