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Economic Structure in Appalachia's Urban Regions: Clustering and Diversification Strategies

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The original version of this report will soon be available on the Appalachian Regional Commission website under the "Research and Data" tab.

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ECONOMIC STRUCTURE IN APPALACHIA'S URBAN REGIONS

Clustering and Diversification Strategies

Abstract

In support of economic development practitioners' efforts to devise strategies that can align with both industrial clustering and industrial diversification, this report provides a wide range of relevant measures and metrics. In addition to standard regional analysis tools like coefficients of specialization, location quotients, and growth rates, we introduce two fundamentally new measures for understanding the nature of regional clusters. These measures focus on the industries that anchor the clusters and characterize their strength and regional dominance. The former measures the share of the anchor industry's direct and indirect requirements that could be satisfied by regional industries, and the latter measures the share of the regional economy that is potentially oriented to the cluster anchor. We then apply an algorithm that identifies anchors and industries that might be further developed to strengthen the region's industrial clusters. The design of the analysis commonly leads to the identification of different clusters, and thereby points to opportunities to strengthen within and diversify across clusters. Results of these analyses for all 120 micro- and metropolitan regions wholly within the Appalachian region are reported in the supplements to this methodological overview.

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Executive Summary

Virtually every economic development plan begins with a comprehensive description of the target regional economy. Industries do not exist in isolation, nor do regions. Interindustry relationships play a key role in industrial production activities and in industrial location decisions, where the co-location of other activities in the industrial supply chain can represent substantial cost savings and enhance profitability. Indeed, this concept underlies much of recent economic development strategy formation as evidenced by the recent dominance of industrial clustering strategies. While not a new concept, industrial clustering strategies gained focus among academics and practitioners alike with Porter's resurrection of its conceptual framework and the formalization of geographical economics by Krugman et al. in the 1990s (Porter, 1996; Krugman, 1991).

Volumes have since been written on cluster identification and agglomeration economies in the years since. Yet, somewhat lost amid the focus on agglomeration economies and industrial clustering is the historically dominant alternative strategy centered on industrial diversification. This strategy emphasizes the regional economic benefit of a diversified regional industrial structure. The foundation of the industrial diversification strategy is that as regions become more specialized in a small number of industrial activities the negative regional economic consequences of economic downturns in specialized industries also become more pronounced. These two economic development strategies, then, would seem to be mutually contradictory.

Some of those who have recognized the tension between clustering and diversity have discussed the possibility for diversifying specializations within a regional economy by strengthening specializations within diverse clusters. Desrochers and Sautet (2008, p. 814), for example, suggest "that the regional setting most conducive to entrepreneurial activity is probably a diversified city made up of many specialized clusters," and, according to Malizia and Feser (1999, p. 92), contrary to the view that diversity is defined by the absence of specialization, "economic diversity is the presence of multiple specializations," adding that "The economic diversity of a city can be defined in reference to its specializations. As additional relatively independent specializations co-locate, the area becomes more diverse. Economic diversity is the presence of multiple specializations."

In line with these positions, Jackson (2015) presented a Cluster and Diversification Strategy (CADS) procedure that can contribute to the identification of one or more industry cluster anchors – industries that sit at the heart of a region's industrial clusters – in a way that the identified industries would be likely to anchor different clusters. This project implements the CADS procedure for all 120 micro- and metropolitan regions wholly within the Appalachian Region. Along the way, we generate and provide an informational foundation for regional economic development professionals to use in developing strategies consistent with clustering, diversification, or a hybrid approach that attempts to reduce the tension between competing concepts. All good development policies and programs should be founded on a solid understanding of existing regional industrial economic structure.

