Intra-Regional Economic Connectivity: The Role of Industry Clusters in Bridging the Urban-Rural Divide

Christiana K. McFarland

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

In

Planning, Governance and Globalization

Margaret M. Cowell, Chair

Thomas W. Sanchez

John A. Provo

A. Scott Tate

February 17, 2020

Arlington, Virginia

Keywords: regional economic development, urban-rural divide, industry clusters

Intra-Regional Economic Connectivity: The Role of Industry Clusters in

Bridging the Urban-Rural Divide

Christiana K. McFarland

ABSTRACT

This research explores an alternative path for economic development via local connections to regional economies. It presents new analysis of the potential and circumstances under which county level employment can be strengthened by connecting to regional clusters – networks of businesses, labor pools, etc., whose linkages cross local and even state jurisdictional boundaries. Specifically, this analysis examines how different types of industry clusters and types of urban and rural communities within regions respond to intra-regional connectivity. Independent-samples t-tests are conducted to assess whether significant differences in the annualized county-cluster employment growth rate (2010-2016) exist between connected and not-connected county-clusters overall, in different types of communities (metropolitan, micropolitan, rural adjacent and rural remote) and across types of industry clusters. The results suggest that intra-regional economic connectivity has a strong, positive association with county-cluster employment growth. These results are particularly pronounced for more rural communities but are present across county types, including metropolitan. The magnitude of the economic impact derived from connectivity with the regional economy varies by industry cluster. The results suggest an alternative approach to cluster-based economic development strategies that more strategically accounts for and bolsters connectivity. Policy recommendations for how to apply an intra-regional connectivity framework to narrow the urban-rural divide, as well as several regional profiles, are offered.

Intra-Regional Economic Connectivity: The Role of Industry Clusters in

Bridging the Urban-Rural Divide

Christiana K. McFarland

GENERAL AUDIENCE ABSTRACT

This research explores an alternative path for economic development via local connections to regional economies. It presents new analysis of the potential and circumstances under which county level employment can be strengthened by connecting to regional industry clusters – networks of businesses, labor pools, etc., whose linkages cross local and even state jurisdictional boundaries. Specifically, this analysis examines how different types of industry clusters and types of urban and rural communities respond to economic connectivity within their regions. Statistical tests are conducted to compare differences in county employment growth (2010-2016) between counties that are economically connected and those that are not. The results suggest that connectivity to regional industry clusters has a strong, positive relationship with local employment growth. These results are particularly pronounced for more rural communities but are present across county types, including metropolitan. The magnitude of the economic impact derived from connectivity with the regional economy varies by the type of industry cluster present. The results suggest an alternative approach to cluster-based economic development strategies that more strategically accounts for and bolsters connectivity. Policy recommendations for how to apply an intra-regional connectivity framework to narrow the urban-rural divide, as well as several regional profiles, are offered.

ACKNOWLEDGEMENTS

The journey and completion of this dissertation and degree would not have been possible without the commitment and support from many people. I would like to thank my committee, Margaret Cowell, Thomas Sanchez, John Provo, and Scott Tate, for their guidance and trust in my capacity to accomplish this feat. They were in the weeds with me when I needed it, and flexible with deadlines when life took me in other directions.

Through generosity of their time and willingness to share their perspective on my ideas, the following policy leaders and practitioners contributed greatly to the development of this dissertation: **Ted Abernathy**, Managing Partner of Economic Leadership LLC; **Marla Akridge**, Alleghany Highlands Economic Development Corporation; **Barry Broome**, President and CEO of the Greater Sacramento Economic Council; **Danielle Casey**, Executive Vice President for the Greater Sacramento Economic Council and board member of the International Economic Development Council; **Brian Dabson**, Research Fellow at the School of Government, University of North Carolina at Chapel Hill; **Mercedes Delgado**, Associate Professor at Copenhagen Business School and Research Scientist at MIT Innovation Initiative; **Sara Dunnigan**, Deputy Director, GO Virginia and Economic Development at Virginia Department of Housing and Community Development; **Chris Mehl**, mayor, city of Bozeman, MT; **Tracey Nichols**, Director of Financial Services, Project Management Consultants, former city of Cleveland Economic Development Director, and board member of the International Economic Development Council; **M. Scott Powell**, Senior Vice President, Business Development and Market Analytics for the Greater Sacramento Area Economic Council; **Dr. John J. Rainone**, President, Dabney S. Lancaster Community College; **John Sampson**, President and CEO, Northeastern Indiana

Regional Partnership; and **Ryan Twiss**, Vice President of Regional Initiatives, Northeastern Indiana Regional Partnership.

I am grateful for the support of my colleagues at the National League of Cities, particularly Brenna Rivett, Anita Yadavalli and Rose Kim. I appreciate their patience over the past couple of years, as well as their insights and smart feedback along the way.

To my husband, Brendan, I could not have done this without your support, love, and encouragement. You provided me the steady foundation to explore, take risks and keep going even with our busy lives. I will be forever grateful to my children, Bryce and Cami, for the sacrifices that they made so that I could spend an inordinate amount of time away and focused on “mom’s big homework project.” They are my motivation and I hope that someday they can reflect on this time as a life lesson in persistence.

That life lesson is just what I learned from my mom, Margaret Brennan-Tonetta, PhD, when she got her PhD a few years ago. To my Mom, I cannot even begin to express all the ways you have inspired and encouraged me. Thank you for your constant support and love, and for being my dissertation editor.

Lastly and most importantly, I thank God for giving me the determination and strength to overcome trials and tribulations, large and small, over the past 15 years. I am also grateful that He gave me the keenness of mind to find small glimmers of hope amidst the piles of literature, data, and research results just when I needed them. It was enough to keep on the path.

Table of Contents

LIST OF FIGURES

INTRODUCTION

Background

The urban-rural divide has become the preeminent economic issue of our time. Once characterized by steady convergence, in which market forces rectified regional economic disparities, the past 40 years have witnessed a shift in the trajectory of the U.S. economy toward divergence (Ganong and Shoag 2017). The rapid rise of highly concentrated urban agglomeration economies, coupled with significant technological advances and the decline in manufacturing, has left many rural and less talent rich places behind. Noted economic geographer Enrico Moretti (2012) describes a “winner-take-all economy” where “winners tend to become stronger and stronger, as innovative firms and innovative workers keep clustering there, while losers tend to lose further ground.” The result is extreme growth in a handful of high tech and coastal regions, while others, namely rural and heartland regions, experience historic levels of brain drain, poverty, drug abuse, unemployment, and suicide (Parker, et. al. 2018).

Despite the magnitude of the challenges posed by the growing urban-rural divide, as well the substantive research and evidence documenting its underlying causes, solutions for effective economic revitalization in lagging communities have been elusive. While some advocate for people-based, mobility strategies to assist population migration away from declining places toward opportunity rich places (Jones 2018), others are proponents of place-based strategies. With loss of industry and the resulting degradation of workforce skills, infrastructure and housing stock, these strategies have tended to focus on rebuilding foundational assets. While investments in these assets are critical for renewed growth, they fall short of providing strategic direction for developing new economic drivers in lagging places. For example, workforce development programs can develop skills, but for what industries?

Additionally, although the challenges of "non-superstar" places are significant, their dire economic prospects are hardly monolithic. Some rural parts of regions are doing well in traditional industries, others are on the frontlines of emerging technologies (Florida 2018). Their success typically hinges on the strength of their traded sectors, and the economic interactions beyond their local borders. This research advances the policy debate on bridging the urban-rural divide and suggests that agglomeration need not be the demise of struggling communities. In contrast, connectivity to industry clusters in the regional economy can offer direction and prospects for growth by broadening the asset base available to lagging communities.

Theoretical Basis

Studies of regional economic diffusion and concentration often suggest that urban economic growth weakens surrounding rural communities, leading to further divergence and backwash effects (Myrdal 1957; Lewin, Weber, and Holland 2013). However, economic geography studies offering a more contextual perspective, particularly when accounting for proximity to urban agglomeration, confirm economic opportunities for rural areas. For example, Barkley, Henry, and Boa (1996) credit proximity of rural communities to their urban cores as a leading explanation for rural growth. The authors recommend that "nonmetropolitan communities benefiting from spread effects can gain from economic development efforts with a regional or metropolitan core focus, and also from programs that enhance their linkages to the core." Similarly, Partridge, Rickman, Ali and Olfert (2008) examine how proximity to urban cores affects population and employment growth in rural areas and find that the closer a county to larger urban areas, the higher its job and population growth. Both Barkley, Henry, and Boa (1996) and Partridge, Rickman, Ali and Olfert (2008) note, however, that the benefits of urban agglomeration on rural growth do not extend to remotely rural areas.

These studies imply that nearness to agglomeration and industry clustering accounts for positive spread effects notably in adjacent rural communities. These studies do not directly test the relationship between growth and industry cluster connectivity or variances in outcomes based on type of cluster, but they do provide fertile ground for further exploration of intra-regional cluster connectivity and urban-rural economic relationships based on cluster linkages.

Industry clusters are firms in related industries that are geographically concentrated and leverage the benefits of their proximity, including knowledge spillovers, thick labor markets and specialized suppliers. For industry clusters to provide a development pathway for disparate parts of regions, however, the spatial scale of their linkages must be regional. The industry cluster literature discusses the spatial implications of these linkages noting that innovation and knowledge-based activities are associated with greater urban density, while other activities such as supply chain relationships and commuting exhibit broader regional, including rural, footprints. Overall, linkages and their spatial scales vary by cluster indicating that some clusters are better suited as targets for bridging the urban-rural divide than others.

Additionally, Porter (2003) examines regional economic performance, the composition of regional economies, and the role of industry clusters in the economy measuring clusters at the spatial scale of broad regions inclusive of highly urban and high rural places (Economic Areas). He finds that key indicators of regional economic performance at the Economic Area level, including wages, wage growth, employment growth and innovation, are strongly and positively influenced by the strength of each region’s clusters. Overall, studies of industry clusters suggest that power of intra-regional cluster connectivity at a scale spanning urban and rural but lack clarity on how different clusters are situated within their regions or the prospects for connectivity to positively impact different parts of regions.

Delgado and Zeuli (2016), however, offer one of the few studies specifically examining the impact of industry cluster linkages within regions on economic outcomes. The authors find that intra-regional connectivity is positively associated with inner city employment growth. In doing so, the authors offer an intra-regional connectivity framework, which this dissertation extends to examining the urban-rural divide.

Research Overview

The purpose of this research is to advance the policy debate on the urban-rural divide by examining how intra-regional industry cluster connectivity influences local economic outcomes. By building on the work of Delgado and Zeuli (2016), this dissertation explores the extent of intra-regional connectivity associated with different industry clusters; whether localities within a region experience spread or backwash effects (employment growth) as a result of intra-regional connectivity via industry clusters; and whether the magnitude of these effects vary by community types and industry cluster. Specifically, this analysis determines whether connectivity, indicated by a presence of industry cluster employment in a county and industry cluster strength (i.e., high relative employment presence based on a location quotient greater than one) in the rest of the region outside of the county, is associated with employment growth in counties between 2010 and 2016. County level connectivity indicates that the county "cluster is connected to the regional cluster through inputs, outputs, skills and other potential linkages" (Delgado and Zeuli 2016).

The study evaluates connectivity using standard county definitions, regions (Economic Areas) as defined by the U.S. Bureau of Economic Analysis, industry cluster definitions developed by the U.S. Cluster Mapping Project, and county rurality categories developed by the USDA (aggregated categories from the Rural-Urban Continuum Codes). The units of analysis are 77,346 county-clusters. County-cluster jobs are sorted into those that are “connected” (county presence and strength in the rest of the region) and those that are not. Independent-samples t-tests are conducted to compare annualized employment growth rates of the county-clusters under connect and not connected conditions. Separate t-tests are also conducted for metropolitan county-clusters, micropolitan county-clusters, rural adjacent county-clusters, and remote rural county-clusters across all industry clusters to determine whether connectivity impacts some community types and some industry clusters more than others.

Hypotheses

This study hypothesizes that connectivity to regional clusters will have positive, spread effects on both urban and rural parts of regions, but that the magnitude of these effects will vary by cluster type and by community type within regions. Thus, the specific hypotheses that are tested in this dissertation research are:

> **H_1** An industry cluster that has a presence in the county and strength in the rest of the region outside of the county (“connected”) will grow faster than the same cluster located in county without strength in the rest of the region outside of the county (“not connected”). The average annualized employment growth rates (2010-2016) for county-clusters that are connected to their regional economies will be greater than for county-clusters that are not connected to their regional economies.
>
> **H_2** The average annualized employment growth rates (2010-2016) for *metropolitan* county-clusters that are connected to their regional economies will be greater than for *metropolitan* county-clusters that are not connected to their regional economies.

H_3 The average annualized employment growth rates (2010-2016) for *micropolitan* county-clusters that are connected to their regional economies will be greater than for *micropolitan* county-clusters that are not connected to their regional economies.

H_4 The average annualized employment growth rates (2010-2016) for *rural adjacent* county-clusters that are connected to their regional economies will be greater than for *rural adjacent* county-clusters that are not connected to their regional economies.

H_5 The average annualized employment growth rates (2010-2016) for *rural remote* county-clusters that are connected to their regional economies will be greater than for *rural remote* county-clusters that are not connected to their regional economies.

H_6 In terms of comparative magnitude of the average employment growth rate differences between connected and not connected county-clusters by county type: *Rural Adjacent* > *Micropolitan* > *Metropolitan* > *Rural Remote*.

H_7 Differences in the average annualized employment growth rates (2010-2016) for connected and not connected county-clusters by *industry cluster* will vary by industry cluster and by county type.

Overall, this research hypotheses that connectivity based on industry cluster linkages will benefit communities throughout regions, both urban and rural. The literature has specified that rural adjacent communities will benefit most given their proximity to metropolitan agglomeration, and that remote rural communities will benefit least. Less understood, however, is the impact of connectivity on micropolitan and metropolitan areas, and even less still is known about the variance in impact based on industry cluster type.

The results of the study suggest that intra-regional economic connectivity has a positive association with county-cluster employment growth across all county types. These results are strongest for remote rural communities, challenging previous findings that remote rural communities benefit least. It is significant, too, that metropolitan counties benefit from intra-regional connectivity with some of the greatest advantages derived from connections with rural-based clusters. Additionally, the magnitude of employment growth impacts varies by industry cluster type, indicating that the footprint of cluster linkages, and their interactions within regions, must be considered when policy leaders and practitioners adopt a cluster-based approach.

LITERATURE REVIEW

Introduction

Regional economic connectivity has its theoretical underpinnings in two distinct but related bodies of literature. The first is the field of economic geography, namely theories of regional economic concentration and diffusion. These theories confront "the issue of whether or not regional disparities in the level of growth and development are likely to remain persistent or even worsen in the absence of public intervention" (Malizia and Feser 1999). They generally answer the question of whether both urban and rural parts of regions can participate in and benefit from the broader regional economy. The second body of literature regards industry clusters, specifically the geographic scale of clusters and their potential to extend beyond metropolitan cores within regions. For each, I outline the theoretical underpinnings, followed by a review of empirical applications and implications for urban-rural economic connectivity.

Economic Geography: Regional Concentration and Diffusion

Perroux's (1950) growth pole theory is central to the body of theories of regional concentration and diffusion. Hirschman's (1958) unbalanced growth and Myrdal's (1957) cumulative causation theories are extensions of growth pole theory and are differentiated based on the economists' perspectives of whether positive (spread) or negative (backwash) effects dominate the intra-regional economic relationship. Spread effects, such as input suppliers in the periphery for industries in the core, are types of economic connections between the core and periphery that are positive and benefit both parts of the region. Backwash effects, such as migration of labor and financial capital from the periphery to the core, are negative economic relationships that drain the periphery to benefit the core.

According to Perroux (1950), growth is characterized as an uneven process, with economic activity concentrating in areas, or growth poles, that offer the assets, resources, and environment necessary to support and sustain major industries. Business and industries with relationships to the "pole," such as suppliers, become linked, prospering, and failing along with the dominant industry. Perroux's initial presentation of growth pole theory was not specifically one of regional spatial development but focused more on the relationship between core industries and other activities within its "economic sphere," whether inside the region via supplier relationships, or outside the region via customers. Later, Perroux (1988) evolved his theory for practical application to account the rise of concentrated economic activity in the form of agglomeration. Simply put, "agglomeration economies are the benefits that come when firms and people locate near one another together in cities and industrial clusters" (Glaeser 2010). The subsequent implication of more concentrated spatial development within regions led to the concept of "growth centers," often the urban core parts of regions.

However, "one of the most basic assumptions of growth center applications has been that the effect of growth will spread or diffuse to the periphery" (Malizia and Feser 1999). This relationship is assumed to exist, but little attention is given to how linkages develop. Other strands of regional concentration and diffusion theory built on Perroux's growth centers to answer this basic question of how and whether the economic relationship between parts of regions were or could be positive and symbiotic (spread effects), or innately negative (backwash effects).

Hirschman's (1958) concept of unbalanced growth presumes positive spread effects from the core to the periphery through a "trickle down process" of growth based on input-output relationships that increase purchases and investments in underdeveloped areas. Although

Hirschman agreed that some level of negative backwash effects, such as outmigration and capital flight from the periphery to the core, are possible at early stages of core development, over time, he posited that positive spread effects, such as investment and buyer-supplier relationships, will become more prevalent. The spatial structure of economic activity in regions is thereby characterized by mutually reinforcing economic connectivity between the core and periphery.

Myrdal (1957), on the other hand, argues that backwash effects dominate the intra-regional relationship. In his cumulative causation theory, Myrdal describes market forces that perpetuate growth in urban cores at the expense of the rural periphery, further isolating peripheries. According to Myrdal, proximity to growth centers results in backwash effects. He notes that some level of spread effects is possible, such as growing markets for primary goods and increased demand for raw materials produced in the periphery (Malizia and Feser 1999), but that negative backwash and weakened economic connectivity generally characterize the intra-regional economic dynamic.

Krugman (1991) later argued that a core-periphery economic structure may exist for a number of years, but that overtime small shifts in economic structure, such as new investment, “can set off a rapid cumulative process of import substitution and growth in the periphery” (Hughes and Holland 1994). He notes that this process of divergence and greater self-reliance, or import substitution, in the periphery often occurs as the core becomes more connected with the global economy.

Several empirical studies examine intra-regional economic dynamics from the regional concentration and diffusion theoretical lens to test whether backwash or spread effects dominate the urban-rural economic relationship. These studies focus on connections including commuting, employment growth, population growth and trading. For example, Lewin, Weber, and Holland

(2013) analyzed commuting and trade relationships between the core and periphery of the Portland economic region between 1982-2006. They found that economic growth of the core led to increased commuting from the periphery to the core (backwash effect). Sectoral linkages and within region trading relationships changed significantly, with the periphery increasing self-sufficiency via import substitution, as described by Krugman (1991). Import substitution in the periphery was made possible by “the powerful redistribution role of the federal government through transfer payments and federal taxes” (Weber and Rah 2010). The core, on the other hand, became better integrated with the rest of the world via globalization and decreased its reliance on the periphery for goods and services. Overall, Lewin, Weber, and Holland (2013) find evidence of increased backwash effects and decreased sectoral linkages between the core and periphery, countering theories that cores, or growth centers, will produce positive outcomes in rural areas without strategic intervention.

Similarly, Dabson, Johnson, Miller, and Robinson (2009) examine sectoral linkages and intra-regional trade flows between urban and rural areas in central Appalachia. They find that rural Appalachia experienced significant backwash effects due to proximity to growing core areas, including outmigration and capital flight to urban cores, decreased economic diversification and increased dependence on natural resource extraction. However, lack of import substitution in the Appalachian periphery stands in contrast to the increased self-reliance of rural parts of Portland, resulting in more significant intra-regional disparities in the former.

The studies above suggest that as urban economies grow, surrounding rural communities diverge and weaken. Barkley, Henry, and Boa (1996), however, add nuance to the study of urban-rural economic dynamics by specifically accounting for intra-regional context. The authors examine the impact of urban population growth on population change in urban fringe and isolated rural places in eight smaller southern economic regions between 1980 and 1990. They account for the proximity of rural communities to their urban cores and find that rural areas at the urban fringe benefit from urban growth as population decentralizes out from the core.

Citing Castel, Wu and Weber (2011) and Irwin, Bell, Bockstael, Newburn, Partridge and Wu (2009), Dabson (2019) notes that “falling transportation and communication costs, technological change and economic restructuring, rising incomes and changing tastes for natural amenities all drive this process of decentralization (or deconcentrating).” Barkley, Henry and Boa (1996) attribute the benefits of proximity to the ascendance of agglomeration economies and recommend that “nonmetropolitan communities benefiting from spread effects can gain from economic development efforts with a regional or metropolitan core focus, and also from programs that enhance their linkages to the core.” They also warn that, in contrast to nearby rural communities, population trends in more remote rural areas exhibit backwash effects with stagnation or decline resulting from urban growth.

Similarly, Partridge, Rickman, Ali and Olfert (2008) examine how proximity to urban cores affects population and employment growth in rural areas over the period of 1950-2000. They find that the further a county is from larger urban areas, the lower its job and population growth. The authors conclude that “despite declines in transport costs, technological advances in communication and the dispersion of manufacturing to low-cost locations, the economic costs of remoteness appear to be increasing.” In a review of studies on specific proximity implications, Dabson (2019) notes, “the spread effects are estimated to be in the range of 75 miles to 125 miles for those rural communities that can offer high quality of life and services for commuting residents. The larger the urban center, the greater its impact on outlying rural economies...”

Overall, empirical studies of regional economic diffusion and concentration have most often bore out negative economic dynamics, or backwash effects, between urban and rural areas within regions. However, studies offering a more contextual perspective, particularly when accounting for proximity, confirm economic opportunities for rural areas as a result of greater regional economic connectivity and access to urban agglomeration. These findings have strong implications for economic development both broadly in regions and specifically in parts of regions outside of metropolitan cores. They encourage economic development practitioners to look to urban agglomeration as a pathway for greater economic growth and intra-regional economic convergence. These studies introduce proximity as a key factor impacting urban-rural economic connectivity, implying that nearness to agglomeration and industry clustering accounts for positive spread effects notably in adjacent rural communities.

Critically, although the economic relationship between urban and rural based on commuting, population trends and trade have been explored and are assumed to be largely grounded in urban agglomeration, the specific relationship between agglomeration and urban-rural connectivity has not been examined. Indeed, the very nature of agglomeration economies is presumed to be urban and tightly concentrated. So, what are the opportunities for urban and rural areas to sustain and grow their local and regional economies via participation in regional industry clusters? The next section compliments the economic geography literature on regional concentration and dispersion with business development literature exploring the spatial implications of agglomeration economies and the capacity of industry clusters to span urban and rural areas within regions.