Specifically, our analyses address all of the following questions for all 120 regions:

- Which regional industries are regionally dominant?
- Which regional industries are growing, and which are in decline?
- Is my region's industrial base specialized or diverse relative to other economies?
- Which clusters are important to the region, and which are becoming more and less so?
- How strongly linked are my regions' industries?
- How well are regional industries supplied by other regional industries?
- Which regional industries depend on other regions for their direct and indirect supply chain support?
- Are the regional anchor industries present in the region specialized within a single cluster, or are the region's clusters diversified?
- Where the region is less than self-sufficient, which industries are responsible for the deficits?
- How do regional supply surpluses and deficits change as additional anchor industries are identified and added to the analysis?
- In which industries could further development most strengthen intraregional linkages in the regions' key clusters and anchor industries?

Each region-specific chapter in the four Supplemental Documents to this report begins with a description of one of the micro- or metropolitan regions fully within the Appalachian Region. Regional area and population are reported along with fundamental employment trend statistics. We identify the region's largest employers by industry and report the 2018 Coefficient of Specialization to characterize overall regional specialization. The top ten growth industries are identified and presented along with their location quotients and regional shift measures.

We then describe the industrial structure of the region by presenting statistics for 17 industry clusters. We report 2005 and 2018 cluster location quotients along with 2018 cluster employment levels. Then, to assist in identifying outliers, we also present cluster traits visually to focus attention on clusters that dominate in terms of employment and those that are concentrated and thereby imply a specialization and revealed regional comparative advantage relative to the nation. A CADS analysis completes the regional analysis. CADS reveals the region's cluster anchor industry or industries and identifies potential supply-chain bottlenecks. The bottlenecks occur in industries that can represent development potential for the regional economy, depending on the location theoretic requirements of the bottleneck industries. In this sense, the deficit industries become candidate industries for economic development.

It is the nature of extensive analyses that the analytical results will be more useful for some regions than for others. Further, quantitative analyses based on secondary data can and should always benefit from the addition of local knowledge and expertise of development professionals deeply familiar with the region for the qualification of some subset of analytical results. Despite the need for such additional steps when formulating development policies, programs, or decisions, the information provided in the region-specific analyses provides a wide range of otherwise unavailable and important contextual information and descriptions of supply chain relationships and regional economic structure that can be used to guide regional decisions effectively and efficiently.

1. Introduction

Regional economic development strategies have historically fallen into two general camps: industrial diversification and industrial clustering. Each of these strategies reflects the underlying assumption that the fortunes of regional economies are tied closely to industrial structure. Diversification strategies guard against excessive dependence on one or a few industries that all might suffer simultaneously from an economic downturn, even if that downturn is limited to a certain sector of the economy. Diversification proponents caution against putting all of a region's employment eggs in too few industry baskets and believe there can also be benefits to employment growth from following the strategy of developing industries whose fortunes are not tied strongly to one another. In contrast, industrial clustering strategies focus on the advantages of co-locating industries that are strongly interrelated in terms of purchases and sales. Synergistic co-location advantages include minimizing transactions costs, and even extend to the benefits of proximity in providing troubleshooting or product improvement feedback to industries in the same supply chain.

Volumes have been written describing theoretical expectations and evaluating empirical regularities to strengthen one approach or another. From an intuitive standpoint, however, it seems clear that a tension exists between a strategy that promotes industrial diversity and another that promotes the kind of synergistic co-location that results in regional economic specialization focused on an industrial cluster. How can decision-makers and analysts balance this seeming contradiction?

This report adds to a companion set of extensive shift-share (SS) based regional analyses to aid regional decision-makers in developing a deeper understanding of their regional industrial structure and performance. SS is a useful descriptive tool that provides a wealth of information on regions, aspects of their industrial structure, and characteristics of regional industries. The SS method, however, is not capable of assessing relationships among co-located industries. The method on which this report is based is aimed at incorporating these interindustry linkages that are critical to the analysis of industry clusters.

There is frequent discussion among development practitioners and analysts on the advisability and risks of "picking winners" for regional economic development. While this report takes no position on the debate, analyses of urban economic regions and their industrial structure can support those on either side of the debate by illuminating the interdependencies among regional industries and identifying those that are likely producing surpluses available for external markets, those that are likely to be oriented to supplying other industries within the same region, and those that are likely underrepresented in the region relative to specific supply chain linkages.

The next section provides an overview of the cluster and diversification strategy approach and is followed by a description of the measures and metrics used in selecting cluster industry anchors. Section 4 provides details on the evaluation of regional industrial structure objectives and procedure, and Section 5 describes the content of each region-specific analysis in the Supplemental Document. Section 6 provides concluding comments. Region-specific reports are provided in the Reports Supplement to this document.

2. Cluster Assessment and Diversification Strategy Overview

The approach and methods on which this report is founded follow on the introduction of a Cluster Assessment and Diversification Strategy (CADS) in Jackson (2015), where interested readers can find a more comprehensive overview of related academic literature. This report first describes the CADS conceptual framework at a highly general level and adds the additional analytical tools and evaluation criteria needed for empirical application.

In general terms, the CADS analysis

- selects an industry or set of industries from a study region to be the anchors of one or more clusters,
- identifies corresponding activity levels for the selected industry or industries,
- determines the necessary distribution and production levels of supporting industries to fully support these anchors at these production levels,
- assesses the sufficiency of the supporting industrial distribution, and
- provides potentially actionable information for decision makers.

These steps combine to identify primary and additional regional industry clusters so that opportunities and motivations for strengthening the industrial structure to support any of them can be identified explicitly and quantified. Developers can choose to strengthen primary clusters by focusing on strengthening supporting industries, or should they choose to diversify their economies, they can focus on strengthening anchors and supporting industries that belong to different industrial clusters. The selection of anchor industries and support-worthy anchor-linked industries can be guided by the results of the extensive analysis, but ultimately should be identified by the analyst based on conditions in the region and an assessment of regional comparative advantage.

While the general framework and key analytical components of CADS have been established, CADS application requires additional metrics and procedures for prioritizing the selection of industry anchors. In the next section, we describe the details of the implementation apparatus we use in generating the reports for the Appalachian study regions.

3. Selecting Industry Anchors

Industrial clusters, as the name suggests, are groups of interrelated industries. We use the term *anchor* to refer to the industry around which a given cluster appears to be centered. In terms of interindustry sales and purchase relationships, or supply chain linkages, industries further downstream in the supply chain will generally have stronger backward linkage potential.
In selecting anchors, we seek to identify industries that meet a number of desirable conditions. We would prefer to select as candidate anchor industries, for example, industries that are sizable and growing, industries that are well supported by supply-chain relationships in the regional economy, and those that have demonstrated viability in terms of some level of regional comparative advantage. The following metrics are used in this CADS implementation. Appendix A provides the mathematical formulations for all of these metrics.

Anchor Industry Strength

Anchor industry strength (AS) is defined as *the share of its direct and indirect requirements that could be provided by the region's industries* if it were the region's only anchor industry. The total regional output from other industries that could be used to meet the selected industry's direct and indirect requirements are divided by its direct and indirect requirements from other industries. The extent of supporting infrastructure for the industry in question is defined by the existence and production levels of input-supplying industries (the *direct* linkages to suppliers), but also the suppliers' suppliers, their suppliers, and so on. This latter set of linkages is called the *indirect* linkages. Direct and indirect linkages are derived from input-output accounts generally,[1] and specifically from a table of national technical coefficients.[2]

An industry whose regional supporting industry infrastructure is fully capable of supplying all of its direct and indirect requirements will have an AS measure of 1.0, and an industry in a region that can support none of its requirements will have an AS measure of zero. In addition to industry specific measures, AS averages by region are reported in Appendix C. AS by industry will not sum to one because each AS is assessed as though no other anchors were competing for regional industry output. This will not be the case in the CADS analysis where one or more anchors are assessed simultaneously.

[1] Direct and indirect linkages also are the foundations for the kinds of economic multipliers that are commonly seen in economic impacts assessments.
[2] The estimates of interindustry linkages throughout the report implicitly assume that when industry A requires inputs produced by industry B, and both industries are present in the region, that establishments in industry B produce the specific goods or services that A requires. This is likely to result in upper bound estimates of the actual interindustry supply-chain transactions. This explains the reason for the qualifying wording, "output from other industries that *could* be used to meet the selected industry's requirements."