Industry Clusters

Competitive nations are made up of competitive regions, and competitive regions consist of localized collections of firms that share common factors, exchange information, and yet still engage in competition. - Porter (2003)

Industry clusters have emerged over the past 30 years as a central focus of economic development. The cluster concept was introduced by Michael Porter in his seminal work, *The Competitive Advantage of Nations* (1990), and draws on a long history of agglomeration economy theory and foundations, namely that of localization economies introduced by Alfred Marshall (1920). Industry clusters are firms in related industries that are geographically concentrated and leverage the benefits of their proximity, including knowledge spillovers, thick labor markets and specialized suppliers. Firms that are part of clusters utilize the benefits of their proximity to create a network "linked either vertically, through buying and selling chains, and/or horizontally, through complementary products and services, the use of similar specialized inputs, technologies or institutions, and other linkages" (Porter 1998). Clusters contrast previous Fordist models of firm and industry organization where all phases and aspects of production are performed in-house (Piore and Sable 1984). Industry clusters arise over time in distinct geographies as a result of the successful integration of underlying processes, assets, and local conditions, or the "diamond of competitive advantage" (Porter 1998). The "diamond" includes factor conditions, demand conditions, related and supporting industries, and firm strategy, structure and rivalry that are linked and drive cluster formation and growth:

- *Factor or input conditions* are factors of production common to all firms in a cluster, such as skilled labor, specialized infrastructure, and educational institutions. Since factor conditions are specialized to a group of firms in a location, the location itself develops a competitive advantage for the services and products developed by the cluster, which is reinforced over time as demand increases.

- *Demand conditions*, or the presence of sophisticated and demanding local customers and niche markets, in a region enable industry cluster firms to more quickly understand demand, test goods and services, and innovate. This process is particularly beneficial to entrepreneurs who can test and refine products and services locally and regionally before taking them to the global market (Martin 2011).
- *Supporting industries*, capable, locally based suppliers and competitive related industries create a supportive web of providers for firms in the cluster. As technical problems arise or demand changes, cooperation between firms and their suppliers leads to innovation because these firms must exchange information and knowledge about new processes and products. "The benefits to supplier location in clusters runs both ways- suppliers gain from the nearby market for their output, while client firms in the cluster gain from easy access to a range of services" (Cortright 2006).
- *Firm strategy and rivalry* are another important feature of how industry cluster firms interact in a way that is competitive and cooperative with each other. As firms compete, they invest and innovate to differentiate themselves. But given the broadly shared resources within their common location (i.e. workforce, infrastructure, etc.) there is also incentive for them to cooperate via joint problem solving to address industry wide issues (Malizia and Feser 1999).

As a result of these factors, the economic impacts of industry clusters tend to be greater than the sum of their parts. Firms that are part of clusters are more productive than those that are not, and the implications for economic development are significant, namely because the impact of clusters are region-wide, not industry or company specific.

Most industry cluster studies, including those by Porter and his colleagues, measure clusters at a regional scale that is inclusive of urban and rural areas, Economic Areas. This is pertinent to this dissertation because Economic Area regions are larger than core-focused regions (i.e. Metropolitan Statistical Areas) and include a broader spectrum of community types, from very urban to very rural. These regions are designated in Porter's industry cluster data portal, the U.S. Cluster Mapping Project, as a core level of geography for measuring clusters. For example, using Economic Area regions, Porter (2003) examines regional economic performance, the composition of regional economies, and the role of clusters in the U.S. economy over the period of 1990 to 2000. He finds that key indicators of regional economic performance at the Economic Area level, including wages, wage growth, employment growth and innovation, are strongly and positively influenced by the strength of each region's clusters.

In a 2014 study, Delgado, Porter and Stern examine the role of clusters in the employment and innovation growth of the individual industries that constitute each cluster. Their study points to the positive impact that high concentrations of cluster employment (cluster strength) have not only on those firms directly within industry clusters, but also on regional (Economic Area) economic performance, including the growth rate of average wages, establishments and patenting within regions. The results suggest that the effect of spillovers associated with cluster activity is a key driver of growth and job creation beyond the cluster itself. In an examination of the impact of clusters on entrepreneurship specifically, Delgado, Porter and Stern (2010) found that industries located in Economic Area regions with strong clusters experience higher growth in new business formation and start-up employment and have greater start-up firm survival.

Strong clusters are also associated with the formation of new establishments of existing firms, thus influencing the location decision of multi- establishment firms. Overall, the evidence supports industry clusters and their significant economic impact on wages, jobs, productivity, and new business creation, along with positive impacts on the broader (urban and rural) regional economies, and local economies in which they operate.

In a more recent study, Delgado and Zeuli (2016) test Porter's (1997) assertion that inner-city economic development should consider connectivity with the regional economy as a growth path. The authors offer one of the few studies examining industry cluster growth at a lower level of geography as it relates relationship to connectivity with agglomeration at a higher regional geography. Although their regional scale is metropolitan, not Economic Area, the author's find that intra-regional connectivity is indeed positively associated with inner city employment growth. In doing so, the authors' offer an intra-regional connectivity framework to approach the study of industry clusters.

These consistently positive economic impacts, as well as the simplicity of the concept, has led to the widespread uptake of strategies to support industry clusters among economic development practitioners (Wolman and Hincapie 2014). Martin and Sunley (2003) warn, however, that "the mere popularity of a construct is by no means a guarantee of its profundity." Specifically, the authors criticize Porter's lack of geographical definitions around the size and density of clusters and the degree of linkages between firms within clusters. They ask, "what spatial scale, and over what geographical range, do clustering processes (inter-firm linkages, knowledge spillovers, rivalry, business and social networks, and so on) operate?" Martin and Sunley (2003) introduce specific questions about the spatial scale, the extent of intra-regional industry cluster linkages and the geographic footprint of the "diamond" within regions, getting to the heart of this dissertation‘s inquiry about the capacity of clusters to foster economic connectivity between urban and rural communities.

Several researchers have approached the question of the geographic “fuzziness” of the cluster concept, finding that variations stem from types of linkages present in the cluster (Markusen 1999). For example, Jaffe et al. (1993) and Rosenthal and Strange (2001) find that knowledge spillovers and highly innovative cluster activity are more prevalent at narrower metropolitan and even neighborhood scales. Knowledge spillovers are a denser economic activity because “the concentration of many people working on a similar set of economic problems produces a widely shared understanding of an industry and its workings” (Cortright 2006). Rosenthal and Strange (2001) also find that cluster supply chain relationships and labor markets operate at broader regional and sometimes state scales.

Feser and Isserman (2009) find that rural areas play an integral part in a great variety of clusters, from those that are global and national in scope to those that are highly localized. Their findings suggest that less urbanized parts of regions have the capacity through value chains to leverage the advantages of rural locations for businesses and industries that are part of agglomerations. While acknowledging rural linkages outside of their regions, the authors note also that “the most important cluster for a given rural community’s economic future might be based in the rural locality itself or in a nearby urban area” (Feser and Isserman 2009). Additionally, Dabson (2011) notes that cluster activity involving extensive supply chain relationships and production with “firms and sectors that require space rather than proximity to operate - like natural resource industries and large land users...” have greater potential to be sustained in rural areas.

Gap

Connectivity and linkages are hallmarks of industry clusters, from labor market pooling and supplier specialization to knowledge spillovers and local demand. As noted in the literature, these cluster foundations have distinct geographical patterns within regions, with innovation and knowledge-based activities associated with greater urban density, while other activities such as supply chain relationships and commuting associated with broader regional, including rural, footprints. While the scale of individual linkages has been examined, the cluster-based combination of linkages within regions has not.

Limited empirical analysis provides evidence of these linkages crossing the urban-rural divide, but industry cluster research lacks clarity on the extent of urban-rural connectivity or the impact of intra-regional connectivity for different types of industry clusters. Porter and his colleagues offer studies of regional clusters measured at regional scales inclusive of both urban and rural areas, but they do not offer insights about how clusters are situated with these regions. As a result, the practice of economic development is left to make assumptions about the benefits and behavior of agglomeration for different parts of regions. Additionally, and perhaps most important, when examining the impact of clusters, cluster studies examine industry clusters in the aggregate, and do not pinpoint differences in these outcomes by cluster type.

This approach to studying industry clusters has led to critiques, such as that from Martin and Sunley (2003), about the difficulty of identifying clusters due to the extensive variation across clusters and the ways that clusters operate within different regional contexts. In Cortright's (2016) thorough review of industry clusters, he acknowledges the variation and proposes that

> …the most potent antidote to ambiguity and competing definitions is for both academics and researchers to step back from the objective of making sweeping, universal

> statements or hypotheses about clusters and to be more nuanced in their descriptions and analysis of different kinds of industry clusters. Rather than working to prove (or disprove) that clustering generally is a benefit to economic performance, research would better be directed to discovering the specific characteristics of clusters that lead to such performance.

One core characteristic of industry clusters that has not yet been explored is the extent to which urban and rural economies benefit from (or are disadvantaged from) connectivity to regional clusters and agglomeration activity and how this varies in different parts of regions and by different types of industry clusters. While theories debate whether spread (positive) or backwash (negative) effects dominate the urban-rural economic relationship, the introduction of proximity to agglomeration provided a more nuanced view suggesting a pathway for rural and regional growth that rests on connectivity. These studies do not directly test the relationship between growth and industry cluster connectivity (using instead “proximity") or variances in outcomes based on type of cluster, but they do provide fertile ground for further exploration of intra-regional cluster connectivity and urban-rural economic relationships based on linkages via agglomeration and industry clusters.

To fill this gap, this study hypothesizes that connectivity to regional clusters will have positive, spread effects on both urban and rural parts of regions, but that the magnitude of these effects will vary by cluster type and by community type. Specifically, this dissertation explores the extent of intra-regional connectivity associated with different industry clusters; whether localities within a region experience spread or backwash effects (employment growth) as a result of intra-regional connectivity via industry clusters; and whether the magnitude of these effects vary by different types of communities and different industry clusters.

Understanding intra-regional cluster connectivity is more than an academic exercise. It is intended to inform the field of practice and identify the opportunities for urban and rural areas to sustain and grow their local economies via participation in regional industry clusters. The extent and impact of intra-regional economic connectivity will have significant implications for strategic priorities, public intervention and investments, namely local and regional business development and retention, workforce development and infrastructure strategies.

DATA AND RESEARCH DESIGN

Introduction

This research applies an industry cluster framework to evaluate the strength of intra-regional economic connectivity across industry cluster types in U.S. Economic Areas (EA) and to determine whether this connectivity is associated with employment growth in urban and rural communities between 2010 and 2016. The analysis determines the connectivity between industry cluster employment in counties and industry cluster strength in the rest of the region (EA) outside of the county. The county-cluster is "connected" if jobs in an industry cluster are present in the county and strong (i.e., high relative employment presence) in the rest of the region. As a result, the county-level "cluster is connected to the regional cluster through inputs, outputs, skills and other potential linkages" (Delgado and Zeuli 2016).

The research tests whether connectivity matters for economic growth. If connectivity to regional clusters positively impacts local growth, it signals that agglomeration effects arise across the same cluster in the county and in its surrounding region and that spread effects characterize the relationship between broader regional agglomeration and local economic growth. Therefore, an industry cluster approach connected to strong regional clusters may present a new, viable path for local economic development, particularly in struggling communities.

Data

Connectivity and economic impact are evaluated by industry cluster and by community type using standard county definitions, regions (Economic Areas) as defined by the U.S. Bureau of Economic Analysis, and industry cluster definitions developed by the U.S. Cluster Mapping

Project. This section defines the primary level of geographies, as well as county designations as metropolitan, micropolitan, rural adjacent and rural remote. Industry cluster definitions are explained, followed by a discussion of the research design.

Urban and Rural

In this analysis, counties are the basic level of geography from which this analysis is based. To understand intra-regional dynamics between different parts of regions, counties are assigned a rurality category - either metropolitan, micropolitan, rural adjacent or rural remote. These categories are adapted from the USDA Rural-Urban Continuum Code (RUCCs) and used in the analysis to determine whether intra-regional connectivity and employment impacts occur across community types within the same regions and vary among community types. As is well documented, the terms "urban" and "rural" can take on many definitions (Dabson 2019). The Office of Budget and Management (OMB) defines urban as "metropolitan," while designating all other counties as "micropolitan" and "non-metropolitan," or rural. While data is more readily available using these categories, the terms mask extensive variation among different types of urban and rural places.

For greater nuance, the U.S. Census Bureau defines rurality based on population size, density, land use and distance to an urban area. Within these parameters, the Bureau defines three levels of rurality: completely rural, mostly rural, and mostly urban. The core challenge with these definitions is that according to the Census definitions, 20 percent of completely rural counties and 31 percent of mostly rural counties are part of OMB-defined metropolitan areas. Likewise, six percent of mostly urban counties are designated as non-metropolitan.

Alternatively, the U.S. Department of Agriculture Economic Research Service offers a more refined approach and defines counties based on Rural-Urban Continuum Codes (RUCCs).

According to USDA, the 2013 Rural-Urban Continuum Codes form a classification scheme that distinguishes metropolitan counties by the population size of their metropolitan area, and nonmetropolitan counties by degree of urbanization and adjacency to a metropolitan area. The official OMB metropolitan and nonmetropolitan categories have been subdivided into three metropolitan and six nonmetropolitan categories. Each county in the U.S. is assigned one of the nine codes (**Figure 1**).[1] This scheme allows researchers to break county data into finer groups, beyond metropolitan and nonmetropolitan, particularly for the analysis of trends in nonmetropolitan areas that are related to population density and regional economic influence. These codes are therefore most suitable for the purposes of this research given the focus on intra-regional economic linkages.

[1] For Virginia, USDA ERS combined nonmetro independent cities with their counties of origin when computing the Rural-urban continuum Codes.

Figure 1: Rural-Urban Continuum Codes (RUCCs) with Aggregated County Types

RUCCs Metropolitan County Codes	RUCCs Definition	McFarland County Type
1	Counties in metro areas of 1 million population or more	Metropolitan
2	Counties in metro areas of 250,000 to 1 million population	Metropolitan
3	Counties in metro areas of fewer than 250,000 population	Metropolitan
RUCCs Nonmetropolitan County Codes		
4	Urban population of 20,000 or more, adjacent to a metro area	Rural Adjacent
5	Urban population of 20,000 or more, not adjacent to a metro area	Micropolitan
6	Urban population of 2,500 to 19,999, adjacent to a metro area	Rural Adjacent
7	Urban population of 2,500 to 19,999, not adjacent to a metro area	Rural Remote
8	Completely rural or less than 2,500 urban population, adjacent to a metro area	Rural Adjacent
9	Completely rural or less than 2,500 urban, not adjacent to a metro area	Rural Remote

In order to both leverage the nuances of RUCCs and to have a reasonable number of categories to conduct comparative analysis, RUCCs categories are collapsed into community types that are based in the literature as engaging in regional economies in distinct ways. Figure 1 details the USDA codes and how they align with the aggregation used in this analysis (i.e., "McFarland county type:" metropolitan, micropolitan, rural adjacent, rural remote).

Metropolitan counties include all counties in metropolitan areas of 1 million population or more (RUCCs 1), counties in metro areas of 250,000 to 1 million population (RUCCs 2), and counties in metro areas of fewer than 250,000 population (RUCCs 3). In total, there are 1,168 metropolitan counties. *Micropolitan* counties are delineated using RUCCs 5, urban population of 20,000 or more, not adjacent to a metro area. These counties are comparable to the OMB definition of micropolitan statistical areas which consist of the county or counties (or equivalent entities) associated with at least one urban cluster of at least 10,000 but less than 50,000 population, plus adjacent counties having a high degree of social and economic integration with the core as measured through commuting ties. There are 654 micropolitan counties. *Rural adjacent* communities are outside of metropolitan areas but adjacent to them. Rural adjacent counties include RUCCs 4, 6 and 8 and comprise 646 counties. *Rural remote* counties are outside of metropolitan areas and are not adjacent to them. They include RUCCs 7 and 9 and comprise 676 counties. These four categories of community types within regions – metropolitan, micropolitan, rural adjacent and rural remote - create consistency with the technical definition and intra-regional dynamics of EAs. In the analysis, data are presented as metropolitan, micropolitan, rural adjacent and rural remote portions of their regions.

Economic Area Regions

The definition of “region” utilized in this analysis is Economic Area (EA). The U.S. Bureau of Economic Analysis (BEA) identifies 179 economically cohesive geographic units that comprise all counties in the U.S. EAs define relevant regional markets surrounding metropolitan and micropolitan areas, including rural areas. The core building blocks of EAs is counties. EAs are widely used in studies of industry clusters and EAs are also widely used throughout the federal government and in the private sector. According to the BEA, examples of federal government uses include defining national transportation analysis regions, assessing competition levels in markets for oil pipeline services, and defining mobile communication licensing territories. Regional councils of government and economic development agencies use EAs for research and market analyses, while the private sector uses the areas to determine markets for products.

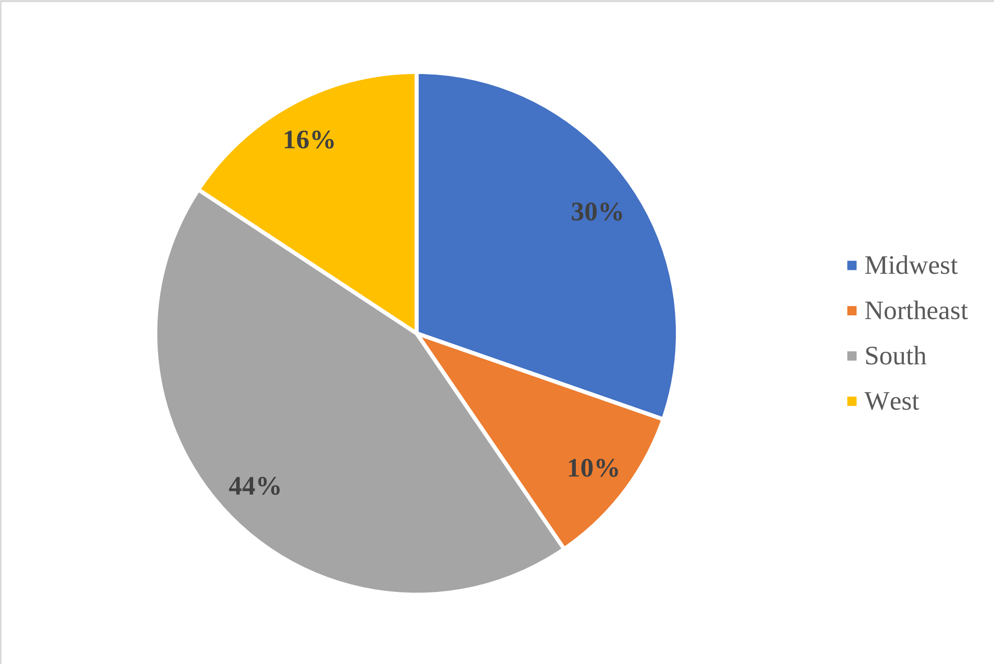
Economic Areas are very diverse when viewed by population size, locations across the country and internal urban-rural dynamics (**Appendix 1**).[2] The average population size of an EA is 1,808,609 (**Figure 2**). EA's range from the largest, New York-Newark-Bridgeport, NY-NJ-CT-PA, at 23,815,321, to the smallest, Aberdeen, SD at 82,553, with a standard deviation of 3,017,540. Across broader Census regions with the U.S. (Northeast, Midwest, South and West), most Economic Areas are in the South (44%), with 30 percent in the Midwest, 16 percent in the West and 10 percent in the Northeast (**Figure 3**).

Figure 2: Descriptive Statistics for Economic Area 2016 Population

Mean	1800357
Median	790005
Standard Deviation	3017540
Minimum	82553
Maximum	23815321
Count	178

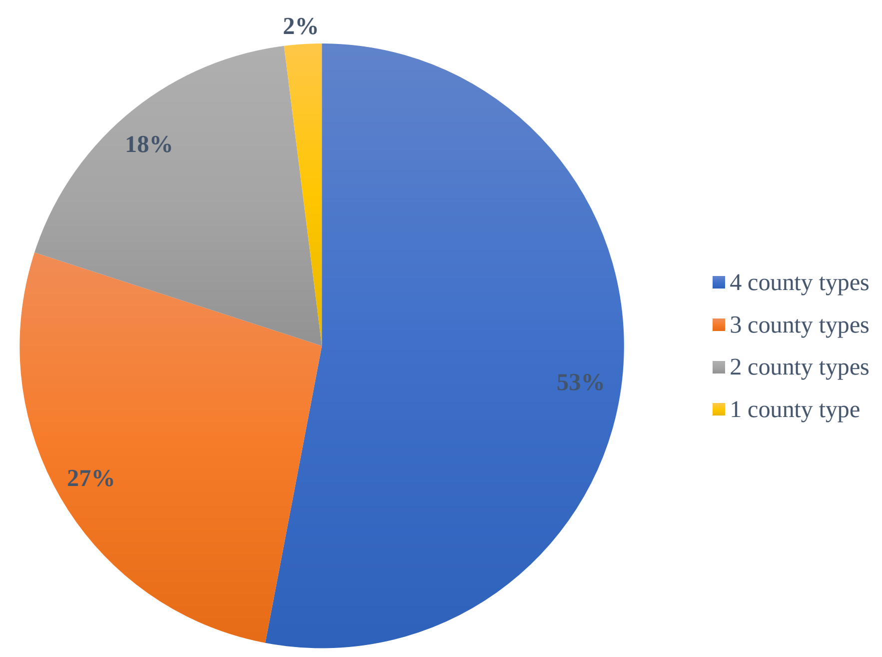
[2] The San Diego Economic Area is excluded from this analysis because the entire region is contained in only one county. Calculating industry cluster specialization "outside of the county in the rest of the region" is not possible for the San Diego region.

Figure 3: Percent of Economic Areas in each Census Region



In addition to population and location across the country, Economic Areas also vary by their internal urban-rural dynamics (**Figure 4**). The previous section on "urban-rural" details how counties within EAs are categorized utilizing an aggregated Rural-Urban Continuum Code (RUCCs) scheme - metropolitan, micropolitan, rural adjacent and rural remote counties. While 94 EAs have all four types of counties within their borders, several, such as Kennewick-Richland-Pasco, WA; Pensacola-Ferry Pass-Brent, FL; San Diego-Carlsbad-San Marcos, CA; and Tampa-St. Petersburg-Clearwater, FL, are comprised entirely of metropolitan counties. Thirty-three regions have two designations, including some with micropolitan and rural remote counties, while others have metropolitan counties and either micropolitan or rural adjacent counties. Forty-eight regions have three designations; 30 of which have metropolitan, micropolitan and rural adjacent counties, but no rural remote counties. Five do not have metropolitan counties: Helena, MT; Mason City, IA; Paducah, KY-IL; Scotts Bluff, NE; and Tupelo, MS.

Figure 4: Percent of Economic Areas with each Number of County Types



Source: Author's calculations based on USDA RUCCs codes and BEA Economic Areas.

One shortcoming of using EAs for this analysis is the heterogeneity of urban-rural dynamics. Using EAs as the regional level of geography presupposes that the impact of, say, intra-regional Aerospace Vehicles and Defense cluster linkages on micropolitan parts of regions operate consistently from EA to EA. Clearly, however, extensive variation exists in the urban-rural composition of regions. For example, a micropolitan county in a region with metropolitan counties has a different intra-regional economic dynamic than a region with no metropolitan counties. In the first scenario metropolitan and micropolitan areas may compete for similar industry cluster firms and functions, whereas in the second, the micropolitan area may serve as the only core urban-type agglomeration within the region. To control for this variation, the analysis includes statistical significance measures to determine whether average differences in economic outcomes produced by connected and not connected clusters experience significant variation across county types and industry clusters, or whether the findings are more consistent across county types and clusters, even within differing urban-rural regional contexts. If extensive variation in the economic impact of connectivity exists for a cluster or type of county, the result will not show statistical significance.