Anchor Industry Dominance

The anchor industry dominance measure is similar to anchor industry strength but is defined as *the share of regional output that could be devoted to supporting a given anchor industry* if it were the region's only anchor and operating at its current level of production. Dominance is used as a measure of each industry's overall importance to the regional economy in terms of driving the demand for regional production. Once an anchor industry's direct and direct input requirements have quantified, they are compared to the availability of those inputs from supplying industries in the region. Some or all of each industry's current production is then counted as available support for the selected industry. The total of all supporting production and the industry's own output is then divided by total regional production in all industries to obtain the dominance measure.

If a region's industries produced precisely but no more than the level of output directly and indirectly required as inputs by the selected industry, then its dominance measure would take on the maximum value of 1.0. The minimum dominance value would be zero if the selected industry were entirely absent from the region. In practice, with a small number of exceptions, few industries dominate the market for the product of all other regional industries. The average anchor dominance measure by industry (across all regions) is listed in Appendix B. The average of these values is small, at 0.01. However, this average is well above the average industry share of the economy (1/181 = 0.0055) and some industries AS values reach levels as high as 0.79 (Motor Vehicle Manufacturing in Talladega-Sylacauga, AL).

The maximum AD values by region are reported in Appendix C. Due to the dominance of small-valued AD measures, minimum values, averages, and other descriptive statistics are of little value and are therefore not reported. Average AD values across all 120 regions are included in Appendix B.

Anchor Industry Regional Specialization

An examination of the entire national economy reveals its industry's shares of total economic employment (or output, or other similar industry-specific value). Each industry share of total is an average value that can be used as the expected industry share for any subnational region in the absence of additional information. If an industry's observed share of total regional employment exceeds its expected value, then the implication of this relative concentration is that the region exhibits some level of specialization in that industry. Carrying the relationship one step further, areas that are increasing in concentration and specialization are assumed to have some degree of comparative regional advantage.

The industry location quotient (LQ) measure formalizes this assessment by dividing the observed industry share of regional total by the corresponding industry share of national total. When this value is greater than 1.0, the region exhibits some specialization and according to this interpretation, while industry LQ values less than 1.0 suggest regional underrepresentation. Larger LQ values also imply some degree of regional comparative advantage, in that their greater than expected regional presence suggests that they are better able to operate in the region in question than in regions where they are less concentrated.

Industry Growth Rates

The regional analyses reported here are based on commercial compilations of Bureau of Labor Statistics (BLS) Census of Employment and Wages data for two time periods, 2005 and 2018 (see the Data section, below). Growth rates of interest include the overall growth rates for the national and regional economies, and growth rates by industry at the national and regional levels. All else equal, industries that are growing faster in the region than in the nation, and those that are growing at rates near to or exceeding the overall national growth rate would be preferable to those that are growing more slowly or even declining nationally. Using employment growth rates rather than absolute changes in employment levels enables a comparison to national counterparts.

We use industry-specific growth rates in a way that directly related to a concept drawn from SS analysis, where the regional shift variable that is often interpreted as reflecting regional comparative advantage. In SS analysis, the regional shift is defined as an industry's employment in an earlier period multiplied by the difference between the industry's growth rates in the region and the nation. When the regional industry grows faster than its national counterpart, the industry's regional shift is positive, indicating better regional than national growth.

Employment Size

When considering the advantages of regional industry clusters from an economic development perspective, it seems clear that one would be hesitant to select as a cluster anchor industry that is relatively quite small, or one that is quite small in absolute terms. If employment in an industry has not grown organically to some substantial size, then it has yet to provide evidence of a high degree of economic viability in the region. The data we use provides detail for regional economies classified into 181 industries. Returning to the concept of an expected value, and given no supplementary information, the average industry size will be 1/181 = 0.55% of the regional economy. However, using this average employment size constraint value resulted in many regions having more and smaller identified anchors and clusters than was deemed useful, to the lower limit on employment size was increased to 1% of regional employment.

Eligibility

A region's industries are often classified as tradable and non-tradable. In general terms, tradable industries are those that are exposed to competition from other regions, and the others are non-tradable. This distinction, which appears to represent a binary choice, is not as clear-cut as it might initially appear and has given rise to a wide-ranging discussion by economists, most of whom would agree that industries lie on a continuum from tradable to non-tradable, and that one might find some activities within an industry that are tradable and others not. Among the many examples, tailors in most regions would be considered to be non-tradable, yet there are those who travel to fashion centers for certain kinds of tailoring services. Construction is another example, where virtually all industry output is non-tradable, but there are specialized construction services that are very clearly tradable.

Tradability and non-tradability are strongly related to spatially concentrated and spatially dispersed. Those activities that are spatially dispersed and generally available anywhere are typically non-tradable, and almost always include industries in personal services and a select few others. Spatially concentrated industries are generally tradable, so the LQ measure we employ in this analysis effectively, which will generally be close to 1.0 for non-tradable goods, excludes industries normally considered to be non-tradable from the set of industries that are eligible for anchor industry status. Indeed, the only typically non-tradable industries that were identified as anchors in the analysis of the 120 study regions were *Government and unclassified* and *Elementary and secondary schools.* For the purposes of our analyses, then, these two industries were excluded from the set of anchor industry candidates.

Data

The data we use are based on 2005 and 2018 employment and wages data originally compiled and published by the Bureau of Economic Analysis in their Census of Employment Wages (CEW). CEW data, however, contain a number of undisclosed values, and these missing values are imputed by the third-party data source from whom we purchased the data (IMPLAN Group, LLC). In addition to CEW data, the BLS publishes the input-output accounts that we use in our estimations of productivity, anchor strength, and anchor dominance. Ancillary data on population, labor force, areal extent, etc., are all drawn from the U.S. Census.

In all, our analysis uses 181 industries and 17 parent clusters. A list of the 181 industries and the clusters to which they belong is included as Appendix B. The 17 regional industry clusters are shown in Table 1, below.

Table 1. Cluster Names and Numbers

#	Cluster Name	#	Cluster Name
1	Agribusiness, Food Processing and Technology	10	Energy (Fossil and Renewable)
2	Apparel and Textiles	11	Forest and Wood Products
3	Arts, Entertainment, Recreation and Visitor Industries	12	Information Technology and Telecommunications
4	Biomedical/Biotechnical (Life Sciences)	13	Machinery
5	Business and Financial Services	14	Mining, Glass and Ceramics
6	Chemicals and Chemical-Based Products	15	Primary and Fabricated Metal Products
7	Computer, Electronic, and Electrical Products	16	Transportation and Logistics
8	Defense and Security	17	Transportation Equipment
9	Education and Knowledge Creation	0	No Cluster

4. Evaluating Regional Industrial Structure

4.1. Objectives

The primary goal of these regional assessments is to provide useful information to regional decision makers that can help in formulating industry recruitment and retention policies and programs, and in addressing physical and programmatic infrastructure support for regional economic development. We accomplish this task by implementing the CADS analyses. CADS identifies important regional industries and clusters and deficits in supply-chain based regional industrial support. These deficits represent gaps in the local interindustry support infrastructure that, if filled, would strengthen the clusters by capturing larger portions of industry supply chains within the regions. Filling these gaps, in turn, will increase regional economic multipliers by substituting regional production for imports and spin-off types of developmental impacts of the clusters and their member industries. Likewise, regional decision-makers might choose physical infrastructure enhancements specifically to support establishments that CADS identifies as among the region's most important industries. Regions also might find value in regional branding consistent with CADS findings.