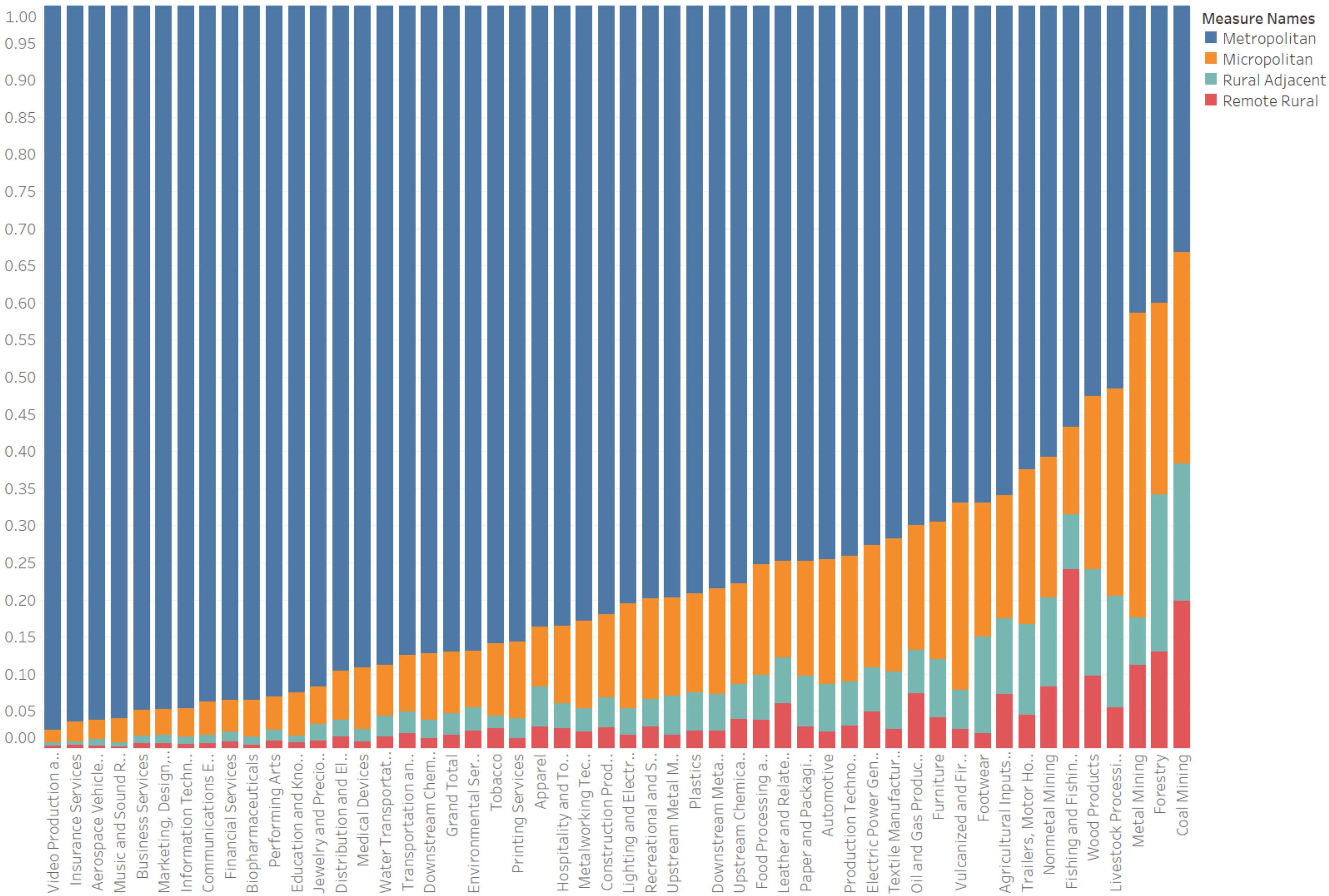
Industry Clusters

This analysis uses the definition of industry clusters developed by Delgado, Porter and Stern (2016). To create cluster definitions, they group together narrowly defined U.S. industry codes that show significant inter-industry linkages based on input-output measures, labor occupations, and the co-location patterns of employment and establishments (Ketels 2017). The main underlying data source for cluster definitions is the U.S. Census Bureau's County Business Patterns data set on employment, establishments, and wages by six-digit NAICS code (North American Industry Classification System). These data are available via the Harvard Business School's Institute for Strategy and Competitiveness U.S. Cluster Mapping Project, a national economic initiative that provides over 50 million open data records on industry clusters and regional business environments in the U.S.

This analysis specifically utilizes the 51 traded sector clusters developed by the project, and these clusters are accounted for in each county and Economic Area. Traded clusters are the focus of this analysis because they serve markets beyond the region and have several notable characteristics. They are highly concentrated in a few regions with specific competitive advantages and they drive high levels of overall regional economic performance. While local clusters account for most of the employment and employment growth in regional economies, traded clusters register higher wages, much higher levels of innovation, and greater overall economic impact (Ketels 2017).

In addition to traded vs. local, industry clusters can also be characterized by the scope of their presence in different parts of regions. As noted earlier, depending on the predominant linkages and combination of linkages, clusters fall on a spectrum from highly metropolitan to more rural. This research identifies the intra-regional employment share of industry clusters within EAs to gauge where different clusters fall on this spectrum. Employment share is based on county industry cluster employment data provided by the U.S. Cluster Mapping Project aggregated by county type. The share of industry cluster jobs for each cluster and for each county type is presented (**Figure 5**).

Figure 5: Intra-Regional Share of Industry Cluster Employment



Industry clusters range from highly metropolitan, such as Aerospace Vehicles and Defense and Biopharmaceuticals to highly rural, such as Forestry and Coal Mining. This feature is introduced into the analysis to understand whether and how the intra-regional geography of cluster employment affects whether cluster connectivity results in spread or backwash effects on different types of communities within regions. For example, does rural adjacent connectivity to the highly metropolitan Aerospace Vehicles and Defense cluster result in greater employment growth to support the cluster in the core with related activities such as parts manufacturing (spread), or does it result in backwash effects where connectivity to the cluster creates intra-regional competition between the rural adjacent and metropolitan areas leading to decline in cluster employment in the rural adjacent community?

Research Design

To assess the impact of intra-regional cluster linkages on county employment growth, this research adapts an approach developed by Delgado and Zeuli (2016). Delgado and Zeuli (2016) examine whether inner-city industry connections to metropolitan regional clusters impact inner-city employment growth. This connectivity between local and regional clusters indicates that the mechanisms of agglomeration such as skilled labor, sophisticated and demanding local customers, niche markets, suppliers, and related industries, are at work regionally and have a positive influence on local development. The authors find that the strength of the cluster in the metropolitan region is positively associated with employment growth within the inner-city cluster. An important contribution of Delgado and Zeuli's (2016) research is that it also measures the cluster composition of inner cities and their nearby regions. They find that inner cities vary in their cluster composition and in their degree of connectivity to the regional clusters.

In accordance with Delgado and Zeuli (2016), and unlike most other industry cluster studies, this research examines intra-regional connectivity impacts by industry cluster type, allowing for more refined results and more specific policy recommendations. Although this dissertation builds on the industry cluster connectivity framework presented by Delgado and Zeuli (2016), it departs from their analysis in two specific ways. First, this dissertation examines higher order geographies, i.e. counties instead of inner cities and Economic Areas instead of metropolitan areas. Additionally, this research examines connectivity and its impacts across different types of communities within a region (metropolitan, micropolitan, etc.,), not just inner cities where industry clusters are presumed to operate. Both adaptations allow for a fuller analysis of urban-rural implications.

Overall, this design helps uncover whether intra-regional connectivity benefits local growth beyond a metropolitan setting. It also broadens the utility of a framework based on industry clusters to economic developers in all types of communities, including rural ones, not just inner city or urban. Lastly, conducting separate analyses on different types of industry clusters by county type allows for a very specific understanding of the connectivity contexts in which specific clusters thrive and others do not.

Presentation of Hypotheses

This research hypothesizes that clusters in counties that are connected to their regional economies experience greater employment growth than those that are not connected, with differences emerging across different types of communities and across different types of industry clusters. Thus, the specific hypotheses that are tested in this dissertation research are:

H_1 An industry cluster that has a presence in the county and specialization in the rest of the region outside of the county ("connected") will grow faster than the same cluster located in county without specialization in the rest of the region outside of the county ("not connected"). The average annualized employment growth rates (2010-2016) for county-clusters that are connected to their regional economies will be greater than for county-clusters that are not connected to their regional economies.

H_2 The average annualized employment growth rates (2010-2016) for *metropolitan* county-clusters that are connected to their regional economies will be greater than for *metropolitan* county-clusters that are not connected to their regional economies.

H_3 The average annualized employment growth rates (2010-2016) for *micropolitan* county-clusters that are connected to their regional economies will be greater than for *micropolitan* county-clusters that are not connected to their regional economies.

H_4 The average annualized employment growth rates (2010-2016) for *rural adjacent* county-clusters that are connected to their regional economies will be greater than for *rural adjacent* county-clusters that are not connected to their regional economies.

H_5 The average annualized employment growth rates (2010-2016) for *rural remote* county-clusters that are connected to their regional economies will be greater than for *rural remote* county-clusters that are not connected to their regional economies.

H_6 In terms of comparative magnitude of the average employment growth rate differences between connected and not connected county-clusters by county type: *Rural Adjacent* > *Micropolitan* > *Metropolitan* > *Rural Remote*.

$\mathbf{H_7}$ Differences in the average annualized employment growth rates (2010-2016) for connected and not connected county-clusters by *industry cluster* will vary by industry cluster and by county type.

As noted by Partridge, Rickman, Ali and Olfert (2008) and Barkley, Henry and Boa (1996), agglomeration has positive impacts on the economic outcomes of nearby rural communities and therefore I expect that connectivity will have a sizable impact on rural adjacent communities. The same authors conclude that agglomeration will have significantly less impact in remote rural communities and may even result in backwash effects. Specifically, Partridge, Rickman, Ali and Olfert (2008) note that "despite declines in transport costs, technological advances in communication and the dispersion of manufacturing to low-cost locations, the economic costs of remoteness appear to be increasing." The economic prospects for remote rural areas are presumed to have minimal connection to the broader regional economy and less positive benefits from connectivity.

For metropolitan areas, authors like Lewin, et al. (2013) suggest that as globalization takes hold, metropolitan areas are much less likely to benefit from intra-regional connectivity, and more likely to benefit from connections outside of the region and around the world. Although less work has been conducted on regional connectivity and micropolitan areas, DeVol and Crews (2019) find that micropolitan proximity to growing metropolitan areas is a strong indicator of micropolitan performance. This suggests that connectivity with the broader region, and specifically with metropolitan clusters, results in spread effects for micropolitan areas. In terms of variation in magnitude of impacts by industry cluster, Delgado and Zeuli (2016) find that nearly all inner-city industry clusters benefit from intra-regional connectivity. Given the extensive variation across regions and across types of cluster linkages present within clusters, this research hypotheses greater variation than Delgado and Zeuli's (2016) finding.

Methodology

To examine the impact of intra-regional economic connectivity on county-clusters, all observations are first categorized as "connected" or "not connected" to the regional economy. T-tests are then performed to assess whether significant differences in the annualized employment growth rate (2010-2016) exist between connected and not connected county-based clusters. A cluster within a county is "connected" if the cluster is both present in the county and strong in the rest of the region.

A cluster is considered present in a county if there are at least 10 jobs within the county in the initial year 2010. This minimal number of jobs indicates that there is at least some presence of the cluster and potential for further growth.[3] The 10-job threshold is also used by Delgado and Zeuli (2016), and specific to their study, observations were "limited to those with at least 10 employees [in the base year] to avoid noisy observations." For example, including all clusters across all counties with less than 10 jobs would result in many observations indicating extremely high levels of employment growth for very minimal new jobs added, thereby skewing the results. With all counties in 178 regions across 51 traded clusters (those where cluster presence is at least 10 jobs), this analysis includes 77,346 unique observations, noted herein as "county-clusters." 82,896 county-cluster observations are excluded from the analysis based on the 10-job threshold.

[3] In addition to a minimum job threshold, Delgado and Zeuli (2016) also normalize across locations by applying a location quotient threshold. To normalize cluster jobs across counties while still accounting for emerging clusters, a minimum location quotient, paired with the 10-job minimum was tested. The new definition excluded fewer than five percent of cases and did not affect the results of the analysis. Therefore, only the 10-job minimum was utilized in this analysis (for more, see Conclusion).

Next, the strength of the cluster in the rest of the Economic Area outside of the county is determined using a location quotient formula. Location quotients measure economic specialization or concentration and are commonly used in industry cluster and economic development analysis. The location quotient (LQ) is the ratio of the cluster's share of total regional employment (outside of the county) relative to its share of total national employment. A location quotient greater than one indicates a higher than average cluster concentration in a location.

Rest of Region Cluster Strength =

([EA cluster employment – county-cluster employment]/ [EA traded employment – county traded employment])/ [U.S. cluster employment/U.S. traded employment]

Based on the county-cluster employment threshold and regional cluster strength, 45 percent of county-clusters are connected to their regional economies (**Figure 6).** For example, Blackford county in Fort Wayne-Huntington-Auburn, IN Economic Area had a 2010 cluster presence of the Paper and Packaging cluster of 350 jobs. The Paper and Packaging industry cluster is also strong in the rest of the region outside of the county, with a location quotient of 1.8. Therefore, the Paper and Packaging in Blackford is considered a "connected" county-cluster.

Those industry clusters with the highest share of county-clusters that are also connected to their regional economies include Nonmetal Mining, Production Technology and Heavy Machinery, Environmental Services, Downstream Metal Products, Wood Products, Forestry and Paper and Packaging. In terms of community types, in total, there are 38,096 metropolitan county-clusters, 43 percent of which are connected to their broader regional economies; 17,456 micropolitan county-clusters, 46 percent of which are connected to their broader regional economies; 12,015 rural adjacent county-clusters, 49 percent of which are connected; and 9,779 remote rural county-clusters, 50 percent of which are connected.

Figure 6: Share of County-Clusters that are Connected, by Industry Cluster, County Type

Industry Cluster	Total	Metropolitan	Micropolitan	Remote Rural	Rural Adjacent	N(connected and not connected)
Aerospace Vehicles and Defense	32.97%	35.02%	29.91%	17.24%	29.55%	634
Agricultural Inputs and Services	57.92%	48.60%	60.26%	79.36%	57.54%	2046
Apparel	29.62%	32.02%	25.08%	24.43%	31.90%	1347
Automotive	43.02%	38.92%	48.00%	47.10%	46.86%	1625
Biopharmaceuticals	36.85%	40.38%	27.71%	26.32%	24.39%	559
Business Services	12.92%	16.33%	10.02%	10.98%	11.37%	2965
Coal Mining	59.49%	51.08%	53.95%	86.36%	67.31%	311
Communications Equipment and Services	37.30%	39.49%	32.75%	27.50%	46.77%	1657
Construction Products and Services	58.69%	54.11%	59.64%	66.27%	61.16%	2624
Distribution and Electronic Commerce	42.23%	46.07%	40.97%	37.36%	41.31%	3055
Downstream Chemical Products	49.40%	51.35%	47.87%	25.97%	55.46%	1255
Downstream Metal Products	64.40%	57.71%	69.60%	69.57%	72.33%	2014
Education and Knowledge Creation	23.35%	29.78%	19.33%	10.85%	19.88%	2137
Electric Power Gen and Transmission	56.37%	55.29%	57.38%	58.68%	57.26%	1059
Environmental Services	64.92%	68.82%	58.66%	64.29%	54.69%	1240
Financial Services	22.99%	29.17%	19.67%	15.04%	20.96%	2740
Fishing and Fishing Products	43.82%	42.92%	44.12%	46.67%	45.45%	372
Food Processing and Manufacturing	59.24%	51.40%	59.96%	73.14%	62.08%	2463
Footwear	35.86%	31.36%	46.67%	33.33%	48.00%	251
Forestry	61.22%	55.75%	59.54%	73.93%	64.74%	1617
Furniture	48.59%	44.16%	47.76%	59.90%	57.00%	1949
Hospitality and Tourism	38.05%	32.43%	36.64%	50.73%	37.28%	3017
IT and Analytical Instruments	28.18%	26.69%	32.17%	24.18%	30.08%	1306
Insurance Services	40.83%	41.45%	38.17%	37.12%	45.62%	2229
Jewelry and Precious Metals	30.58%	30.54%	34.72%	38.10%	17.65%	497
Leather and Related Products	51.46%	50.09%	56.60%	55.56%	46.77%	822
Lighting and Electrical Equipment	51.31%	49.01%	54.75%	57.14%	54.55%	1146
Livestock Processing	49.65%	44.69%	49.26%	54.87%	57.91%	1734
Marketing, Design, and Publishing	31.98%	38.01%	24.47%	23.67%	33.49%	2392
Medical Devices	39.98%	39.76%	40.80%	32.61%	44.44%	993
Metal Mining	50.66%	38.66%	58.97%	75.61%	53.57%	227
Metalworking Technology	45.48%	43.19%	51.46%	40.99%	46.67%	1724
Music and Sound Recording	34.53%	33.33%	34.48%	57.14%	55.56%	530
Nonmetal Mining	74.96%	69.35%	77.10%	83.40%	81.29%	1885
Oil-Gas Production and Transportation	39.90%	26.38%	40.69%	64.01%	48.47%	1852
Paper and Packaging	61.10%	58.27%	65.25%	62.22%	67.83%	1090
Performing Arts	34.96%	37.78%	29.13%	33.94%	35.93%	1885
Plastics	58.01%	54.84%	62.71%	53.10%	64.90%	1722
Printing Services	47.93%	48.34%	45.55%	41.56%	55.16%	2126
Production Technology-Heavy Machinery	65.20%	57.10%	70.51%	78.42%	69.25%	2092
Recreational and Small Electric Goods	51.39%	47.48%	59.44%	52.17%	52.97%	1510
Textile Manufacturing	36.52%	34.30%	33.76%	44.12%	48.89%	1128
Tobacco	43.90%	42.19%	41.67%	100.00%	50.00%	82
Trailers, Motor Homes, and Appliances	45.18%	37.23%	57.64%	55.88%	52.83%	737
Transportation and Logistics	57.81%	48.14%	58.46%	73.74%	59.60%	2958
Upstream Chemical Products	40.99%	33.91%	48.31%	63.83%	44.64%	988
Upstream Metal Manufacturing	47.22%	43.10%	55.36%	46.88%	52.41%	1296
Video Production and Distribution	6.26%	7.93%	3.61%	0.00%	1.49%	974
Vulcanized and Fired Materials	51.94%	47.75%	54.39%	50.52%	66.47%	1363
Water Transportation	31.46%	28.46%	36.77%	51.79%	26.19%	801
Wood Products	61.98%	53.46%	64.17%	75.00%	69.58%	2320
Grand Total	**45.39%**	**42.93%**	**45.90%**	**49.90%**	**48.76%**	**77346**

Next, independent-samples t-tests are performed. A t-test is a type of inferential statistic used to determine whether a significant difference exists between the means of two mutually exclusive groups based on their relationship to a specific factor. In this case, that factor is connectivity. County-cluster jobs are sorted into those that are "connected" and those that are not. An independent-samples t-test is conducted to compare the annualized employment growth rate of the county-clusters under connect and not connected conditions. Separate t-tests are conducted for metropolitan county-clusters, micropolitan county-clusters, rural adjacent county-clusters, and remote rural county-clusters to determine whether connectivity impacts some community types more than others. Separate t-tests are also conducted by industry clusters to examine the impacts of connectivity across different types of industry clusters.

The results of these tests suggest that intra-regional economic connectivity has a positive association with county-cluster employment growth, but that this relationship and the magnitude of the impact varies across community types and industry cluster types. Detailed findings are presented in the next section.

FINDINGS

Introduction

The results support all hypotheses, except how the magnitude of the average employment growth rate differences between connected and not connected county-clusters play out by county type. Connectivity has the strongest impact on remote rural county-clusters, with significant differences emerging by industry cluster type (for a ranking of which Economic Areas benefits most from intra-regional connectivity, see **Appendix 2**). More detailed findings relating to the seven hypotheses are explored below.

Hypothesis 1

An industry cluster that has a presence in the county and strength in the rest of the region outside of the county ("connected") will grow faster than the same cluster located in a county without specialization in the rest of the region outside of the county ("not connected"). The average annualized employment growth rates (2010-2016) for county-clusters that are connected to their regional economies will be greater than for county-clusters that are not connected to their regional economies.

The first hypothesis, that county-clusters grow faster than not connected county-clusters, is supported by the analysis (**Figure 7)**. In aggregate, the average employment growth rate of connected county-clusters is 4.87 percent, whereas not connected county-clusters grew by only 3.56 percent. There is a statistically significant difference (*t*-statistic = 2.81) in the scores for connected (M=4.87%, SD=0.76) and non-connected (M=3.56%, SD=0.48) conditions.

Figure 7: T-Test Results Comparing Average Annualized Employment Growth Rate 2010-2016 between Connected and Not Connected County-Clusters

	Metropolitan	Micropolitan	Rural Adjacent	Remote Rural	All County-Clusters
N	**38,096**	**17,456**	**12,015**	**9,779**	**77,346**
Not Connected County- Cluster Jobs (standard deviation)	4.67% (.57)	3.32% (.42)	2.40% (.33)	0.54% (.23)	3.56% (.48)
Connected County-Cluster Jobs (standard deviation)	5.67% (1.04)	4.68% (.39)	4.09% (.37)	3.45% (.35)	4.87% (.76)
Difference in Average Growth Rate	1.00%*	1.36%**	1.69%**	2.92%**	1.31%**
t-statistic	1.65	3.13	3.71	6.92	2.81

*p<.10, **p<.05

Hypotheses 2 – 5

The average annualized employment growth rates (2010-2016) for (metropolitan, micropolitan, rural adjacent or rural remote) county-clusters that are connected to their regional economies will be greater than (metropolitan, micropolitan, rural adjacent or rural remote) county-clusters that are not connected to their regional economies.

Statistically significant differences also hold across all county types, with average growth in connected county-clusters exceeding that in not connected county-clusters. The second through fifth hypotheses are supported by the analysis. For metropolitan county-clusters, there is a statistically significant difference (*t*-statistic = 1.65) in the scores for connected (M=5.67%, SD=1.04) and non-connected (M=4.67%, SD=0.57) conditions. For micropolitan county-clusters, there is a statistically significant difference (*t*-statistic = 3.13) in the scores for connected (M=4.68%, SD=0.39) and non-connected (M=3.32%, SD=0.42) conditions. For remote rural county-clusters, there is a statistically significant difference (*t*-statistic = 6.92) in the scores for connected (M=3.45%, SD=0.35) and non-connected (M=.54%, SD=0.23) conditions. For rural adjacent county-clusters, there is a statistically significant difference (*t*-statistic = 3.71) in the scores for connected (M=4.09%, SD=0.37) and non-connected (M=2.40%, SD=0.33) conditions.

Hypothesis 6

In terms of comparative magnitude of the average annualized employment growth rate differences between connected and not connected county-clusters by county type: Rural Adjacent > Micropolitan > Metropolitan > Rural Remote.