Because CADS is being implemented extensively, i.e., for all 120 ARC micro- and metropolitan regions wholly within the Appalachian Region, it was beyond the scope of the project and resources to provide a detailed focus on each region. Thus, the list of identified deficit industries will invariably include some that are poorly represented because they are ill-suited to the region in question for location theoretic reasons. Some industries, for example, require certain types of utilities infrastructure (e.g., large volumes of water or high voltage electric lines) that are unavailable locally, and others will be localized to the availability of certain natural or human resources. Nevertheless, the employment and output gaps can still provide important information on supply-chain related industry viability.

As a result of the CADS procedure implementation, which will be described in greater detail below, experience with CADS suggests that secondary and subsequently identified anchors are often members of clusters not associated with the primary anchor. Thirty-two of the 120 regions analyzed have only one cluster. Of these 32 regions, 29 have only one identified cluster anchor. Seventy-five of the 120 regions have the same number of anchors as clusters, 29 have one more anchor than the number of clusters, 13 have two more anchors than clusters, and only three regions have three more anchors than clusters. This outcome supports the potential utility of CADS in devising cluster diversification strategies at the regional level. Thus, CADS provides some balance between the dual but otherwise conflicting goals of specialization and diversification.

The anchor industry selection variables described in the previous section also provide a number of regional descriptors that help illuminate regional industrial structure. The anchor industry dominance and anchor industry strength variables define regional industry importance relative to their overall size and presence of supporting industries, and these are reported for the regions' most important industries. Other industry statistics, including the industry and cluster location quotients, are also reported for highly specialized industries and for every regional cluster, respectively. Regional coefficients of specialization (COS) that provide a summary indicator of

overall regional specialization are derived from industry LQs and reported for each region, along with the regional shift summary variable (RS) derived from Shift Share analysis. Together, these variables along with selected Census data provide a compendium of measures and indicators that should be useful for regional economic development policies and programs. COS and RS are reported for all regions in Appendix C.

4.2 Procedure

The CADS algorithm requires establishing a set of critical values for each of the selection criteria. Any decision process that is based on multiple criteria will need to either engage in some form of multi-objective optimization or as is more often the case, adopt one criterion as primary and include first (or next) in the selection set the one (industry, in this case) with the highest ranked primary variable value, subject to a set of conditions that apply to the remaining criteria. CADS follows this latter approach.

The conditions that industries must meet are shown in Table 2. The analysis is sensitive to each of the conditions shown. Increases and decreases in cutoff values for the various criteria decrease or increase the numbers of identified anchor industries and clusters. When constraints are too relaxed, the numbers of industries and clusters grows too large to be useful, and when they are too tight, large numbers of regions lacked any identified anchors at all. The values displayed in Table 2 were selected following extensive assessments of various combinations of criteria and results in numbers of anchors and clusters within a range that was deemed to be of most value to the greatest number of Appalachian study regions. As a result, there are no more than eight cluster anchor industries and no more than six clusters identified for any given region.[3]

An inspection of Table 2 reveals a cutoff value of 1.2 for industry LQs. Industries with shares of regional employment equal to their corresponding national shares, (LQ = 1.0) are neither under- nor over-represented relative to expectations. In many published studies, an LQ > 1.2 implies a level of specialization in the industry. The SS based regional shift (RS) for an industry will be positive when the industry is growing faster regionally than nationally. Further, the growth rate criterion ensures that the regional industry growth rate is at least 75% as high as the overall national growth rate.

The primary criterion driving the CADS procedure is anchor industry dominance, which coincides with the intuitively appealing goal of building on a region's established strengths. Accordingly, and with the anchor candidate set identified for the region in question, CADS first finds the candidate industry with the largest dominance measure. The first selected industry anchor will therefore be the industry that most heavily dominates the regional economy, directly and indirectly, that also rises above the established threshold levels for all of the conditions.

[3] Striking this balance among anchor industry selection criteria and the numbers of clusters and anchors will inevitably make these standard CADS analyses quite interesting and informative for some regions but less so for other regions. More informative CADS results tailored to individual regions can be obtained for this latter group by evaluating the responses to modifying the anchor selection criteria.

Table 2. Anchor Industry Candidacy Evaluation Criteria

Anchor Industry Constraint Variables	Condition	Interpretation/Use
Anchor Dominance	no minimum	Primary anchor candidate selection criterion
Location Quotient	> 1.2	Some specialization
Regional Shift	> 0	Regional growth rate > national industry growth rate
Growth Rate	((4/3) * grRi) > grN	Greater than 75% of national average growth
Employment Size	> 99	At least 100 employees
Employment Share	> 1%	Larger than 1% of regional employment
Eligibility	by Assignment	Determined by conceptual justifications
Anchor Strength	no minimum	Regional supply chain requirement support

The minimum number of employees to qualify a regional industry as an anchor candidate is 100, and the industry in question must also be at least 1% of regional employment. The Eligibility requirement is the result of assignment as related to the concept of tradability discussed earlier. Anchor Strength values for each industry were computed for every region in which the industry was present in 2018. Imposing an Anchor Strength criterion to eliminate only those industries with very weak AS from anchor candidacy resulted in eliminating all industry anchors from five regions.[4] Relaxing this constraint entirely had no impact on the maximum number of anchors or clusters identified in the set of regions but restored at least one anchor to regions that otherwise would have been eliminated. Hence, this variable is not used as a constraint on anchor selection but is reported for its informational value. As a result of applying the criteria described in Table 2, regions will have differing sets of candidate anchor industries that meet all of the specified requirements.

Once a primary anchor has been identified, CADS uses the supply-chain input-output relationships to quantify the average levels of output that are required to support this first anchor at its current level of operations. Next, this set of support requirements is compared to the output available from the region's industries. This enables a determination of which regional industries are large enough to support the identified anchor. Industries that operate at levels that exceed requirements will have surplus output that can go to supporting other regional or export demands. Industries that operate at levels that fall short of requirements are categorized as *deficit* industries. Those with the largest deficits would be added to the set of candidates that, were they developed further would strengthen the industry's parent cluster, subject to location theoretic viability as discussed above.

Having identified a high priority anchor in the first phase of the analysis, phase two begins with a search for a second anchor. However, industry output that supports the supply-chain requirements for the first anchor can no longer be considered to be available for subsequently identified anchors. To account for this, the selection algorithm creates a *residual* economy from the regional industries that were determined in Phase 1 to have a surplus of output, and this

[4] However, AS values were computed for all industries and all regions. This allowed us to use the set of 120 AS values for each industry and to identify constraints that would eliminate from consideration industries whose AS values were among the smallest N% of all regional AS values for a given industry. A constraint value of 5% reduced the number of clusters to zero in 5 regions, whereas eliminating this constraint resulted in identifying at least one cluster for every micro-and metropolitan region in the analysis.

residual economy is used to compute Phase 2 dominance and anchor strength measures. The second anchor, if one exists, will be the most dominant candidate anchor industry from the residual economy that meets the other anchor industry conditions.

If and when a second anchor can be identified, CADS once again uses the supply-chain input-output relationships to quantify the average levels of required output that are required to support the first *and* second anchors at their current levels of operations. Phase 2 requirements can once again be compared to 2018 levels of industry output to identify output surplus and output deficit industries. Phase 2 deficits have the same interpretations as phase 1 deficits and identify a set of industries that are candidates for further development, again subject to location theoretic viability considerations.

The search and selection algorithm then continues based on a new set of surplus industries and associated surplus output levels, and a newly derived residual economy. If and when a third anchor is identified, Phase 3 will quantify supply-chain requirements needed for the support of the first three anchors, and the process continues until there are no remaining industries that meet all of the necessary conditions.

5. Region-Specific Reports

There are 120 micro- and metropolitan regions in the 420 county Appalachian Regional Commission region, and 120 separate region-specific reports. Each report begins with a study region overview that is intended to provide some context for the CADS analytical results that follow. With the exception of the five regions for which no cluster anchors were identified, each report then includes the following tables:

Regional Analysis Table 1. Top Ten Growth Industries
Regional Analysis Table 2. Cluster Concentrations, 2005 and 2018
Regional Analysis Table 3. Anchors, Clusters, and Employment
Regional Analysis Table 4. Anchor Industry Statistics
Regional Analysis Table 5. Deficit Industries by CADS Analysis Phase

5.1. Regional Analysis Table Descriptions

There are four Supplemental Documents accompanying this report. As a guide to interpreting these tables, we provide sample Regional Analysis Tables and discuss content and interpretation.