Overall, the t-test results suggest that intra-regional economic connectivity has a positive association with county-cluster employment growth. However, the hypothesis on the magnitude of differences in growth rate by county type is not supported (also shown in **Figure 7**). Whereas the hypothesis states that rural adjacent communities will have the greatest benefits from connectivity, and rural remote will have the least, the results indicate that the impact of connectivity is particularly pronounced for remote rural communities. Remote rural connected county-clusters experienced, on average, 3.45 percent annual employment growth between 2010 and 2016, whereas not connected county-clusters experienced only .54 percent annual growth – a difference of 2.92 percent.

These findings run counter to those by Barkley, Henry, and Boa (1996) and Partridge, Rickman, Ali and Olfert (2008), who note that remote rural counties are least likely to benefit from agglomeration. Their results are specific to rural relationships with urban agglomeration, whereas the current research explores the relationship to broader regional cluster specialization. It is possible that the differences in findings reflect the prior authors' findings that connectivity is difficult to achieve in these communities, however, when connectivity is achieved, significant economic impacts are evident.

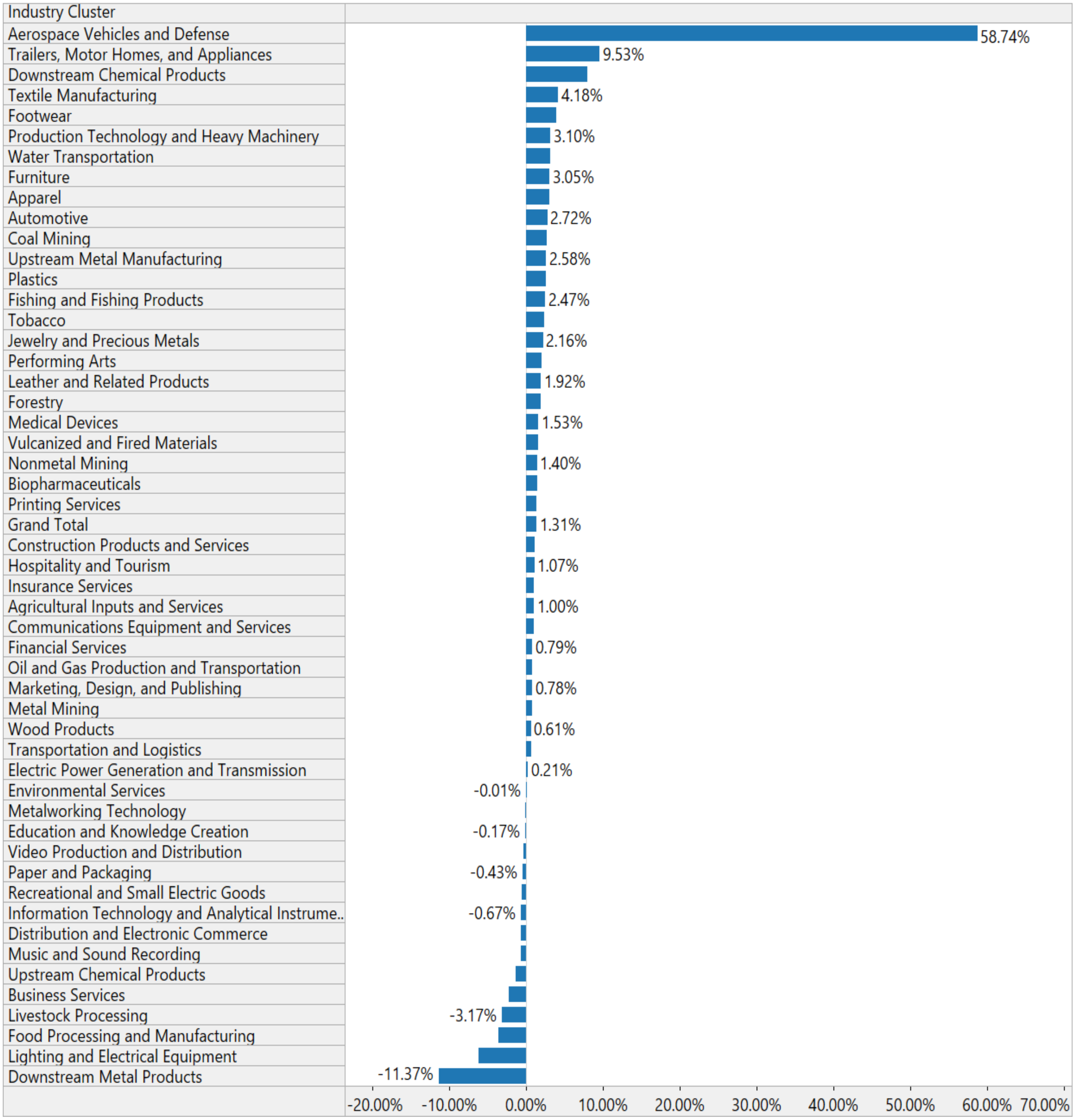
The ability to connect to regional clusters will also be based on the specific industry cluster composition of the region. To test whether these findings by county type hold across different industry cluster types, another set of t-tests are conducted to compare annualized county employment growth rate under these conditions.

Hypothesis 7

Differences in the average annualized employment growth rates (2010-2016) for connected and not connected county-clusters by will vary by industry cluster type and by county type.

When t-tests are conducted by industry cluster and by county type, the hypothesis that differences exist in average annualized employment growth between connected and not connected county-clusters is supported (**Appendix 3**). The average annualized employment growth rate is greater in connected vs. not-connect county-clusters in 36 out of 51 industry clusters (**Figure 8**).

Figure 8: Difference in Annualized Employment Growth Rate 2010-2016 between Connected and Not Connected County-Clusters, by Industry Cluster



The chart below (**Figure 9**) summarizes those clusters that exhibit positive, statistically significant differences in average annualized employment growth rates between connected and not connected county-clusters across different county types. Notably, the profile of clusters that benefit each county type is vastly different, both in terms of type and number. Discussions about intra-regional connectivity in the context of industry cluster types are presented below for each county type.

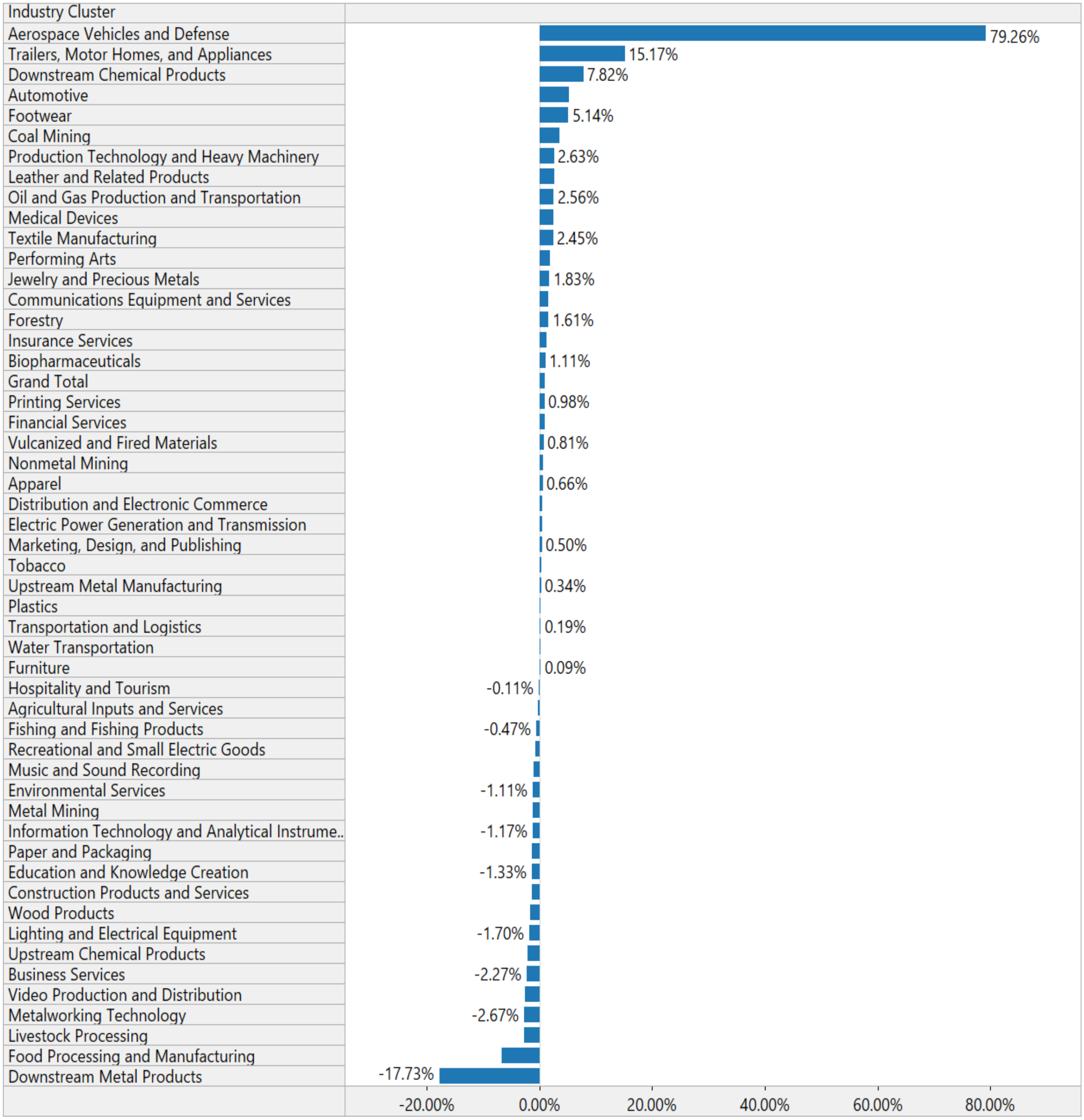
Figure 9: Industry Clusters Exhibiting Greater Average Annualized Employment Growth Rates (2010-2016) Under Connected (vs. Not Connected) Conditions, by County Type

Metropolitan	**Micropolitan**
Aerospace Vehicles and Defense Automotive Downstream Chemical Products Financial Services Footwear Forestry Insurance Services Jewelry and Precious Metals Leather and Related Products Performing Arts Textile Manufacturing Trailers, Motor Homes, and Appliances	Fishing and Fishing Products Furniture Metalworking Technology Production Technology and Heavy Machinery Textile Manufacturing Tobacco Upstream Metal Manufacturing Water Transportation
Rural Adjacent	**Rural Remote**
Agricultural Inputs and Services Apparel Communications Equipment and Services Textile Manufacturing Education and Knowledge Creation Environmental Services Fishing and Fishing Products Forestry Hospitality and Tourism Insurance Services Marketing, Design, and Publishing Nonmetal Mining Wood Products	Apparel Automotive Biopharmaceuticals Construction Products and Services Distribution and Electronic Commerce Fishing and Fishing Products Furniture Hospitality and Tourism Metal Mining Metalworking Technology Nonmetal Mining Oil and Gas Production and Transportation Production Technology and Heavy Machinery Performing Arts Plastics Printing Services Textile Manufacturing Transportation and Logistics Upstream Chemical Products Water Transportation Wood Products

Metropolitan

Positive, statistically significant employment growth resulting from connectivity between metropolitan counties and the rest of their regions can be found in 12 clusters: Aerospace Vehicles and Defense; Trailers, Motor Homes, and Appliances; Downstream Chemical Products; Automotive; Footwear; Leather and Related Products; Textile Manufacturing; Performing Arts; Jewelry and Precious Metals; Forestry; Insurance Services; and Financial Services (**Figure 10**). These clusters grow stronger in metropolitan counties, not when they are concentrated, but when the cluster is also present in the rest of the region. Metropolitan economic developers can strengthen these clusters by working regionally to ensure that necessary cluster assets, from talent to supply chain, are coordinated and bolstered.

Figure 10: Difference in Annualized Employment Growth Rate 2010-2016 between Connected and Not Connected Metropolitan County-Clusters, by Industry Cluster



One may expect that metropolitan counties would benefit most from clusters that are highly concentrated in metropolitan parts of the region. However, the metropolitan clusters benefiting most from connectivity are highly varied, from those with large employment concentrations in metropolitan areas, like Insurance Services, to those with employment that is more regionally dispersed, like Forestry. This indicates that metropolitan counties benefit not only from urban agglomeration, but also from connectivity to clusters that are more rural based.

However, the metropolitan county-cluster benefiting most from connectivity also happens to be the cluster with the highest average share of metropolitan employment – the Aerospace Vehicles and Defense cluster. Stunningly, in connected metropolitan county-clusters, Aerospace Vehicles and Defense cluster employment grew at an annualized rate of 90 percent from 2010-2016. In not connected county-clusters, the cluster only grew by an annualized rate of 10 percent. According to the U.S. Cluster Mapping Project, "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." Given the heavy focus on manufacturing in the Aerospace cluster and given that manufacturing operations tend to require more land, the significant growth difference between connected vs. not-connected county-clusters could be attributed to stronger networks of manufacturing and supply chain participation throughout the region.

For example, in Cleveland, OH, a major Aerospace manufacturer wanted to expand operations but could not do so at its current downtown site because the land was built up around it. The firm was also not able to build a new facility in the vicinity because the location was too expensive. According to Tracey Nichols, former Cleveland Economic Development Director, in order to keep its trained workforce, the plant decided to relocate outside the area but still within the region. This allowed the firm to expand while operating within the commuting shed for its workers.

Several metropolitan county-clusters also exhibit a statistically significant negative relationship between connectivity and cluster employment growth, such as Wood Products, Business Services, Metalworking Technology, Food Processing and Manufacturing and Downstream Metal Products. There could be several reasons for this negative relationship. First, if the metropolitan county-cluster is not growing but is regionally connected, it may be the case that metropolitan counties are experiencing backwash effects from more rural parts of the region. If metropolitan counties have become too expensive for cluster firms to operate or they no longer have the required assets or space, and industries and firms can find the necessary assets elsewhere in the region, it is possible that they may leave the area, taking jobs with them.

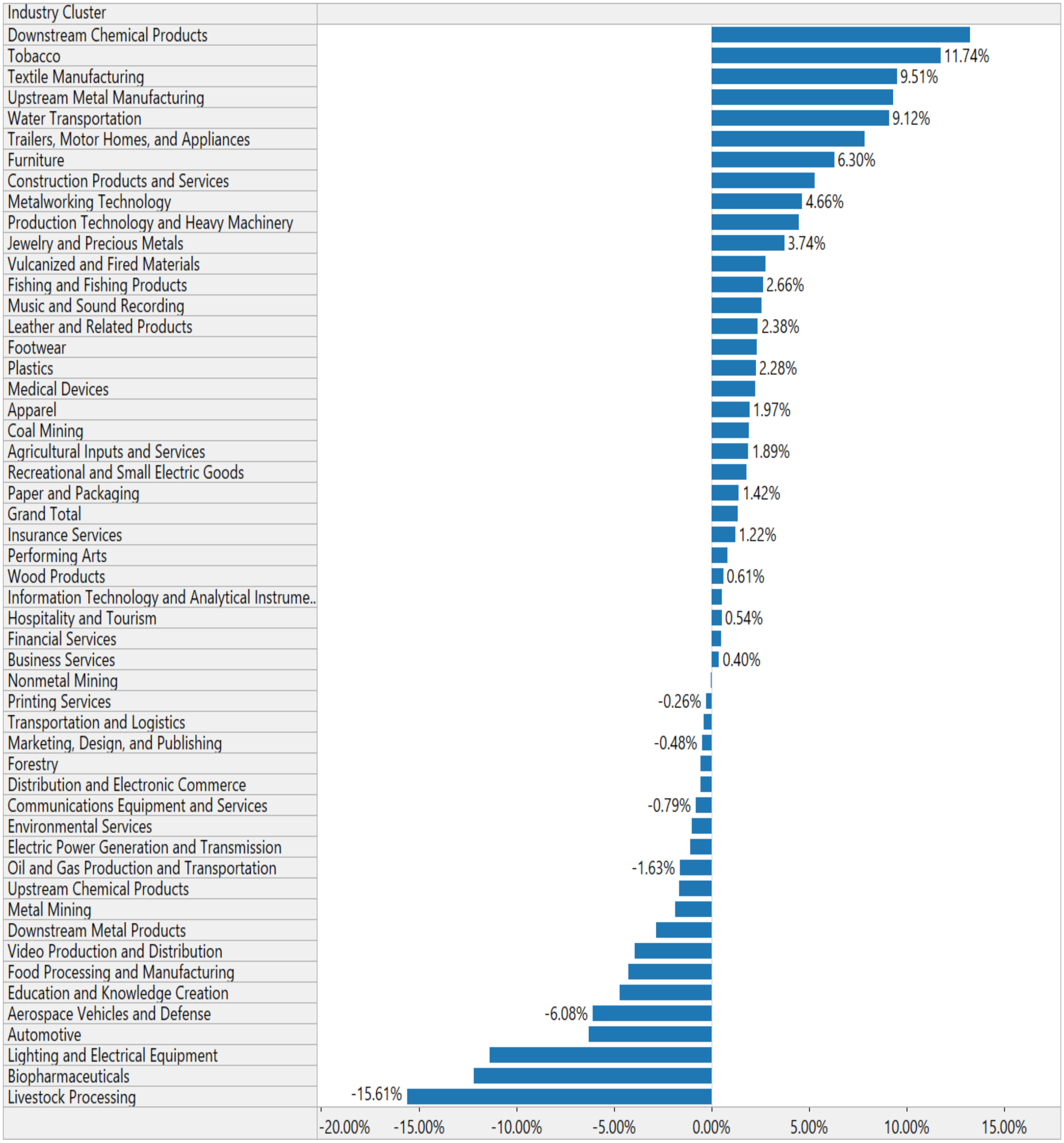
Secondly, if the metropolitan county-cluster is growing but not regionally connected (i.e. negative relationship with connectivity), it is possible that the necessary cluster linkages are contained within the metropolitan county and that the geographical reach of its linkages are more concentrated locally. For metropolitan counties this might reflect unique urban competitive advantage for a cluster. Lastly, if the metropolitan county-cluster is growing but not regionally connected, it is also possible, as described by Lewin, et al. (2013) and others, that metropolitan cluster growth is stemming not from intra-regional linkages, but instead linkages between other regions and across the world.

Micropolitan

Positive, statistically significant employment growth resulting from connectivity between *micropolitan* counties and the rest of their regions can be found in the following eight clusters:

Tobacco; Textile Manufacturing; Upstream Metal Manufacturing; Water Transportation; Furniture; Metalworking Technology; Production Technology and Heavy Machinery; and Fishing and Fishing Products (**Figure 11**). These clusters grow stronger in micropolitan counties when the cluster is also present in the rest of the region. This indicates that micropolitan counties benefit from the agglomeration effects that reach beyond their county borders. These micropolitan clusters represent a diverse mix of cluster types, from those that are more metropolitan based, like Water Transportation, to those that have a more distributed intra-regional employment geography, such as Production Technology and Heavy Machinery. Micropolitan counties, however, are the county type with the fewest clusters benefitting from intra-regional connectivity. This may be the result of competition for firms between micropolitan areas and larger metropolitan areas within the same regions.

Figure 11: Difference in Annualized Employment Growth Rate 2010-2016 between Connected and Not Connected Micropolitan County-Clusters, by Industry Cluster

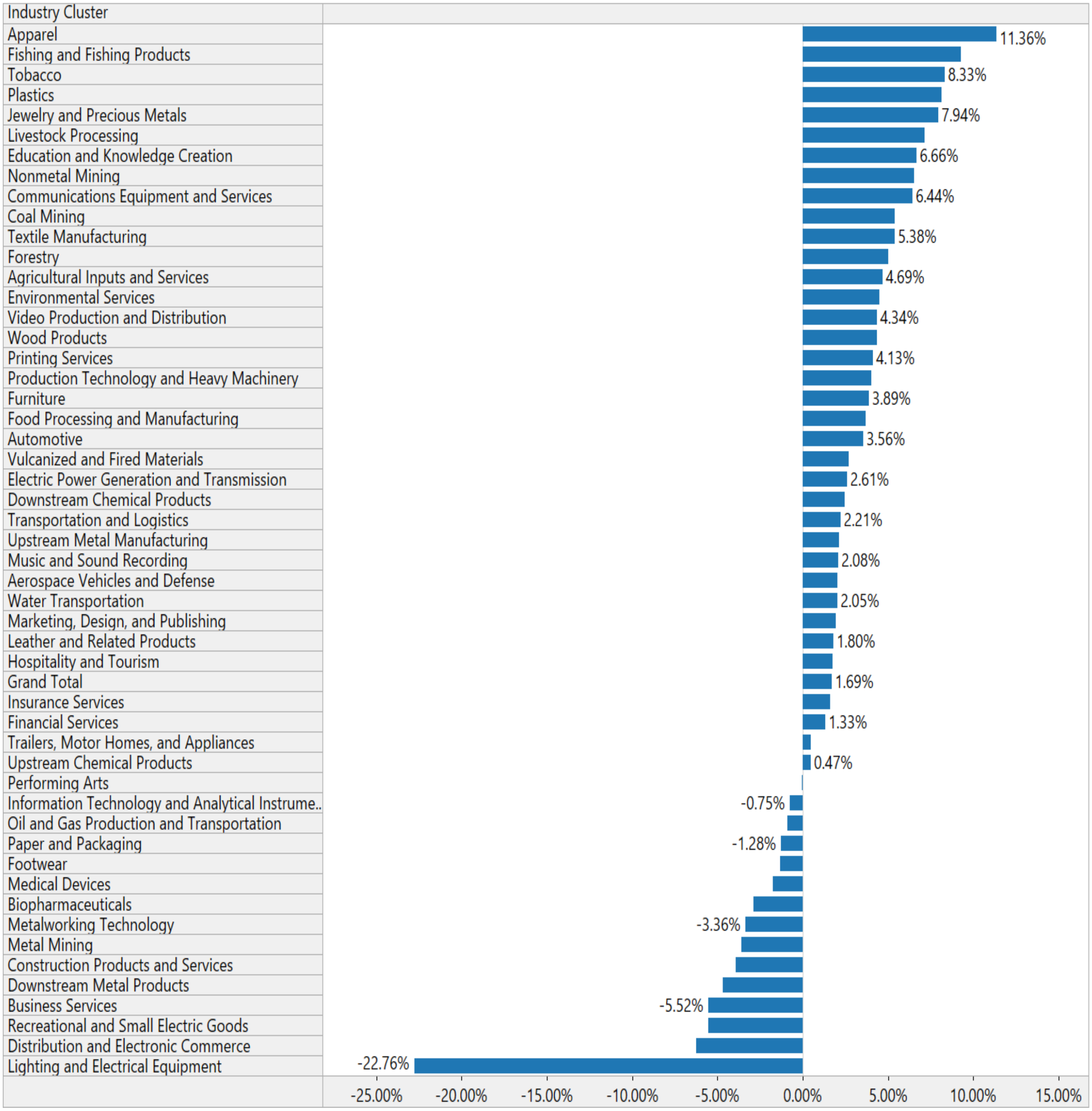


Alternatively, the following micropolitan clusters exhibit a statistically significant negative relationship between growth and connectivity: Video Production and Distribution; Food Processing and Manufacturing; Education and Knowledge Creation; Aerospace Vehicles and Defense; Automotive; and Biopharmaceuticals. This finding indicates that for these clusters, when agglomeration is present in the broader region, micropolitan counties may experience backwash effects as a result of connectivity (such as competition for talent and firms with metropolitan counties in the region). If connectivity is not present but the micropolitan cluster is growing, it is possible that micropolitan areas may have a specific competitive advantage in these clusters and as a result, their growth is more significant when cluster linkages are concentrated. It is also possible that the source of growth for the micropolitan cluster is external to the region.

Rural Adjacent

Positive, statistically significant employment growth resulting from connectivity between *rural adjacent* counties and the rest of their regions can be found in the following clusters: Apparel; Fishing and Fishing Products; Education and Knowledge Creation; Nonmetal Mining; Communications Equipment and Services; Textile Manufacturing; Forestry; Agricultural Inputs and Services; Environmental Services; Wood Products; Marketing, Design, and Publishing; Hospitality and Tourism; and Insurance Services (**Figure 12**). These clusters grow stronger in rural adjacent counties when the cluster is also present in the rest of the region. Many of these clusters have large shares of employment outside of metropolitan areas. This could mean that although rural adjacent areas are thought to have the greatest economic benefit from nearby metropolitan agglomeration, in fact, some of their best growth opportunities may stem from more rural-based clusters. Interestingly, the studies on adjacency reviewed earlier focused heavily on commuting and labor pool relationships between urban cores and their nearby rural communities. Although this may be true, from the perspective of developing and growing businesses and industry within the rural adjacent area itself (as opposed to exporting workers), rural clusters may prove a more fruitful opportunity for rural adjacent communities than metropolitan based ones.

Figure 12: Difference in Annualized Employment Growth Rate 2010-2016 between Connected and Not Connected Rural Adjacent County-Clusters, by Industry Cluster



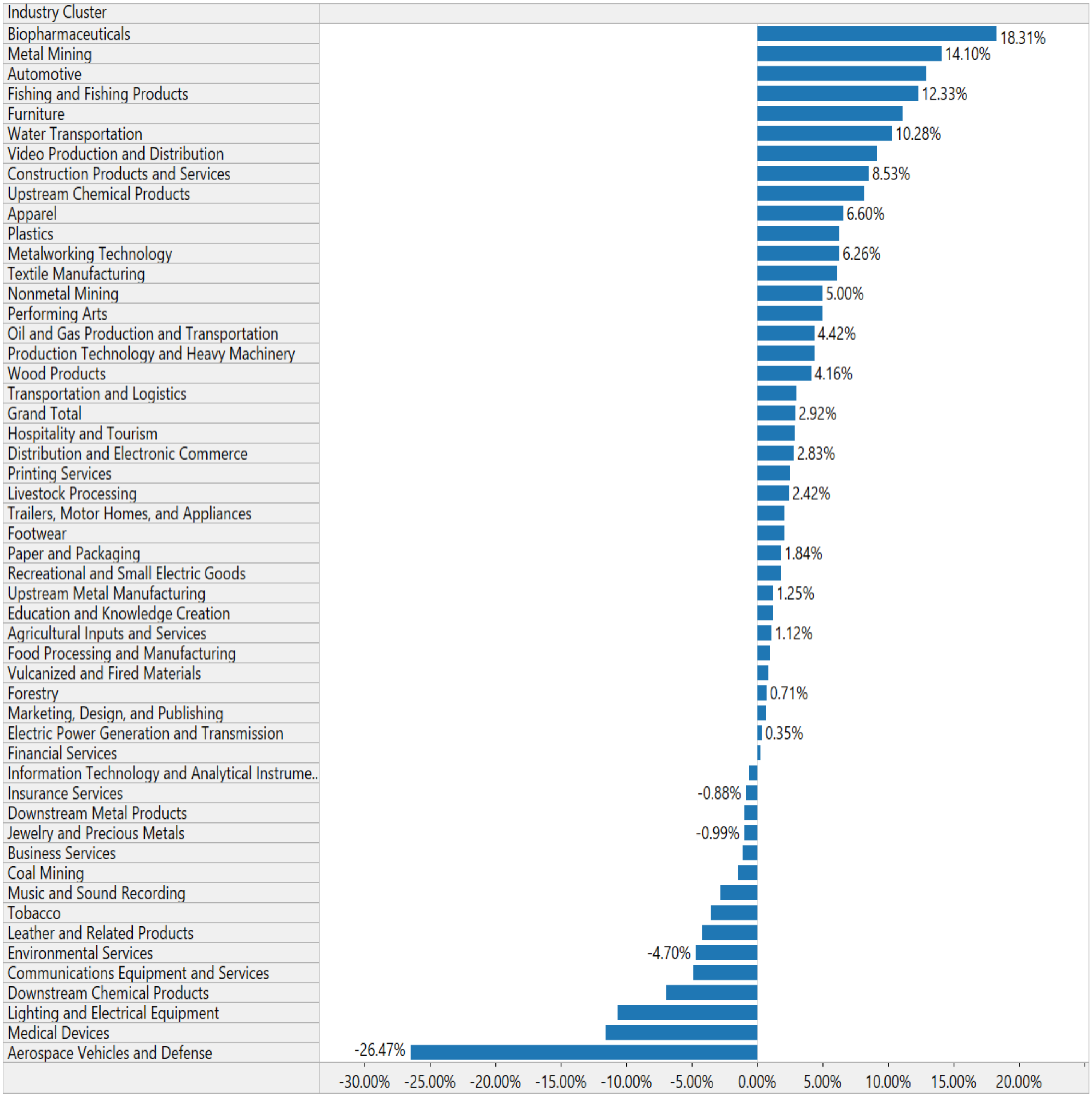
Alternatively, the following rural adjacent clusters exhibit a statistically significant negative relationship between growth and connectivity: Construction Products and Services;

Downstream Metal Products; Business Services; Recreational and Small Electric Goods; Distribution and Electronic Commerce; and Lighting and Electrical Equipment. Rural adjacent counties may experience a backwash effect of employment being drawn out of the county when the cluster is strong in the rest of the region. However, rural adjacent areas may have unique assets to support these clusters in the absence of broader agglomeration.

Remote Rural

Positive, statistically significant employment growth impacts resulting from connectivity between *remote rural* counties and the rest of their regions can be found in the following 21 clusters: Biopharmaceuticals; Metal Mining; Automotive; Fishing and Fishing Products; Furniture; Water Transportation; Construction Products and Services; Upstream Chemical Products; Apparel; Plastics; Metalworking Technology; Textile Manufacturing; Nonmetal Mining; Performing Arts; Oil and Gas Production and Transportation; Production Technology and Heavy Machinery; Wood Products; Transportation and Logistics; Hospitality and Tourism; Distribution and Electronic Commerce; and Printing Services (**Figure 13**). Remote rural counties are home to the largest number of clusters that benefit from regional connectivity. Many clusters can be sustained in remote rural communities when they are connected to the regional economy. Although connectivity to broader regional agglomeration may be more difficult for remote rural areas to achieve, those that do benefit significantly.

Figure 13: Difference in Annualized Employment Growth Rate 2010-2016 between Connected and Not Connected Remote Rural County-Clusters, by Industry Cluster



The remote rural county-cluster benefiting most from connectivity, Biopharmaceuticals, is also a “metropolitan concentrated” cluster, meaning it has a very high average share of metropolitan employment across U.S. regions. According to the U.S. Cluster Mapping Project, “establishments in this cluster produce complex chemical and biological substances used in medications, vaccines, diagnostic tests, and similar medical applications.” In connected remote rural county-clusters, Biopharmaceutical cluster employment grew at an annualized rate of 20 percent from 2010-2016. In not connected county-clusters, the Biopharmaceuticals cluster only grew by an annualized rate of 1 percent. Although this cluster, often associated with Life Sciences, tends to be largely metropolitan, intra-regional connectivity provides positive spread effects to remote rural parts of regions in the form of employment growth.

The following remote rural clusters exhibit a statistically significant negative relationship between growth and connectivity: Environmental Services; Communications Equipment and Services; and Downstream Chemical Products. Again, this finding may indicate the presence of backwash effects when specialization is present in the region outside of the county. It may also indicate a unique competitive advantage for remote rural areas and/or signify clusters in which remote rural counties have stronger cluster linkages with the global economy.

Summary

Overall, the analysis finds that in aggregate across county-clusters, the average employment growth rate of connected county-clusters is greater than not connected county-clusters. These findings suggest that local economic growth is bolstered by intra-regional linkages between a county-cluster and the same cluster in the Economic Area. However, the analysis also suggests that employment impacts from intra-regional connectivity vary by county type and by industry cluster.

Specifically, the results indicate that the impact of intra-regional connectivity is most pronounced for remote rural communities. These findings run counter to previous studies of regional concentration and diffusion which concluded that backwash effects more often characterize the impact of regional economic activity on remote rural areas. Conversely, this dissertation finds that remote rural counties are home to the largest number of clusters that benefit from regional connectivity, including some metropolitan-based clusters. Therefore, many types of industry clusters can be sustained in remote rural communities and flourish when they are connected to the regional economy.

In terms of other county types, although the literature indicates that due to proximity, rural areas adjacent to metropolitan areas experience the greatest benefits from intra-regional connectivity, some of the best growth opportunities for rural adjacent counties appear to be not with nearby metropolitan areas, but instead stem from more rural-based clusters. Metropolitan counties benefit not only from urban agglomeration, but also from connectivity to clusters that are more rural based. Micropolitan counties have the fewest clusters benefitting from connectivity. This may be the result of competition for jobs between micropolitan areas and larger metropolitan areas within the same regions.

For most clusters, the regional mechanisms of agglomeration such as skilled labor, sophisticated and demanding local customers, niche markets, suppliers, and related industries, benefit local development. However, economic impacts vary by cluster, with significant implications for the practice of economic development. The next section discusses the policy implications of these findings followed by case studies demonstrating the utility of an intra-regional industry cluster connectivity framework on local and regional economic development practice.

POLICY IMPLICATIONS

Introduction

The findings from this research suggest that for most community types and under most conditions, a cluster strategy is more effective when it is considered within a regional context. More specifically, most industry clusters thrive when cluster firms and cluster-related employment are present and supported throughout urban and rural parts of regions. This contrasts the common understanding of agglomeration which focuses on clusters as only an urban-based activity. Regional clusters benefit local communities, including rural, in that these communities, and the firms and industries within them, can tap a broader range of assets present in the region for the cluster to flourish, such as talent, critical infrastructure, specialize suppliers and niche customers.

The findings, however, also reveal that the extent of the impact of intra-regional connectivity varies not only by where a county is situated within a region, but also by type of industry cluster. Additionally, the cluster composition within each region varies greatly. This indicates that a one-size fits all cluster strategy is not going to provide the greatest economic benefit to a community, neither is targeting clusters without an existing asset based within the region. Strategies to both target clusters and support clusters should be refined and consider the relationship between existing assets and intra-regional connectivity. Economic development organizations should tailor policies to connect local economies to their regional economies in ways that account for specific regional contexts and cluster compositions.

Cluster Targeting

Typical cluster strategies target clusters for growth based on economic specialization, composition of firms, development stage, intensity of inter-firm dependence, reliance on complex knowledge, and ability to create inclusive employment opportunities (Donohue, et al. 2018). These are critical factors, but because intra-regional connectivity also has implications for cluster growth, economic development organizations should also consider the relationship of local cluster activity to broader regional specialization. For example, speaking to the interaction of rural development, industry type and regional context, Dabson (2019) notes that

> …rural development strategies must be based on a realistic assessment of opportunities and constraints, which will determine whether improving integration with the urban economy through infrastructure improvements and supply chain management, or place-based development through enhancing amenities and entrepreneurship (or some combination) are the right priorities…Areas of focus in this regard could include fostering urban-rural interaction around policy decision points where there seem to be a convergence in the interests of the two constituencies.

The results from this dissertation suggest that these areas of "convergence of interest" can be found in regionally connected industry clusters that benefit both urban and rural places within regions, such as the Production Technology and Heavy Machinery cluster (see **Appendix 3**).

Given the extensive variation in cluster composition from region to region, when targeting industry clusters for expansion, economic development organizations can "map the cluster composition of [their location] and nearby region, identifying strong and emerging clusters in the region that have some strength in the [locality]" (Delgado and Zeuli (2016). In other words, what clusters are present in the county that are also strong in the broader region? Or what assets and industries are present in the locality that can support regional clusters? Next, using data provided by this research, economic development organizations can identify how connectivity is likely to impact local growth and select those cluster with predicted positive impact. Once those clusters are narrowed, policy leaders and practitioners can work to build economic connections within the region via an adapted cluster upgrading strategy.

Cluster Upgrading

In terms of bolstering clusters, cluster-based economic development focuses on cluster upgrading strategies that "enable competition to be more productive and sophisticated" (Ketels and Memedovic 2008). Specifically, it encourages public organizations, like city governments or regional economic development organizations, to pursue activities like collective marketing of a region's cluster specialties; providing firms and entrepreneurs with local services, such as financial advice, marketing and design; identifying weaknesses in existing cluster value chains and attracting investors and businesses to fill those gaps; ensuring local skills and workforce programs are aligned with industry needs; and streamlining the regulatory environment (Delgado 2018; Cortright 2016).

In addition to these critical cluster-supporting activities, practitioners and policy makers should also consider how to approach these strategies within the framework of intra-regional connectivity. Practitioners and researchers have conducted regional case studies illuminating how different intra-regional cluster connectivity strategies - ranging from entrepreneurship to supply chains – have impacted regional development and cluster growth. For example, in a study of the connections between rural hops growers and urban markets in Oregon, Martin (2011) finds that "rural connections to metropolitan areas facilitate the development of niche markets that can test and refine products in adjacent urban areas before taking them to the global market." Additionally, a 2016 study of European rural entrepreneurship found that "rural entrepreneurs with linkages to proximate urban areas can access some urban features, such as knowledge and markets, while at the same time profiting from the advantage of their peripheral location" (Mayer, Habersetzer and Meili 2016).

Mayer and Provo (2007) investigate the potential of domestic outsourcing, or "farmshoring," from urban firms to drive economic connectivity and growth in more rural areas of Virginia "…driven by needs like lower costs, data security, skilled and stable labor forces, and geographic constraints." The authors go on to note that the benefits of farmshoring will only be realized if broader state and regional efforts are in place to create interfaces between urban and rural areas. These interfaces allow local and regional leaders and businesses to share information about local assets, as well as industry sectors, products and processes that may be candidates for farmshoring.

In addition to rural linkages to urban clusters, rural focused clusters can also drive growth via connectivity with urban economies. For example, in an analysis of urban-rural economic divides within states, McFarland (2018) finds that urban traded sector businesses such as legal, financial, trade and transportation thrive as a result of providing economic support to rural-based clusters. In a study examining the interdependence between Minnesota's urban and rural areas, Searls (2011) finds that urban regions receive substantial economic benefits from improved prosperity in rural areas. Every $1 billion increase in rural manufacturing output produces a 16 percent increase in urban jobs, significant additional business-to-business transactions and statewide consumer spending and investment. Similarly, a study of the Sacramento, California, region finds that most jobs and economic activity resulting from the region's rural food and agriculture cluster occurs in urban parts of the region (Sacramento Area Council of Governments 2008).

These regional case studies identify several strategies to strengthen intra-regional cluster connectivity including entrepreneurship and regional markets, supply chains, farmshoring and complimentary cluster activities and services. Marrying case study evidence with the new framework of intra-regional connectivity presented in this dissertation provides practitioners with a stronger cluster-based economic development approach. The framework helps policy makers target clusters and upgrade clusters in ways that are inclusive and beneficial to the cluster overall. It can also help local and regional economic development organizations articulate to state, federal and university partners the capacities and resources they need to strengthen intra-regional connectivity and bridge the urban-rural divide. In the next section, specific applications of the data and framework are presented for two regions, Roanoke, VA and Sacramento-Arden-Arcade-Truckee, CA-NV Economic Areas.

REGIONAL PROFILES

Profile 1: Roanoke, VA Economic Area

The Roanoke, VA regional profile is one that demonstrates how emerging growth in a rural part of a region can be strengthen by an intra-regional connectivity approach. The profile features a snapshot of the region's overall intra-regional connectivity results, employment growth for metropolitan and rural adjacent counties by industry cluster, a discussion of current economic development activities related to the drone industry, and recommendations for the rural-based economic development organization to apply an intra-regional economic connectivity framework to strength the local industry and regional clusters.

Data Snapshot

The Roanoke, VA Economic Area consists of 21 counties, a mix of metropolitan counties and rural counties that are adjacent to a metropolitan area.[4] In the region, "connected" county-cluster jobs grew at an annualized rate 2010-2016 of 9.50 percent, whereas "not connected" county-cluster jobs grew on average 2.2 percent (**Figure 14**). These growth rates vary by county type, with connectivity having the most significant economic benefit for metropolitan counties. Rural adjacent counties appear disadvantaged overall by connectivity to the regional economy. This may be the result of an economic relationship between rural adjacent counties and metropolitan counties within the region that is characterized by competition for jobs when a cluster is present in both areas within the region.

---

[4] For Virginia, USDA ERS combined nonmetro independent cities with their counties of origin when computing the Rural-urban continuum Codes.

Figure 14: Annualized Employment Growth Rate 2010-2016 for County-Clusters in the Roanoke, VA Economic Area under Connected and Not Connected Conditions, by County Type

	Metropolitan	**Rural Adjacent**	**Total**
Not Connected	4.82%	-5.93%	2.43%
Connected	11.2%	-.169%	9.50%

Rural adjacent counties in the region are home to 21 types of industry clusters that are connected to the broader regional economy (**Figure 15**). Of these clusters, 10 have experienced declines in employment, while another five have experienced no growth. Within these 15 regionally connected industry clusters with no or declining growth in rural adjacent counties, nine also exhibit positive employment growth in metropolitan counties. For example, the Metalworking Technology cluster grew on average 12.58 percent under metropolitan county connected conditions, whereas the cluster declined on average 5.56 percent under rural adjacent county connected conditions. This indicates that for this cluster, backwash effects may be at play in the region where industries are minimizing their presence in rural adjacent communities and bolstering their presence in the metropolitan area.

Figure 15: Annualized Employment Growth Rate 2010-2016 for County-Clusters in the Roanoke, VA Economic Area under Connected Conditions, by Industry Cluster and County Type

	Metropolitan	Rural Adjacent	Grand Total
Aerospace Vehicles and Defense	0.00%	0.00%	0.00%
Automotive	-3.77%	8.84%	-1.48%
Biopharmaceuticals	-13.81%		-13.81%
Construction Products and Services	26.71%	-6.15%	19.41%
Distribution and Electronic Commerce	-0.92%		-0.92%
Downstream Chemical Products	64.46%	-8.33%	51.23%
Downstream Metal Products	32.71%	-2.78%	26.06%
Education and Knowledge Creation	24.43%	16.67%	23.39%
Environmental Services	-4.51%		-4.51%
Forestry	3.38%	-0.42%	2.43%
Furniture	1.61%	0.00%	1.50%
Insurance Services	-6.11%	8.33%	-4.05%
Jewelry and Precious Metals	-16.67%	-16.67%	-16.67%
Leather and Related Products	-12.50%	0.00%	-10.00%
Lighting and Electrical Equipment	1.83%	0.00%	1.55%
Metalworking Technology	12.58%	-5.56%	10.76%
Nonmetal Mining	-5.71%	0.46%	-4.38%
Paper and Packaging	-0.95%	0.00%	-0.79%
Plastics	8.84%	25.51%	10.23%
Printing Services	6.32%	-1.19%	5.32%
Production Technology and Heavy Machinery	42.29%	-7.69%	39.17%
Recreational and Small Electric Goods	129.17%		129.17%
Textile Manufacturing	8.77%	-10.95%	6.98%
Upstream Chemical Products	-8.33%		-8.33%
Upstream Metal Manufacturing	0.00%		0.00%
Vulcanized and Fired Materials	-2.91%	-8.33%	-3.46%
Wood Products	-0.50%	0.50%	-0.31%

**Other clusters are present in the region but are not "connected" to the broader regional economy, meaning they have a narrower presence in specific locations.*
***Blank cells indicate no presence of the cluster in that type of county in the region, i.e. there are no connected Biopharmaceuticals jobs in rural adjacent places in the Roanoke region.*

Alternatively, there are several intra-regionally connected clusters that have stronger employment growth in rural adjacent communities, with slower growth or declines in nearby metropolitan counties, including Automotive, Insurance Services, Nonmetal Mining, Plastics and Wood Products. These clusters are gaining strength in rural adjacent communities while metropolitan strength is waning, indicating that the region may be undergoing transition in its broader economy. This may also indicate that specific industry clusters, like Insurance Services for example, may be transitioning or growing in ways that benefit more rural locations. For example, Insurance Services often requires many back-office activities, like data and claims processing, that could more affordably locate in rural adjacent areas instead of metropolitan counties. Lastly, over this time, connected Education and Knowledge Creation county-clusters grew at a significant rate in both metropolitan and rural adjacent parts of the region.

The cluster connectivity profile for the Roanoke, VA Economic Area is an interesting one. Nearly all clusters that are growing in one part of the region are declining in the other. The region is truly one of transition from mining and natural resource-based industries to emerging growth in higher paying industries and clusters. Much of the growth and benefits of this transition however have thus far benefitted metropolitan parts of the Roanoke region. This is due in part to disadvantages of rural areas in the region that have thus far dissuaded economic development, including mountainous terrain, vacant mines, far distance from airports, brain drain and poor housing stock. The challenge for the region, therefore, is to ensure that all parts can participate in emerging development.

Economic Development

Due to the vision of economic development leaders in the area, rural adjacent communities have recently started to seed growth in unexpected ways via a new industry focus on drones. For the past seven years, Covington, Va., in the rural Alleghany Highland part of the Roanoke region, has hosted one of the world's largest drone racing competitions, attracting flyers from across the country. With the growing success of this competition, economic development leaders began to think about drones as more than just tourism. They also began to realize their potential for industry growth in the area, which required seeing their economic liabilities in a new light, for example:

- Distance from airport: Airports serve as critical sources of connectivity for rural communities (Rasker, et al. 2009). The Alleghany Highlands are far from an airport, a feature long viewed as an economic development liability. However, FAA regulation bans drone flying within proximity to airports, making the Highlands location attractive to companies interested in testing drones.
- Underground Vacant Iron Ore Mines: The transition away from mining has been devastating to the economies of many rural communities, the Alleghany Highlands included. However, because abandoned mines are a GPS-denied environment, they provide ideal testing conditions for emerging drone technology focused on drone operations without GPS. "Potential applications for the technology include safely and quickly scanning for threats inside a building before military teams enter, searching for a downed pilot in a heavily forested area or jungle in hostile territory where overhead imagery can't see through the tree canopy, or locating survivors following earthquakes or other disasters when entering a damaged structure could be unsafe" (DARPA 2017).

- Mountainous Terrain: Topography often hinders development in rural areas and economically isolates them due to transport and other challenges (Gallup, et al. 1999). The mountainous terrain in the Alleghany Highlands, however, allows for drone experimentation without risk to humans. 6,000 acres of the mountain range have recently been approved for testing.

With a newfound appreciation for these local economic assets, the local economic development organization and its partners shifted focus on strategies to develop the drone industry. One of the most notable investments has been the establishment of the *Enhancing the Region through New Technology for Unmanned Systems,* or Drone Zone. "The Drone Zone specializes in developing facilities for businesses engaged in the design, testing, manufacturing, and development of applications for unmanned systems vehicles" (VT Office of Economic Development). The Drone Zone is essentially an abandoned and dilapidated school building that has been transformed into an incubator with several small businesses and start-ups. The co-location of these businesses has facilitated extensive collaboration on grants, workforce, and contracts. With support for the industry in place, the city of Covington recently landed a major drone operations command and control center. Together with regional partners, the state and workforce development agencies, the city beat out locations in Florida and California and is poised to be a significant player in the industry overall, and especially in the region, serving as a hub for drone-related economic activity (Williamson 2019).

One challenge facing the industry, however, is brain drain and lack of talent in the Alleghany Highlands. To support the growth and development of the emerging drone industry, several colleges and universities have created an intra-regional talent pipeline via specialized offerings and research. For example, the Dabney S. Lancaster Community College (DSLCC) provides high school students drone-centered learning and training opportunities through dual enrollment (VT Office of Economic Development). The program is seeing early success, with over 20 students participating and plans to expand to two additional high schools in 2020. Liberty University has also instituted an unmanned systems program. Additionally, the Virginia Tech Mid-Atlantic Aviation Partnership (MAAP), an FAA-designated test site for unmanned aircraft systems, is active in the area working with the private sector to provide research-driven solutions to critical challenges in the industry. These higher education partnerships open pathways for students throughout the region to become aware of the growing new industry, to help them obtain the foundational knowledge and skills needed to perform drone-related jobs, and to help them engage directly with drone businesses.

Recommendations

In addition to bolstering the talent pipeline, this research recommends that economic developers in the Alleghany Highlands also consider connecting the drone industry to clusters that are strong and growing in the broader region. Key to this intra-regional economic connectivity-focused cluster approach is the extensive commercial applications of drones and drone technology (Mazur and Wiśniewski 2016). Specifically, the Transportation and Logistics cluster, which has a very strong presence in the Roanoke region, is one with significant potential to leverage drones as part of its supply chain. "By replacing manual processes with drone technology, powered by purpose-built, enterprise mobile devices (the true brains behind the operation), companies can extend real-time communication and data-sharing capabilities with workers to optimize productivity and profitability and, ultimately, remain competitive over the long term" (Hall 2019). One path for growth for the drone industry in the Alleghany Highlands is integration with the regional Transportation and Logistics cluster. Like rural hops growers in

Oregon, Alleghany Highlands drone companies could work closely with Transportation and Logistics businesses within the region, thereby allowing them to test, refine and strengthen their technologies with faster feedback from the regional market. This would also allow the drone companies to more quickly position their products for a global market.

The analysis from this dissertation across all clusters and regions shows that the Transportation and Logistics cluster exhibits higher employment growth in both metropolitan (.19%) and rural adjacent counties (2.21%) when it is economically connected within regions than when it is not connected (see **Appendix 3**). Therefore, an intra-regional connectivity approach for the Transportation and Logistics cluster in Roanoke has the potential to benefit all parts of the region. As such, the results of this Roanoke regional profile suggest several recommendations for the economic development leaders of the Alleghany Highlands:

- **Analyze**: Conduct an analysis of drones in the Transportation and Logistics cluster supply chain. Integrating drones into the cluster requires an extensive understanding of the supply chain in the region to get a sense of where drones and drone technology can support the cluster. This specialized capacity is likely not available at the economic development organization in the Alleghany Highlands. Local and regional economic development leaders can work with the Virginia Economic Development Partnership via GO VA to request funding for technical support and collaboration with university partners to conduct the analysis. GO VA is an economic development initiative to help Virginia's diverse regions grow jobs that pay higher than the regional median wage through collaborative regional strategies on economic and workforce development;
- **Convene**: Connect drone companies with leaders in the Transportation and Logistics cluster so that they can build relationships and better understand how and whether

Transportation and Logistics companies could consider drones within their operations and supply chains;

- **Collaborate**: Engage with metropolitan and regional political leaders. Using data from this research, demonstrate that metropolitan growth in the Transportation and Logistics cluster will benefit from an intra-regional cluster approach. Additionally, if supply chain relationships develop between drone and Transportation and Logistics firms, regional collaboration will be necessary to build out infrastructure and other needed assets to sustain the new economic activity; and
- **Expand Demand Conditions**: Help expand the regional market for drones with pathways into other clusters by conducting background research on key industries and clusters in addition to Transportation and Logistics that use drones and drone technology; identify target industries and clusters with a presence in the region; begin engaging business leaders associated with these cluster; and convene them with drone industry leaders.

As noted in the intra-regional connectivity profile of the region, rural adjacent communities appear to be benefitting less from connectivity than metropolitan parts of the region. However, a strategic, intra-regional economic connectivity cluster approach can help bolster the rural drone industry by integrating it into the regional Transportation and Logistics cluster. Communication with business leaders in the cluster and commitments from regional partners and the state can help fast track success in a high-paying, technology-based industry in ways that can bridge the urban-rural divide within the region.

Profile 2: Sacramento-Arden-Arcade-Truckee, CA-NV Economic Area

The Sacramento, CA region is one that demonstrates how a region can leverage assets in both urban and rural areas to target a cluster for growth. This profile features a snapshot of the region's overall intra-regional connectivity results, employment growth for metropolitan, micropolitan and rural adjacent connected counties by industry cluster, and a discussion of current economic development activities related to the Life Sciences cluster. The profile concludes with recommendations for economic development organizations to strengthen the Life Sciences cluster in all parts of the region by applying an intra-regional economic connectivity framework.

Data Snapshot

The Sacramento-Arden-Arcade-Truckee, CA-NV Economic Area region provides an illustrative example not only of intra-regional connectivity, but also regional leadership and partnerships actively seeking to bolster these connections as a part of its broader economic development strategy. The 13-county region of the Sacramento Economic Area is home to a diverse mix of county types, including those that are metropolitan and micropolitan and those that are rural adjacent to urban areas. In the region, "connected" county-cluster jobs grew at an annualized rate 2010-2016 of 3.49 percent, whereas "not connected" county-cluster jobs grew 1.81 percent (**Figure 16**). These growth rates vary by county type, with connectivity having the most significant economic benefit for rural adjacent counties, as well as metropolitan counties. Micropolitan counties appear disadvantaged overall by connectivity to the regional economy.

Figure 16: Annualized Employment Growth Rate 2010-2016 for County-Clusters in the Sacramento-Arden-Arcade-Truckee, CA-NV Economic Area under Connected and Not Connected Conditions, by County Type

	Metropolitan County-Clusters	**Micropolitan County-Clusters**	**Rural Adjacent County-Clusters**	**Total**
Not Connected	2.19%	2.92%	-1.12%	1.81%
Connected	4.36%	-0.35%	4.23%	3.49%

Digging deeper into specific industry clusters, the figure below shows the annualized growth rate for county industry clusters that are connected to the broader region (**Figure 17**). The metropolitan county-clusters benefiting most from connectivity appear to be those that are traditionally rural-based, such as Agriculture Inputs and Services, Food Processing and Manufacturing, and Forestry. Micropolitan county-clusters benefiting most from connectivity include Communications Equipment and Services, Financial Services and Insurance Services, and Food Processing and Manufacturing. Rural adjacent counties have a very interesting profile for growth in connected clusters, with Financial Services, IT and Analytical Instruments, Marketing Design, and Publishing and Performing Arts all on a growth trajectory in these counties.

Figure 17: Annualized Employment Growth Rate 2010-2016 for County-Clusters in the Sacramento-Arden-Arcade-Truckee, CA-NV Economic Area under Connected Conditions, by Industry Cluster Type and County Type

Industry Cluster	Metropolitan County-Clusters	Micropolitan County-Clusters	Rural Adjacent County-Clusters	Average County-Cluster
Aerospace Vehicles and Defense	0.00%			0.00%
Agricultural Inputs and Services	12.56%	0.07%	2.78%	8.03%
Communications Equipment and Services	-0.14%	22.08%	0.00%	5.44%
Distribution and Electronic Commerce	2.62%	1.49%	-2.31%	1.20%
Environmental Services	-1.36%	-8.33%	-8.33%	-3.98%
Financial Services	5.23%	6.44%	5.19%	5.44%
Food Processing and Manufacturing	11.96%	11.51%	5.58%	10.29%
Forestry	42.08%		0.00%	28.06%
Hospitality and Tourism	1.76%	-1.43%	-0.38%	0.61%
Information Technology and Analytical Instruments	-2.21%	-1.96%	14.29%	1.98%
Insurance Services	-1.08%	5.56%	5.56%	1.68%
Jewelry and Precious Metals	-3.51%	-11.46%		-4.84%
Leather and Related Products	-1.86%	-13.81%		-4.84%
Marketing, Design, and Publishing	-0.58%	-1.29%	4.33%	-0.08%
Medical Devices	-5.54%	-4.90%		-5.36%
Metal Mining	-16.67%			-16.67%
Nonmetal Mining	-2.08%	-5.56%	-5.56%	-3.12%
Performing Arts	-0.29%	-2.50%	22.92%	7.75%
Printing Services	-2.01%	-8.26%	-5.56%	-4.32%
Recreational and Small Electric Goods	39.83%	0.00%	0.00%	29.87%
Wood Products	-4.46%	-1.97%	9.26%	-0.62%
Grand Total	**4.36%**	**-0.35%**	**4.23%**	**3.49%**

**Other clusters are present in the region but are not “connected” to the broader regional economy, meaning they have a narrower presence in specific locations.*

***Blank cells indicate no presence of the cluster in that type of county in the region, i.e. there are no connected Aerospace Vehicles and Defense jobs in micropolitan or rural adjacent counties in the Sacramento region.*

Economic Development

To bolster growth in the region, economic development leaders, industry and university partners and policy officials recently committed to accelerating the Life Sciences cluster. Life Sciences is a broader industry cluster category that includes traded and local industries, many of which are already present in the Sacramento region such as medical devices, biotechnology, health care diagnostics and information technology, laboratory instrument manufacturing, research and development and automated technology development. In targeting this cluster, leaders recognized the significant presence of life sciences in both urban and rural locations. These businesses contribute 10,859 Life Sciences jobs to the region.

Additional Life Sciences cluster assets include $231 million in NIH funding and a university, University of California Davis, producing the second highest number of Life Sciences graduates in the nation. Despite these assets, the region is not currently ranked a top region for the Life Sciences cluster (CLSA California Life Sciences Industry Report 2019; 2019 U.S. Life Science Clusters: Markets Positioned for 'Century of Biology' (CBRE)). Regional leaders affirmed, however, that the region was poised for growth in the Life Sciences cluster. They decided to leverage existing assets, to strengthen and retain top life sciences talent in the region, to incubate and develop new life sciences businesses, and to develop training for incumbent life sciences businesses in the region. More so, economic development and university leaders are committed to strengthening the Life Sciences cluster by building a cohesive, connected ecosystem.

Aggie Square, the region's answer to anchoring and upgrading the life sciences cluster, was launched in 2018 and will be built out over the next decade. According to the Greater Sacramento Area Economic Council, Aggie Square is a university-led research park that allows for services and innovative partnerships that reach companies and communities across the region. The park will create an innovation ecosystem for life sciences, anchored by UC Davis, and includes 25 acres for classrooms, lab space, industry real estate, retail stores, and a public square, about 2 million square feet of development, estimated 10,000 direct jobs, and estimated additional 27,000 jobs in the surrounding area (Greater Sacramento Area Economic Council 2019). “Aggie Square will bring together a diverse array of startups, established companies, community organizations and UC Davis researchers, faculty and students. It will be a place to discover new partners, launch businesses, scale ideas, and provide economic opportunity to residents across demographics, skill levels and industries. It will leverage our strengths and partnerships in health, agriculture, food technology, clean energy, clean transportation and more” (May 2019).

Aggie Square offers several training programs to regional businesses, serving to strengthen the intra-regional connectivity of the cluster. For example, one program, sponsored by businesses for their employees, offers training, organizational development, and coaching services. This program is targeted to developing a pipeline of talent from Aggie Square, and leveraging the expertise of UC Davis, to help integrate and introduce established businesses, including rural, to new industry standards.

Recommendations

Regional economic development leaders can complement the efforts of Aggie Square by more broadly connecting rural Life Sciences businesses with other regional Life Sciences businesses and with new innovations, suppliers and cluster-related assets emerging from Aggie Square. The analysis from this dissertation across all clusters and regions shows that the Biopharmaceuticals and Medical Devices clusters, both major parts of the Life Sciences supercluster, exhibit higher employment growth in both metropolitan and more rural counties when they are economically connected within regions than when they are not connected (see **Appendix 3**). Therefore, an intra-regional connectivity approach for the Life Sciences supercluster in Sacramento has the potential to benefit all parts of the region.

Like the Sacramento region, the Indianapolis-Anderson-Columbus, IN region has a strong higher education system and growing Life Sciences cluster with cluster firms located in urban and rural parts of the region. Given the urban-rural distribution of cluster assets, an economic development study analyzing the cluster in the Indianapolis region suggested a two-pronged approach that is applicable to Sacramento. “First, the region should attempt to take advantage of existing cluster strengths in its more rural areas. Second, the strategy should create stronger connections between the lesser and more developed via workforce development, vendor relationships and entrepreneurship” (Nolan, et al. 2007). Specifically, when regional leaders came together, they mapped out a plan to help small advanced materials and manufacturing firms in rural communities retool to supply the growing biotech sector of the cluster.

Similarly, Cumbers (2019), founder and CEO of a leading biotechnology firm, sees great promise for Life Sciences, particularly biotechnology, in rural communities. “…rural America remains one of our nation’s most fertile regions, and recent advances in biotechnology are making it easier than ever to sustainably grow new kinds of valuable goods, from biopharmaceuticals to biomaterials. With the right strategic investments, rural America could see a biotech "bloom”” (Cumbers 2019). He suggests that government and economic development organizations incentivize partnerships between rural businesses and academia, particularly agricultural extension schools that can deliver research and job training closer to where these businesses are located. Cumbers also suggests working with the Federal government to expand National Laboratories into rural areas to serve as incubators for rural biotechnology firms.

Recommendations from the Indianapolis region, as well as a Life Sciences CEO, suggest a role for the Sacramento area economic development organizations to strengthen the regional Life Sciences cluster by bolstering participation of rural-based businesses. Strategies range from strengthening the intra-regional supply chain, expanding workforce development and R&D into rural areas, and supporting rural start-ups. For example, economic developers can convene rural-based firms with larger Life Sciences firms in the regional cluster to discuss how rural firms can tailor their products and services to the supply needs of the cluster. Regional economic developers can also bring developers from Aggie Square to showcase their innovations to more rural parts of the region. This could seed relationships for supply chain innovations between rural-based businesses and new technologies developed at Aggie Square, help rural firms integrate new industry innovations into their processes, and provide a feedback mechanisms from rural firms to developers at Aggie Square to refine their innovations. Additionally, in lieu of a massive Federal effort to expand a National Laboratory, local and regional organizations can build high quality incubators so that rural startups can "test their products without having to make a major investment in equipment themselves" (Cumbers 2019).

Although only in its initial stages, Aggie Square establishes an aggressive Life Sciences vision for the region - a vision that is grounded in a deep understanding of regional assets both urban and rural. The key to its continued success will be participation by rural-based businesses and partnerships with local and regional economic developers committed to continuing to grow Life Sciences in all corners of the region.

Summary

The policy implications of this analysis on intra-regional connectivity are significant. They signal to economic developers when an integrated approach is beneficial to a regional cluster, and to different parts of their regions. As is demonstrated in Roanoke and Sacramento, both recognize urban and rural cluster-based assets. Long-term sustainability and growth of these clusters, however, will rely on strategic and intentional efforts to ensure intra-regional economic connectivity. For example, in Roanoke, an intra-regional connectivity approach could include supply chain analysis, convening industry partners, facilitating collaboration across jurisdictional boundaries to develop new regional assets, and expanding regional demand conditions for drones and drone technology. In Sacramento, Aggie Square is poised to launch the region as a top location for the Life Sciences cluster. However, to ensure that all parts of the region are connected to and benefit from new growth, economic developers can complement the new talent pipeline and innovations emerging from Aggie Square by strengthening the intra-regional supply chain, expanding workforce development and R&D into rural areas, and supporting rural start-ups. Overall, the intra-regional connectivity approach to targeting and upgrading clusters serves to strengthen regional economies and narrow the urban-rural divide in ways that are beneficial to the cluster, localities within the region, and ultimately, the people who live there.

CONCLUSION

Introduction

Overall, this dissertation finds that for most clusters, the regional mechanisms of agglomeration such as skilled labor, sophisticated and demanding local customers, niche markets, suppliers, and related industries, benefit local growth. However, the analysis, based on 77,346 observations across all counties, clusters and regions, also reveals that the impact of regional connectivity on county-based industry cluster employment growth varies by industry cluster type as well as by location within a region. Specifically, the results of the analysis indicate that:

> **H_1** is supported. An industry cluster that has a presence in the county and strength in the rest of the region outside of the county ("connected") grows faster than the same cluster located in county without specialization in the rest of the region outside of the county ("not connected"). The average annualized employment growth rates (2010-2016) for county-clusters that are connected to their regional economies are greater than for county-clusters that are not connected to their regional economies.
>
> **H_2** is supported. The average annualized employment growth rates (2010-2016) for *metropolitan* county-clusters that are connected to their regional economies are greater than for *metropolitan* county-clusters that are not connected to their regional economies.
>
> **H_3** is supported. The average annualized employment growth rates (2010-2016) for *micropolitan* county-clusters that are connected to their regional economies are

greater than for *micropolitan* county-clusters that are not connected to their regional economies.

H_4 is supported. The average annualized employment growth rates (2010-2016) for *rural adjacent* county-clusters that are connected to their regional economies are greater than for *rural adjacent* county-clusters that are not connected to their regional economies.

H_5 is supported. The average annualized employment growth rates (2010-2016) for *rural remote* county-clusters that are connected to their regional economies are greater than for *rural remote* county-clusters that are not connected to their regional economies.

H_6 is not supported. The alternative hypothesis that rural adjacent county-clusters will benefit more from intra-regional connectivity than micropolitan county-clusters, that rural adjacent and micropolitan county-clusters will benefit more than metropolitan county-clusters, and that rural remote county-clusters will benefit least was not supported. In terms of comparative magnitude of the average employment growth rate differences between connected and not connected county-clusters by county type: *Rural Remote* > *Rural Adjacent* > *Micropolitan* > *Metropolitan*.

H_7 is supported. Differences in the average annualized employment growth rates (2010-2016) for connected and not connected county-clusters vary by industry cluster and by county type.

These findings have significant implications for the practice of economic development. Integrating an intra-regional connectivity framework into cluster-based economic development helps local and regional policy makers and practitioners target clusters that will have the greatest region-wide benefits, and tailor investments toward the most advantageous parts of regions to support cluster growth. Examples from the drone industry in Roanoke region and Life Sciences in Sacramento demonstrate the potential impact of this approach.

Limitations

Despite the utility of this new approach to regional economic development, several limitations should be considered, including methodological limitations of t-tests; a drawback of defining urban and rural according to USDA RUCCs; shortcomings of measuring connectivity using minimum threshold county-level jobs; and potential weaknesses of industry clusters as a framework for practice. First, while t-tests determine statistically significant differences among county-clusters under connected and not connected conditions, the test does not control for other factors unique to the two groups. The analysis partially overcomes this limitation by refining the sample and rerunning t-tests by county type and industry cluster type. These disaggregations help control for characteristics of connected and not connected county groups that may be related to rurality and agglomeration linkages within specific industry clusters. The research lays the groundwork for more significant inquiry into the specific factors driving growth under connected and not connected conditions.

Additionally, this research utilizes the USDA RUCCs codes to classify counties along an urban-rural spectrum. The USDA definition delineates counties into nine categories ranging from very large metropolitan counties to counties that are completely rural and not near a metropolitan area. This scheme is more favorable than that offered by the U.S. Census Bureau or the Office of Management and Budget because the scale considers adjacency to larger economies making it best suited for analysis of intra-regional economic dynamics (Hall, et al. 2006). A key drawback, however, is that RUCCs lacks inclusion of a specific micropolitan category. Micropolitan areas have emerged in recent years has key drivers of growth in the heartland and more rural regions. Connectivity to micropolitan areas have been identified as key pathways for rural communities to achieve economic opportunity (DeVol and Crews 2019). Understanding the relationship between micropolitan counties to the rest of their regions, therefore, becomes critical when proposing solutions to bridging the urban-rural divide.

To account for the gap in the RUCCs codes, this research applies a "micropolitan" definition to RUCCs code five, which is roughly analogous to the OMB definition of micropolitan areas. RUCCs code five is defined as a county having an "urban population of 20,000 or more, not adjacent to a metro area." OMB definition of micropolitan area is a labor market area with an urban core population of at least 10,000 but fewer than 50,000 people. Stronger alignment of definitions would bolster this research.

Another potential shortcoming of this research is the measure of intra-regional connectivity that relies on a minimum threshold of county-level jobs. This approach was selected to be able to identify whether a county had a basic level of assets to enable it to support a cluster. The presence of 10 jobs indicates that there is some level of market, talent base and other resources available in the location. The challenge of this definition, however, is that it does not normalize cluster activity across counties. For example, the 10-job minimum in Blackford county, IN is treated the same as the 10-job minimum in New York county (Manhattan) despite the significant difference in the size of these economic markets. One approach to normalizing cluster jobs across counties while still accounting for emerging clusters is to designate a minimum location quotient, paired with the 10-job minimum. For example, a county-cluster could be required to have a LQ of .1 and have a minimum of 10 jobs in order to be considered as part of the sample. A LQ of .1 is categorized by the U.S. Cluster Mapping Project as a "qualified" cluster, meaning that some level of cluster activity is detected at the spatial scale. When this definition is applied to the current sample of 77,346 observations, fewer than five percent are excluded. When t-tests are rerun with the adjusted sample, there is no meaningful change in the results. This could be, again, because the analysis already accounts for differences in county type and industry cluster type, which sufficiently normalizes economic activity across county types.

Finally, although industry clusters are universally understood as a concentration of economic activity based on similar and complimentary industries, the way that the cluster approach is operationalized by economic development organizations varies extensively. For example, GO VA Region 2 (Roanoke) determines priority "clusters" of economic activity that are not clusters in the same sense as the U.S. Cluster Mapping Project, but instead groupings of industries (i.e. "emerging technologies" is not one of the 51 traded industry clusters). In Sacramento, the life sciences cluster is a "super cluster" with loose boundaries including healthcare, medical devise, biotechnology, and other sciences. Despite the drawback of "fuzziness" around cluster definitions, the benefit of cluster-informed strategies is that they can be a successful analytical tool and approach. Once clusters are identified, regardless of the final cluster categories, economic development organizations have a focal point to onboard and engage stakeholders, to direct investments and resources, to identify gaps and new opportunities for collaboration, and to market the region.

Key limitations of this research relate to the methodology, data definitions, operationalization of the connectivity concept, and practical application of the broader cluster framework. As detailed, efforts have been made in this research to minimize these limitations and improve the applicability of this work to real world urban-rural economic challenges.

Future Research

This dissertation lays the groundwork for significant future research to further move the field toward greater understanding of how to bridge the urban-rural economic divide. First, building off the methodological limitations of this dissertation, future research can examine the specific factors driving connectivity. In terms of approach, first a literature review should be conducted to understand what types of factors contribute to intra-regional connectivity, such as physical proximity and regional density; migration trends and population size of the region; educational institutions; shared governance; national cluster growth trends; overall regional growth trends; and presence of infrastructure. A researcher can use an econometric model with connectivity of the region as the dependent variable (i.e. a connectivity scale based on county-level connectivity), with the factors identified above as independent variables. These findings would help uncover specific strategies to support intra-regional connectivity.

Additionally, the findings from this dissertation reveal several county-clusters that exhibit a statistically significant negative relationship between connectivity and cluster employment growth. Another line of inquiry could investigate the explanations and factors accounting for this negative relationship. For example, if the county-cluster is not growing but is regionally connected, the negative relationship may reflect backwash effects from the rest of region. This may indicate that a specific location may no longer have the necessary cluster assets, have become too expensive to operate, or be unable to sustain growth. Under these circumstances, the location may lose cluster employment while regional specialization is maintained. With this information, an economic development organization can decide how or whether to revive the cluster (i.e. combine parcels of land in a more densely populated part of the region so that a manufacturer can continue operations).

Alternatively, if the negative relationship is based on growth in the county-cluster that is *not* regionally connected it is possible that the necessary cluster linkages are contained within the locality and that the geographical reach of its linkages are more concentrated. This would reflect that the area has a unique competitive advantage for the cluster. For example, urban concentration could indicate more knowledge-based, innovation-focused cluster linkages that tend to operate at more localized, dense scales. Also, if the county-cluster is growing but not regionally connected, it could indicate that cluster growth is stemming from linkages between the locality and other regional or global markets, not intra-regional cluster linkages. Each of these "negative relationship" scenarios have different implications for economic development policy, so understanding the explanatory factor underlying the relationship between growth and connectivity becomes critical to sustaining and growing the cluster.

Summary

Limitations of the analysis do not prevent a practical application of the intra-regional connectivity framework, but they do open pathways for additional research that can strengthen it. The findings from this analysis suggest that intra-regional economic connectivity has a positive association with county-cluster employment growth, results that are particularly pronounced for more rural communities but that vary across industry clusters. This analysis offers a jumping off point for economic developers and other regional leaders to better understand their regional economic landscape, to inform strategy, to offer new ideas and opportunities, and to encourage growth by leveraging existing regional assets. Specifically, the intra-regional connectivity approach alters cluster-based strategies, particularly the role of public sector actors. The examples of Roanoke and Sacramento demonstrate intra-regional strategies (and potential strategies) with a targeted focus by economic development organizations and universities on bolstering regional supply chains, laying the groundwork for enhanced regional demand conditions and building the connective tissue and infrastructure for collaboration between urban and rural firms within a cluster. Utilizing an intra-regional industry cluster connectivity framework as an analytical tool presents economic development organizations with a new context-specific pathway for regional and local economic growth.

APPENDICES

Appendix A: Key Features of Economic Areas

Economic Area	Region	Population
Aberdeen, SD	Midwest	82553
Abilene, TX	South	228656
Albany, GA	South	608828
Albany-Schenectady-Amsterdam, NY	Northeast	1389924
Albuquerque, NM	South	949196
Alpena, MI	Midwest	228926
Amarillo, TX	South	503749
Anchorage, AK	West	740525
Appleton-Oshkosh-Neenah, WI	Midwest	867318
Asheville-Brevard, NC	South	717404
Atlanta-Sandy Springs-Gainesville, GA-AL	South	7918175
Augusta-Richmond County, GA-SC	South	645100
Austin-Round Rock, TX	South	2122342
Bangor, ME	Northeast	324374
Baton Rouge-Pierre Part, LA	South	860706
Beaumont-Port Arthur, TX	South	465563
Bend-Prineville, OR	West	234747
Billings, MT	West	368083
Birmingham-Hoover-Cullman, AL	South	1768448
Bismarck, ND	Midwest	201736
Boise City-Nampa, ID	West	780884
Boston-Worcester-Manchester, MA-NH	Northeast	8541840
Buffalo-Niagara-Cattaraugus, NY	Northeast	1452231
Burlington-South Burlington, VT	Northeast	394985
Cape Girardeau-Jackson, MO-IL	Midwest	298657
Casper, WY	Midwest	371928
Cedar Rapids, IA	Midwest	531625
Champaign-Urbana, IL	Midwest	548609
Charleston, WV	South	1173470
Charleston-North Charleston, SC	South	781776
Charlotte-Gastonia-Salisbury, NC-SC	South	3132231
Chicago-Naperville-Michigan City, IL-IN-WI	Midwest	10474843
Cincinnati-Middletown-Wilmington, OH-KY-IN	Midwest	2380081
Clarksburg, WV + Morgantown, WV	South	345800
Cleveland-Akron-Elyria, OH	Midwest	4538867

Colorado Springs, CO	West	765194
Columbia, MO	Midwest	517777
Columbia-Newberry, SC	South	1109681
Columbus-Auburn-Opelika, GA-AL	South	494393
Columbus-Marion-Chillicothe, OH	Midwest	2820954
Corpus Christi-Kingsville, TX	South	884256
Dallas-Fort Worth, TX	South	8729391
Davenport-Moline-Rock Island, IA-IL	Midwest	487551
Dayton-Springfield-Greenville, OH	Midwest	1370524
Denver-Aurora-Boulder, CO	West	4479649
Des Moines-Newton-Pella, IA	Midwest	1305747
Detroit-Warren-Flint, MI	Midwest	6820069
Dothan-Enterprise-Ozark, AL	South	314116
Dover, DE	Northeast	612908
Duluth, MN-WI	Midwest	353066
El Paso, TX	South	1204945
Erie, PA	Northeast	504001
Eugene-Springfield, OR	West	830552
Evansville, IN-KY	Midwest	770708
Fargo-Wahpeton, ND-MN	Midwest	323536
Farmington, NM	South	224177
Fayetteville-Springdale-Rogers, AR-MO	South	578180
Flagstaff, AZ	South	145885
Fort Smith, AR-OK	South	341515
Fort Wayne-Huntington-Auburn, IN	Midwest	801329
Fresno-Madera, CA	West	1752706
Gainesville, FL	South	496149
Grand Forks, ND-MN	Midwest	208560
Grand Rapids-Muskegon-Holland, MI	Midwest	1976925
Great Falls, MT	West	147955
Greensboro--Winston-Salem--High Point, NC	South	2008996
Greenville, NC	South	725688
Greenville-Spartanburg-Anderson, SC	South	1455339
Gulfport-Biloxi-Pascagoula, MS	South	429608
Harrisburg-Carlisle-Lebanon, PA	Northeast	2225671
Harrisonburg, VA	South	325551
Hartford-West Hartford-Willimantic, CT	Northeast	2301880
Helena, MT	West	275477
Honolulu, HI	West	1421658
Houston-Baytown-Huntsville, TX	South	7657910

Huntsville-Decatur, AL	South	1130818
Idaho Falls-Blackfoot, ID	Midwest	354461
Indianapolis-Anderson-Columbus, IN	Midwest	3536815
Jacksonville, FL	South	1855563
Jackson-Yazoo City, MS	South	1665791
Johnson City-Kingsport-Bristol (Tri-Cities), TN-VA	South	864216
Jonesboro, AR	South	313805
Joplin, MO	Midwest	370307
Kansas City-Overland Park-Kansas City, MO-KS	Midwest	2723943
Kearney, NE	Midwest	328530
Kennewick-Richland-Pasco, WA	West	591793
Killeen-Temple-Fort Hood, TX	South	738932
Knoxville-Sevierville-La Follette, TN	South	1242914
La Crosse, WI-MN	Midwest	262013
Lafayette-Acadiana, LA	South	867951
Lake Charles-Jennings, LA	South	351135
Las Vegas-Paradise-Pahrump, NV	West	2577223
Lewiston, ID-WA	West	93131
Lexington-Fayette-Frankford-Richmond, KY	South	1551225
Lincoln, NE	Midwest	430068
Little Rock-North Little Rock-Pine Bluff, AR	South	1570906
Los Angeles-Long Beach-Riverside, CA	West	20624421
Louisville-Elizabethtown-Scottsburg, KY-IN	South	1648382
Lubbock-Levelland, TX	South	463806
Macon-Warner Robins-Fort Valley, GA	South	673373
Madison-Baraboo, WI	Midwest	1215779
Marinette, WI-MI	Midwest	328662
Mason City, IA	Midwest	155921
McAllen-Edinburgh-Pharr, TX	South	1344999
Memphis, TN-MS-AR	South	2048593
Miami-Fort Lauderdale-Miami Beach, FL	South	9494089
Midland-Odessa, TX	South	649872
Milwaukee-Racine-Waukesha, WI	Midwest	2361139
Minneapolis-St. Paul-St. Cloud, MN-WI	Midwest	5495260
Minot, ND	Midwest	165172
Missoula, MT	West	316140
Mobile-Daphne-Fairhope, AL	South	761736
Monroe-Bastrop, LA	South	338347
Montgomery-Alexander City, AL	South	553410
Myrtle Beach-Conway-Georgetown, SC	South	1129125

Nashville-Davidson--Murfreesboro--Columbia, TN	South	3049468
New Orleans-Metairie-Bogalusa, LA	South	1702187
New York-Newark-Bridgeport, NY-NJ-CT-PA	Northeast	23815321
Oklahoma City-Shawnee, OK	South	2179313
Omaha-Council Bluffs-Fremont, NE-IA	Midwest	1107093
Orlando-The Villages, FL	South	4964381
Paducah, KY-IL	South	243790
Panama City-Lynn Haven, FL	South	303119
Pendleton-Hermiston, OR	West	147077
Pensacola-Ferry Pass-Brent, FL	South	737750
Peoria-Canton, IL	Midwest	873362
Philadelphia-Camden-Vineland, PA-NJ-DE-MD	Northeast	7147858
Phoenix-Mesa-Scottsdale, AZ	South	5142569
Pittsburgh-New Castle, PA	Northeast	2863382
Portland-Lewiston-South Portland, ME	Northeast	1005784
Portland-Vancouver-Beaverton, OR-WA	West	3291774
Pueblo, CO	West	243217
Raleigh-Durham-Cary, NC	South	3476981
Rapid City, SD	Midwest	251231
Redding, CA	West	360731
Reno-Sparks, NV	West	731135
Richmond, VA	South	1731893
Roanoke, VA	South	830402
Rochester-Batavia-Seneca Falls, NY	Northeast	1526741
Sacramento--Arden-Arcade--Truckee, CA-NV	West	2897832
Salina, KS	Midwest	190098
Salt Lake City-Ogden-Clearfield, UT	West	2791297
San Angelo, TX	South	149974
San Antonio, TX	South	2686312
San Jose-San Francisco-Oakland, CA	West	10371198
Santa Fe-Espanola, NM	South	275043
Sarasota-Bradenton-Venice, FL	South	2034231
Savannah-Hinesville-Fort Stewart, GA	South	893437
Scotts Bluff, NE	Midwest	90830
Scranton--Wilkes-Barre, PA	Northeast	651314
Seattle-Tacoma-Olympia, WA	West	5072675
Shreveport-Bossier City-Minden, LA	South	560626
Sioux City-Vermillion, IA-NE-SD	Midwest	377208
Sioux Falls, SD	Midwest	516522
South Bend-Mishawaka, IN-MI	Midwest	958987

Spokane, WA	West	876937
Springfield, IL	Midwest	621780
Springfield, MO	Midwest	1036778
St. Louis-St. Charles-Farmington, MO-IL	Midwest	3390389
State College, PA	Northeast	798233
Syracuse-Auburn, NY	Northeast	2011246
Tallahassee, FL	South	541864
Tampa-St. Petersburg-Clearwater, FL	South	2978209
Texarkana, TX-Texarkana, AR	South	314557
Toledo-Fremont, OH	Midwest	980565
Topeka, KS	Midwest	480589
Traverse City, MI	Midwest	283625
Tucson, AZ	South	1180131
Tulsa-Bartlesville, OK	South	1395059
Tupelo, MS	Midwest	549413
Twin Falls, ID	West	192082
Virginia Beach-Norfolk-Newport News, VA-NC	South	1917743
Washington-Baltimore-Northern Virginia, DC-MD-VA-WV	Northeast	10015999
Waterloo-Cedar Falls, IA	Midwest	226117
Wausau-Merrill, WI	Midwest	518730
Wenatchee, WA	West	269781
Wichita Falls, TX	South	187897
Wichita-Winfield, KS	Midwest	1087575

Appendix B: Intra-Regional Connectivity Ranking of Regions (Difference in Average Annualized Employment Growth Rate (2010-2016) of County-Clusters in Connected and Not Connected Conditions, by Economic Area and County Type)

Economic Area	Rank	EA Avg. Difference	Metropolitan	Micropolitan	Rural Adjacent	Remote Rural
Denver-Aurora-Boulder, CO	1	23.92%	50.97%	-0.41%	-13.08%**	4.20%**
Pendleton-Hermiston, OR	2	20.21%		8.24%**		33.02%**
Fort Wayne-Huntington-Auburn, IN	3	12.52%	1.75%	17.93%*	6.29%	
Monroe-Bastrop, LA	4	12.13%	1.87%	37.24%*	8.20%	7.54%**
South Bend-Mishawaka, IN-MI	5	9.51%	0.05%	6.50%**	36.68%**	16.98%**
Columbia, MO	6	9.46%	14.84%	-1.65%	11.03%	3.63%
Toledo-Fremont, OH	7	9.13%	-0.07%	21.46%**	0.97%	-3.59%
Mobile-Daphne-Fairhope, AL	8	8.88%	1.47%	23.00%	62.02%*	2.95%
Oklahoma City-Shawnee, OK	9	7.96%	8.74%**	-1.17%	6.65%**	13.72%**
Jonesboro, AR	10	7.73%	23.45%	5.83%	-3.61%	-0.41%
Roanoke, VA	11	7.32%	8.49%**		0.41%	
Tallahassee, FL	12	7.17%	4.06%*	2.77%	12.95%	
Santa Fe-Espanola, NM	13	7.06%	0.22%	11.44%**		-2.09%
Boise City-Nampa, ID	14	6.90%	1.12%	-13.39%**	57.61%**	5.19%
Louisville-Elizabethtown-Scottsburg, KY-IN	15	6.79%	4.12%*	6.57%**	21.59%*	5.19%
Jackson-Yazoo City, MS	16	6.70%	2.72%*	10.67%*	2.15%	10.33%**
Twin Falls, ID	17	6.66%		3.57%		9.85%**
Pensacola-Ferry Pass-Brent, FL	18	6.62%	6.62%*			
Aberdeen, SD	19	6.49%	27.78%	8.13%**	13.89%	5.89%
Anchorage, AK	20	6.43%	17.37%*	12.20%**	9.22%	2.05%
Grand Rapids-Muskegon-Holland, MI	21	6.40%	7.80%**	3.95%	2.06%	
Minot, ND	22	6.32%		9.43%**		3.20%
Rapid City, SD	23	6.19%	-0.18%	8.37%**	3.31%	13.82%**
Peoria-Canton, IL	24	5.86%	-0.22%	4.56%	28.43%*	-6.75%
Traverse City, MI	25	5.49%		6.60%**		2.96%
Bend-Prineville, OR	26	5.37%	5.91%*	15.29%*	-10.25%*	10.97%
Asheville-Brevard, NC	27	5.04%	2.97%	8.75%*	0.53%	7.87%
Harrisonburg, VA	28	4.94%	4.51%*		5.67%**	
Texarkana, TX-Texarkana, AR	29	4.80%	4.32%	8.42%**	8.02%**	1.35%
La Crosse, WI-MN	30	4.77%	4.11%		5.54%	
McAllen-Edinburg-Pharr, TX	31	4.60%	4.96%*	7.34%**		
Wichita-Winfield, KS	32	4.59%	6.25%**	8.71%**	-1.05%	1.14%
Abilene, TX	33	4.51%	8.01%**	7.21%	1.14%	-3.12%
Charleston, WV	34	4.49%	4.24%**	-0.32%	6.72%**	4.92%**
Salina, KS	35	4.48%		4.13%		4.61%**
Gulfport-Biloxi-Pascagoula, MS	36	4.41%	5.52%		1.66%	
Corpus Christi-Kingsville, TX	37	4.30%	11.98%**	-8.82%**	11.23%**	4.67%

Dothan-Enterprise-Ozark, AL	38	4.25%	3.09%	4.23%	6.68%	
Houston-Baytown-Huntsville, TX	39	3.90%	5.37%**	0.95%	2.61%*	10.93%**
Omaha-Council Bluffs-Fremont, NE-IA	40	3.89%	3.54%	-7.09%**	10.92%**	2.21%
Killeen-Temple-Fort Hood, TX	41	3.85%	3.18%		5.76%	1.47%
Huntsville-Decatur, AL	42	3.78%	4.06%	3.91%**	4.58%	
Jacksonville, FL	43	3.77%	2.67%	7.58%*	4.90%	-7.67%
Little Rock-North Little Rock-Pine Bluff, AR	44	3.74%	3.15%	-0.17%	6.99%**	6.11%**
Rochester-Batavia-Seneca Falls, NY	45	3.68%	10.32%	-2.79%	-7.60%**	
Kearney, NE	46	3.64%	4.20%*	3.55%*	-7.74%**	4.86%**
Pittsburgh-New Castle, PA	47	3.62%	5.27%**	-10.17%**	6.43%	16.58%**
Fort Smith, AR-OK	48	3.56%	1.91%		7.23%**	6.67%
Montgomery-Alexander City, AL	49	3.54%	5.78%	2.83%	-0.83%	
Scotts Bluff, NE	50	3.43%		8.85%*	6.96%*	0.34%
Indianapolis-Anderson-Columbus, IN	51	3.40%	1.23%	6.61%**	3.90%**	10.86%*
Des Moines-Newton-Pella, IA	52	3.29%	-4.20%*	4.11%**	-4.44%	10.17%**
Knoxville-Sevierville-La Follette, TN	53	3.23%	1.87%	12.40%*	-0.16%	
Erie, PA	54	3.16%	-1.99%	5.26%**	2.84%	-0.55%
Buffalo-Niagara-Cattaraugus, NY	55	3.13%	1.64%	4.36%		3.29%
Madison-Baraboo, WI	56	2.99%	9.97%**	3.80%	-0.94%	-10.47%*
Helena, MT	57	2.97%		4.48%	-2.08%	3.18%*
Midland-Odessa, TX	58	2.89%	1.37%	1.62%	-0.79%	12.58%**
Detroit-Warren-Flint, MI	59	2.81%	5.18%**	-4.86%*	1.18%	3.43%
San Jose-San Francisco-Oakland, CA	60	2.66%	1.33%	7.26%*	3.89%	
Fayetteville-Springdale-Rogers, AR-MO	61	2.63%	2.15%		5.32%	
Casper, WY	62	2.49%	9.10%	7.81%**	1.21%	-1.84%
Bismarck, ND	63	2.43%	2.15%	-3.50%	-12.99%*	11.79%
Beaumont-Port Arthur, TX	64	2.27%	0.36%		8.09%**	
Lincoln, NE	65	2.22%	-0.98%	7.17%	3.93%*	2.40%
Billings, MT	66	2.13%	-3.27%	1.04%	-24.28%*	6.98%**
Alpena, MI	67	2.09%		6.24%		1.63%
Greensboro-Winston-Salem-High Point, NC	68	2.04%	-4.61%**	8.98%	-8.29%**	22.02%*
Macon-Warner Robins-Fort Valley, GA	69	2.00%	4.35%	-8.12%**	2.58%	5.91%*
Lexington-Fayette-Frankfort-Richmond, KY	70	1.98%	19.63%	-5.30%	3.66%	-1.74%
Chicago-Naperville-Michigan City, IL-IN-WI	71	1.89%	2.13%**	2.05%	-2.29%	-2.04%
Sioux Falls, SD	72	1.87%	-3.05%	0.55%	7.40%**	2.58%
Dallas-Fort Worth, TX	73	1.84%	2.22%	2.36%	-0.66%	3.87%
Dayton-Springfield-Greenville, OH	74	1.83%	4.70%**	-2.27%	4.74%	
Cincinnati-Middletown-Wilmington, OH-KY-IN	75	1.80%	2.64%	-8.67%**	3.62%	0.43%
Lewiston, ID-WA	76	1.75%	-2.00%		4.55%	
Sacramento-Arden-Arcade-Truckee, CA-NV	77	1.67%	2.18%	-3.27%	5.35%**	
Tulsa-Bartlesville, OK	78	1.66%	1.87%	2.89%	0.15%	
Syracuse-Auburn, NY	79	1.63%	0.48%	0.47%	7.19%	
Redding, CA	80	1.54%	-1.72%	1.31%	6.47%	
Kansas City-Overland Park-Kansas City, MO-KS	81	1.49%	3.32%*	-0.75%	-3.54%	3.54%*

Grand Forks, ND-MN	82	1.43%	-3.49%		4.35%	1.81%
Kennewick-Richland-Pasco, WA	83	1.43%	1.43%			
Birmingham-Hoover-Cullman, AL	84	1.22%	0.78%	-0.67%	2.25%	8.26%
Duluth, MN-WI	85	1.13%	7.54%	-11.28%	2.44%	-6.58%*
Joplin, MO	86	0.95%	2.36%	9.03%	-2.80%	-0.80%
Milwaukee-Racine-Waukesha, WI	87	0.90%	0.14%	1.62%	4.05%	
Lake Charles-Jennings, LA	88	0.84%	-8.25%	6.97%	1.76%	
Baton Rouge-Pierre Part, LA	89	0.78%	-0.79%		13.83%	
Hartford-West Hartford-Willimantic, CT	90	0.74%	1.01%	-1.53%		
Appleton-Oshkosh-Neenah, WI	91	0.64%	1.24%	-4.30%	0.82%	
Johnson City-Kingsport-Bristol (Tri-Cities), TN-VA	92	0.58%	1.27%	5.11%*	-3.53%	-9.06%**
State College, PA	93	0.57%	-2.02%	2.30%	2.92%	0.20%
Columbus-Marion-Chillicothe, OH	94	0.51%	4.66%*	-1.77%	-5.63%	0.58%
Albany, GA	95	0.48%	-1.26%	1.91%	1.04%	-0.03%
Burlington-South Burlington, VT	96	0.47%	5.29%	-1.21%	3.91%**	-8.72%
Portland-Vancouver-Beaverton, OR-WA	97	0.46%	-2.13%	-2.86%	21.31%	57.83%
Flagstaff, AZ	98	0.44%	-3.43%		9.26%**	
Topeka, KS	99	0.44%	5.99%	-17.41%*	-1.36%	4.83%
Orlando-The Villages, FL	100	0.40%	0.28%	5.50%		
St. Louis-St. Charles-Farmington, MO-IL	101	0.37%	-1.20%	1.78%	3.62%**	-7.06%**
Pueblo, CO	102	0.34%	-6.60%		9.90%**	1.35%
Tupelo, MS	103	0.13%		-6.24%	5.73%	4.08%*
Phoenix-Mesa-Scottsdale, AZ	104	0.06%	-1.70%	-5.40%	14.10%	23.66%**
Los Angeles-Long Beach-Riverside, CA	105	0.03%	-0.93%		17.17%**	1.70%
Savannah-Hinesville-Fort Stewart, GA	106	0.02%	-1.21%	-1.45%	-0.11%	5.75%**
Tampa-St. Petersburg-Clearwater, FL	107	-0.01%	-0.01%			
Fargo-Wahpeton, ND-MN	108	-0.04%	-1.01%	6.21%**	-1.68%	-2.02%
Wichita Falls, TX	109	-0.04%	8.46%	5.69%*	-0.52%	-12.56%**
Washington-Baltimore-NoVA, DC-MD-VA-WV	110	-0.07%	-0.50%	-4.08%**	2.74%	1.13%
Greenville-Spartanburg-Anderson, SC	111	-0.11%	0.53%	-0.57%	-4.51%	
Bangor, ME	112	-0.16%	-6.05%*		-2.83%	6.42%**
Springfield, IL	113	-0.17%	5.00%**	-0.52%	-3.17%	-3.45%*
Paducah, KY-IL	114	-0.22%		-1.86%	-0.69%	4.18%
Great Falls, MT	115	-0.26%	-9.27%*		-4.72%	5.15%**
Waterloo-Cedar Falls, IA	116	-0.26%	3.21%		-4.24%	
El Paso, TX	117	-0.27%	3.21%	1.05%	-12.50%	-25.44%
Springfield, MO	118	-0.29%	0.42%	1.46%	-3.44%	-0.76%
Virginia Beach-Norfolk-Newport News, VA-NC	119	-0.35%	2.78%	-4.12%**	-2.95%	-6.09%*
Philadelphia-Camden-Vineland, PA-NJ-DE-MD	120	-0.40%	-0.53%	1.57%		
Salt Lake City-Ogden-Clearfield, UT	121	-0.40%	2.23%	-3.83%	-5.65%	-1.40%
Nashville-Davidson-Murfreesboro-Columbia, TN	122	-0.45%	-4.44%**	2.56%	0.13%	10.42%
Honolulu, HI	123	-0.49%	-1.24%	0.68%		
Reno-Sparks, NV	124	-0.49%	-5.48%*	-0.43%	-2.87%	10.44%**
Boston-Worcester-Manchester, MA-NH	125	-0.55%	-0.30%	-1.59%	-0.66%	2.55%

Portland-Lewiston-South Portland, ME	126	-0.61%	-5.19%	-8.18%	5.75%**	0.00%
New York-Newark-Bridgeport, NY-NJ-CT-PA	127	-0.74%	-0.43%	-5.01%	-8.53%**	
Mason City, IA	128	-0.82%		0.28%	-2.37%	-1.09%
Memphis, TN-MS-AR	129	-1.00%	-1.23%	0.46%	-1.52%	-2.75%
Richmond, VA	130	-1.01%	-1.18%		1.12%	-3.14%
San Antonio, TX	131	-1.34%	-4.39%	4.44%	-10.37%	3.53%
Charlotte-Gastonia-Salisbury, NC-SC	132	-1.40%	-2.57%	1.56%	1.94%	
Spokane, WA	133	-1.40%	0.04%	-0.78%	-6.74%**	0.06%
Shreveport-Bossier City-Minden, LA	134	-1.56%	-3.33%	-0.65%	1.32%	
Cape Girardeau-Jackson, MO-IL	135	-1.59%	1.67%	0.52%	-4.95%	-2.48%
Dover, DE	136	-1.59%	-0.88%		-3.91%	
Cleveland-Akron-Elyria, OH	137	-1.63%	-1.48%	-1.73%	-15.77%	6.91%**
Lafayette-Acadiana, LA	138	-1.67%	0.41%	-10.64%	0.25%	
Cedar Rapids, IA	139	-1.69%	0.98%	3.75%	-8.93%**	
Myrtle Beach-Conway-Georgetown, SC	140	-1.73%	-3.17%*	-2.95%	1.73%	
Missoula, MT	141	-1.84%	-4.65%	-3.63%	-2.29%	7.84%
Panama City-Lynn Haven, FL	142	-1.87%	-2.30%		-1.32%	
Sioux City-Vermillion, IA-NE-SD	143	-1.91%	4.18%	-6.11%	3.19%	-5.60%*
Columbia-Newberry, SC	144	-1.94%	-5.62%	-0.52%	13.78%	16.89%**
Charleston-North Charleston, SC	145	-2.12%	-4.22%		4.11%	
Austin-Round Rock, TX	146	-2.18%	-0.09%		-5.05%	-4.65%
Farmington, NM	147	-2.24%	-5.94%*	-2.41%	-3.12%	1.20%
Evansville, IN-KY	148	-2.26%	1.38%	2.18%	-5.69%*	-18.54%
Minneapolis-St. Paul-St. Cloud, MN-WI	149	-2.42%	-5.22%	-0.68%	0.50%	-1.00%
Seattle-Tacoma-Olympia, WA	150	-2.54%	-2.96%**	-1.46%	-0.92%	-4.41%**
Eugene-Springfield, OR	151	-2.55%	-2.54%	-1.91%		
Raleigh-Durham-Cary, NC	152	-2.56%	-4.46%**	-2.96%*	5.49%*	
Albany-Schenectady-Amsterdam, NY	153	-2.72%	-5.77%**	2.36%	1.55%	
Augusta-Richmond County, GA-SC	154	-3.21%	-6.98%		7.33%	-4.17%
Idaho Falls-Blackfoot, ID	155	-3.26%	-2.26%	-8.07%	3.47%	-6.55%**
Atlanta-Sandy Springs-Gainesville, GA-AL	156	-3.34%	-3.37%**	-2.09%	-5.47%**	0.15%
Clarksburg, WV + Morgantown, WV	157	-3.35%	-2.28%	-3.11%	-24.09%**	3.50%
Lubbock-Levelland, TX	158	-3.44%	-2.71%	-0.70%	-6.11%	-3.88%
Fresno-Madera, CA	159	-3.56%	-3.70%		3.47%	
Gainesville, FL	160	-3.68%	-18.76%**	8.11%	-0.10%	23.08%*
Harrisburg-Carlisle-Lebanon, PA	161	-3.73%	-6.76%**	4.15%	4.12%	
Sarasota-Bradenton-Venice, FL	162	-3.80%	-2.97%	-4.84%		
Wenatchee, WA	163	-3.93%	2.24%	-11.82%	-2.89%	
Wausau-Merrill, WI	164	-4.21%	4.06%	0.35%	-10.77%*	-4.96%
New Orleans-Metairie-Bogalusa, LA	165	-4.34%	-4.66%	-2.01%		
Las Vegas-Paradise-Pahrump, NV	166	-4.88%	-6.24%**	-10.75%	-3.47%	21.33%**
Marinette, WI-MI	167	-4.98%		-7.83%		3.17%
Scranton-Wilkes-Barre, PA	168	-5.07%	-10.87%		5.32%	
Miami-Fort Lauderdale-Miami Beach, FL	169	-5.10%	-5.91%**	-3.26%	13.03%**	

Tucson, AZ	170	-5.36%	-5.53%	-4.94%		
Colorado Springs, CO	171	-6.31%	-7.78%*	3.49%	-12.88%*	-9.53%*
Albuquerque, NM	172	-6.43%	-4.93%	-6.24%**	-15.69%	
San Angelo, TX	173	-6.45%	-10.35%		-1.36%	2.72%
Champaign-Urbana, IL	174	-8.83%	-10.07%	-18.96%**	-0.06%	-8.45%
Columbus-Auburn-Opelika, GA-AL	175	-10.25%	-8.01%		-22.45%	
Davenport-Moline-Rock Island, IA-IL	176	-11.92%	-15.65%	-5.53%		
Greenville, NC	177	-15.01%	5.34%**	-52.00%	7.05%	-6.78%
Amarillo, TX	178	-23.12%	-81.28%	8.99%**	3.59%	0.79%

Blank cells indicate no presence of the cluster in that type of county in the region, i.e. there are no connected Aerospace Vehicles and Defense jobs in micropolitan or rural adjacent counties in the Sacramento region.

*p<.10

**p<.05

Appendix C. Difference in Annualized Employment Growth Rate 2010-2016 between Connected and Not Connected County-Clusters, by Industry Cluster Type and by County Type

	Metropolitan	**Micropolitan**	**Remote Rural**	**Rural Adjacent**	**Grand Total**
Aerospace Vehicles and Defense	79.26%*	-6.08%**	-26.47%	2.05%	58.74%
Agricultural Inputs and Services	-0.21%	1.89%	1.12%	4.69%*	1.00%
Apparel	0.66%	1.97%	6.60%**	11.36%**	3.04%
Automotive	5.29%**	-6.28%**	12.94%**	3.56%	2.72%
Biopharmaceuticals	1.11%	-12.17%**	18.31%*	-2.88%	1.39%
Business Services	-2.27%*	0.40%	-1.07%	-5.52%**	-2.28%
Coal Mining	3.62%	1.91%	-1.45%	5.39%	2.66%
Communications Equipment and Services	1.63%	-0.79%	-4.88%**	6.44%**	0.93%
Construction Products and Services	-1.35%	5.30%	8.53%*	-3.94%**	1.10%
Distribution and Electronic Commerce	0.53%	-0.55%	2.83%*	-6.22%*	-0.72%
Downstream Chemical Products	7.82%**	13.28%	-6.96%**	2.47%	7.90%
Downstream Metal Products	-17.73%*	-2.81%	-0.98%	-4.68%*	-11.37%
Education and Knowledge Creation	-1.33%	-4.71%**	1.21%	6.66%**	-0.17%
Electric Power Generation and Transmission	0.53%	-1.06%	0.35%	2.61%	0.21%
Environmental Services	-1.11%	-0.98%	-4.70%**	4.49%**	-0.01%
Financial Services	0.95%*	0.49%	0.27%	1.33%	0.79%
Fishing and Fishing Products	-0.47%	2.66%*	12.33%**	9.29%**	2.47%
Food Processing and Manufacturing	-6.72%**	-4.24%**	1.00%	3.67%	-3.62%
Footwear	5.14%**	2.33%	2.08%	-1.33%	3.92%
Forestry	1.61%*	-0.54%	0.71%	5.01%**	1.92%
Furniture	0.09%	6.30%**	11.12%**	3.89%	3.05%
Hospitality and Tourism	-0.11%	0.54%	2.90%**	1.77%*	1.07%
Information Technology and Analytical Instruments	-1.17%	0.56%	-0.58%	-0.75%	-0.67%
Insurance Services	1.37%*	1.22%	-0.88%	1.61%**	1.01%
Jewelry and Precious Metals	1.83%*	3.74%	-0.99%	7.94%	2.16%
Leather and Related Products	2.62%*	2.38%	-4.21%	1.80%	1.92%
Lighting and Electrical Equipment	-1.70%	-11.38%	-10.64%	-22.76%**	-6.18%
Livestock Processing	-2.72%	-15.61%	2.42%	7.13%	-3.17%
Marketing, Design, and Publishing	0.50%	-0.48%	0.65%	1.93%*	0.78%
Medical Devices	2.52%	2.23%	-11.55%	-1.75%	1.53%
Metal Mining	-1.11%	-1.85%	14.10%**	-3.58%	0.73%
Metalworking Technology	-2.67%**	4.66%**	6.26%*	-3.36%	-0.16%
Music and Sound Recording	-0.94%	2.57%	-2.78%	2.08%	-0.73%
Nonmetal Mining	0.72%	-0.02%	5.00%**	6.52%**	1.40%
Oil and Gas Production and Transportation	2.56%	-1.63%	4.42%**	-0.89%	0.78%

Paper and Packaging	-1.32%	1.42%	1.84%	-1.28%	-0.43%
Performing Arts	1.92%*	0.84%	4.98%**	-0.04%	1.95%
Plastics	0.30%	2.28%	6.31%**	8.16%	2.55%
Printing Services	0.98%	-0.26%	2.48%**	4.13%	1.34%
Production Technology and Heavy Machinery	2.63%	4.48%**	4.41%**	4.04%	3.10%
Recreational and Small Electric Goods	-0.76%	1.79%	1.82%	-5.54%**	-0.60%
Textile Manufacturing	2.45%*	9.51%**	6.08%**	5.38%**	4.18%
Tobacco	0.42%	11.74%*	-3.51%	8.33%	2.31%
Trailers, Motor Homes, and Appliances	15.17%**	7.88%	2.09%	0.48%	9.53%
Transportation and Logistics	0.19%	-0.40%	2.97%**	2.21%	0.59%
Upstream Chemical Products	-2.06%	-1.66%	8.19%**	0.47%	-1.41%
Upstream Metal Manufacturing	0.34%	9.33%*	1.25%	2.11%	2.58%
Video Production and Distribution	-2.60%	-3.94%**	9.12%	4.34%	-0.39%
Vulcanized and Fired Materials	0.81%	2.78%	0.86%	2.71%	1.50%
Water Transportation	0.12%	9.12%*	10.28%**	2.05%	3.06%
Wood Products	-1.64%**	0.61%	4.16%**	4.33%**	0.61%

*p<.10

**p<.05

CITATIONS

2019 California Life Sciences Industry Report. California Life Sciences Association and PwC, November 14, 2018. Retrieved from http://info.califesciences.org/2019report

Barkley, D. L., Henry, M. S., & Bao, S. (1996). Identifying "Spread" versus "Backwash" Effects in Regional Economic Areas: A Density Functions Approach. *Land Economics*, 72(3): 336-357.

Castel, E., Wu, J. and Weber, B. (2011). Place Orientation and Rural–Urban Interdependence. *Applied Economic Perspectives and Policy*, 33(2):179-204.

Cortright, J. (2006). *Making sense of clusters: regional competitiveness and economic development*. Washington, D.C.: Brookings Institution.

Cumbers, J. "The Bio-Belt: Growing the Future in Rural America." *Forbes*, June 15, 2019. Retrieved from https://www.forbes.com/sites/johncumbers/2019/07/15/the-bio-belt-growing-the-future-in-rural-america/#49ba15ad5461

Dabson, B. (2019). *Regional Solutions to Rural and Urban Challenges (a review of the literature)*. LOCUS Impact Investing.

Dabson, B. (2011). Rural regional innovation: A response to metropolitan-framed place-based thinking in the United States. *Australasian Journal of Regional Studies*, 17(1).

Dabson, B., Johnson, T. G., Miller, K. K., & Robinson, D. P. (2009). *Rural–urban interdependence in Central Appalachia*. Columbia, MO: Rural Policy Research Institute.

Delgado, M., M.E. Porter, and S. Stern. (2014). Clusters, Convergence, and Economic Performance. *Research Policy*, 43(10): 1785–99.

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

Delgado, M., Porter, M. E., & Stern, S. (2016). Defining clusters of related industries. *Journal of Economic Geography*, 16(1): 1-38.

Delgado, M. & Zeuli, K. (2016). Clusters and regional performance: Implications for inner cities. *Economic Development Quarterly,* 30(2): 117-136.

DeVol, R. and Crews, J. "Most Dynamic Micropolitans." *The Walton Foundation*, February 2019.

Donahue, R., Parilla, J. and McDearman, B. "Rethinking cluster initiatives." *The Brookings Institution*, July 25, 2018.

Feser, E., & Isserman, A. (2009). The Rural Role in National Value Chains. *Regional Studies, 43*(1), 89-109.

Feser, E., Renski, H. & Goldstein, H. (2008). Clusters and Economic Development Outcomes: An Analysis of the Link Between Clustering and Industry Growth. *Economic Development Quarterly*, *22*(4), 324–44.

Florida, Richard. "The Divides Within, and Between, Urban and Rural America." *CityLab*, September 18, 2018.

Gallup, J., Sachs, J., & Mellinger, A. "Geography and Economic Development." International Regional Science Review 22, no. 2 (August 1999): 179–232. doi:10.1177/016001799761012334.

Glaeser, E. (2010). *Agglomeration Economies*. University of Chicago Press.

Growth and Diversification Plan GO Virginia Region 2. July 2019, Prepared by the Virginia Tech Office of Economic Development. Retrieved from https://econdev.vt.edu/content/dam/econdev_vt_edu/govirginia_documentation/GOVA%20REVISED_GD_Plan_FINAL%208.22.19.DOCX.pdf

Hall, C. “Operations in Flight: How Drones Are Revolutionizing Transportation and Logistics.” *Supply Chain Brain*, March 26, 2019. Retrieved from https://www.supplychainbrain.com/blogs/1-think-tank/post/29505-keeping-operations-in-flight-how-drones-are-revolutionizing-transportation-and-logistics

Hall, S. A., Kaufman, J. S., & Ricketts, T. C. (2006). Defining urban and rural areas in U.S. epidemiologic studies. *Journal of urban health: bulletin of the New York Academy of Medicine, 83*(2): 162–175.

Hirschman, A. (1958). *The Strategy of Economic Development*. New Haven: Yale University Press.

Hughes, D. W., & Holland, D. W. (1994). Core-Periphery Economic Linkage: A Measure of Spread and Possible Backwash Effects for the Washington Economy. *Land Economics*, 70(3): 364-377.

Irwin, E. G., K. P. Bell, N. E. Bockstael, D. A. Newburn, M. D. Partridge, and J. Wu. (2009). The Economics of Urban-Rural Space. *Annual Review of Resource Economics*, 1:435-462.

Jaffe, A., Trajtenberg, M., & Henderson, R. (1993). Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *The Quarterly Journal of Economics*, 108(3): 577-598.

Jones, S. “Telling Rural People to Move Won’t Solve Poverty.” *The New Republic*, January 23, 2018.

Ketels, C. (2017). *Cluster Mapping as a Tool for Development.* Harvard Business School Institute for Strategy and Competitiveness.

Ketels, C.H.M. and Memedovic, O. (2008). From clusters to cluster-based economic development. *Int. J. Technological Learning, Innovation and Development*, 1(3): 375–392.

Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy*, 99(3): 483-499.

Lewin, P., Weber, B., & Holland, D. (2013). Core-periphery dynamics in the Portland, Oregon, region: 1982-2006. *The Annals of Regional Science*, 51(2), 411-432.

"Life Sciences Cluster and Aggie Square." PowerPoint presentation, Greater Sacramento Area Economic Council, 2019.

Malizia, E. E., & Feser, E. J. (1999). Understanding Local Economic Development. *Rutgers, NJ: Center for Urban Policy Research.*

Markusen, A. (1999) Fuzzy Concepts, Scanty Evidence, Policy Distance: The Case for Rigor and Policy Relevance in Critical Regional Studies. *Regional Studies*, 33(9), 869-884.

Marshall, A. (1920). *Principles of Economics; an Introductory Volume*. London: Macmillan.

Martin, R.L. & Sunley, Peter. (2003). Deconstructing Clusters: Chaotic Concept or Policy Panacea? *Journal of Economic Geography*, 3: 5-35.

Martin, S. (2011). *"Critical Linkages: Strengthening Clusters in Urban and Rural Oregon," in Toward One Oregon: Rural-Urban Interdependence and the Evolution of a State*. Oregon State University Press. Corvallis.

May, G. "UC Davis' Aggie Square Can Lead to Regional Prosperity." *Comstock's Magazine*, last accessed January 2020.

Mayer, H., Habersetzer, A. & Meili, R. (2016). Rural—urban linkages and sustainable regional development: The role of entrepreneurs in linking peripheries and centers. *Sustainability*, vol 8.

Mayer, H. and Provo, J. (editors). *Farmshoring in Virginia: Domestic Outsourcing Strategies for Linking Urban and Rural Economies in the Commonwealth of Virginia*. VA Tech, Urban Affairs and Planning, April 2007.

Mazur, M. and Wiśniewski, A. “Clarity from above: A PwC global report on the commercial applications of drone technology.” *PwC*, May 2016.

McFarland, C. “Bridging the Urban-Rural Economic Divide.” *National League of Cities*, 2018.

Myrdal, G. (1957). *Economic Theory and Underdeveloped Regions*. London: Gerald Duckworth.

Nolan, C., Richey, T., & Convover, J. (2007). Applying Cluster Insights in a Rural Region. *INContext*, 8(4). Retrieved from http://www.incontext.indiana.edu/2007/april/1.asp

Parker, K., Menasce Horowitz, J., Brown, A., Fry, R., Cohn, D., and Igielnik, R. “What Unites and Divides Urban, Suburban and Rural Communities.” *Pew Research Center*, May 22, 2018.

Partridge, M. D., Rickman, D. S., Ali, K., & Olfert, M. R. (2008). Lost in space: population growth in the American hinterlands and small cities. *Journal of Economic Geography, 8*(6): 727-757.

Perroux, F. (1950). Economic Space: Theory and Applications. *The Quarterly Journal of Economics*, 64(1: 89–104.

Piore, M. J. & Sabel, C. F. (1984). *The Second Industrial Divide*. New York.

Porter, M. (2000). Location, Competition and Economic Development: Local Clusters in a Global Economy. *Economic Development Quarterly*, *14*(1), 15-34.

Porter, M.E. (2003). The Economic Performance of Regions. *Regional Studies*, 37(6-7): 549-578.

Porter, M. E. (1998). Clusters and the New Economics of Competition. *Harvard Business Review*, 76(6): 77–90.

Porter, M. E. (1990). *The Competitive Advantage of Nations*. New York: Free Press.

Rasker, R., P.H. Gude, J.A. Gude, J. van den Noort. (2009). The Economic Importance of Air Travel in High-Amenity Rural Areas. *Journal of Rural Studies*, 25(2009): 343-353.

Ratcliffe, M. Burd, C., Holder, K., & Fields, A. (2016). *Defining Rural at the U.S. Census Bureau*. U.S. Census Bureau.

Richardson, T., Anderson, I., Levy, S. & Denight, L. *2019 U.S. Life Sciences Clusters: Markets Positioned for 'The Century of Biology.'* CBRE Research, Q4 2018.

Rosenthal, S. S. & Strange, W. C. (2001). The Determinants of Agglomeration. *Journal of Urban Economics*, 50(2): 191-229.

"Rural-Urban Connections Strategy (RUCS)." *Sacramento Area Council of Governments*, 2008. Retrieved from Sacago.org/rural-urban-connections-strategy

"Smart Quadcopters Find their Way without Human Help or GPS." *Defense Advanced Research Projects Agency*, June 28, 2017. Retrieved from https://www.darpa.mil/news-events/2017-06-28

Searls, K. (2011). "Pilot Study: Estimating Rural and Urban Minnesota's Interdependencies." *Minnesota Rural Partners, Inc.*

UC Davis. *Request for Proposals for the Development of Aggie Square Phase 1: A New Innovation District*, UC Davis Sacramento Campus, September 13, 2019.

United States Department of Agriculture. "Rural-Urban Commuting Area Codes." Retrieved from https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes/

U.S. Cluster Mapping Project, Institute for Strategy and Competitiveness, Harvard Business School. Retrieved from http://clustermapping.us

Williamson, J. "Covington beats out California, Florida for drone command, control center." Published in *WSLS News* on October 8, 2019. Retrieved from https://www.wsls.com/news/2019/10/08/covington-beats-out-california-florida-for-drone-command-control-center/

Wolman, H., & Hincapie, D. (2015). Clusters and Cluster-Based Development Policy. *Economic Development Quarterly*, 29(2).