Regional Analysis Table 1 Content: Top Growth Industries

The industries in this table are those whose employment grew most between 2005 and 2018, irrespective of their cluster anchor eligibility status. For each the top ten regional growth industries, the table displays industry number and name, 2005 to 2018 the employment change, the 2018 Regional Shift value (the inter-period growth that cannot be attributed to overall national growth or industry-specific national growth trends), and the 2018 industry location quotient. Most industries will have experienced some employment growth during the period of analysis, but if the rate of growth was less than that observed in the corresponding national industry, then its RS value will be negative. There also is no necessary relationship between the LQ and the industry's employment change.

From this table we can see which industries have gained the largest number of employees and whether they are performing as well as or better than their national counterpart industry. Here we see from the RS values that, with the exception of the Food Services and Drinking Places industry, all of the top ten growth industries are not only growing but are growing faster than their national counterparts. Further, except for Construction, they also have larger than national average regional employment concentrations. Regionally concentrated industries appear to have benefited from regional comparative advantage in terms of employment growth.

[Sample] Regional Analysis Table 1. Top 10 Growth Industries

Industry #	Industry Name	Employment Change	RS	LQ
10	Support Activities for Mining	444	410	15.17
155	Individual and Family Services	357	134	2.36
81	Motor Vehicle Parts Manufacturing	306	306	5.35
43	Rubber Product Manufacturing	247	282	33.97
14	Construction	237	250	0.88
145	Other Educational Services	218	200	2.70
167	Food Services and Drinking Places	166	-166	1.11
154	Nursing and Residential Care Facilities	153	31	2.63
78	Other Electrical Equipment and Component Manufacturing	142	142	10.10
99	Truck Transportation	135	132	2.46

Regional Analysis Table 2 Content: 2005 and 2018 Cluster Concentrations

Location quotients can be derived for entire clusters in the same way that location quotients are derived for individual industries. Values for all industries in each cluster are summed, and their regional distributions are compared to the respective national values to generate cluster location quotients, or CLQs. Regional Analysis Table 2 lists these CLQs for all regional cluster categories for 2005 and 2018, along with 2018 employment. Clusters are presented in order of employment, high to low. Most clusters will have grown, but not all will have become more concentrated and specialized. Those clusters whose CLQ has increased, indicating increased specialization, are highlighted in blue.

[Sample] Regional Analysis Table 2. Cluster Concentrations, 2005 and 2018

Cluster #	Cluster Name	2005 CLQ	2018 CLQ	Employment
4	Biomedical/Biotechnical (Life Sciences)	1.98	1.63	2,595
3	Arts, Entertainment, Recreation and Visitor Industries	1.06	1.03	1,775
5	Business and Financial Services	0.53	0.36	1,063
6	Chemicals and Chemical-Based Products	5.99	7.03	1,060
9	Education and Knowledge Creation	2.63	2.08	1,053
16	Transportation and Logistics	1.02	0.93	1,045
8	Defense and Security	0.29	0.32	720
10	Energy (Fossil and Renewable)	1.26	5.25	583
15	Primary and Fabricated Metal Products	2.46	3.04	501
13	Machinery	5.46	4.20	450
17	Transportation Equipment	0.00	2.67	306
1	Agribusiness, Food Processing and Technology	0.41	0.45	184
7	Computer, Electronic, and Electrical Products	0.20	1.08	150
11	Forest and Wood Products	0.20	0.71	106
14	Mining, Glass and Ceramics	4.19	1.41	95
12	Information Technology and Telecommunications	0.28	0.25	26
2	Apparel and Textiles	0.00	0.00	0

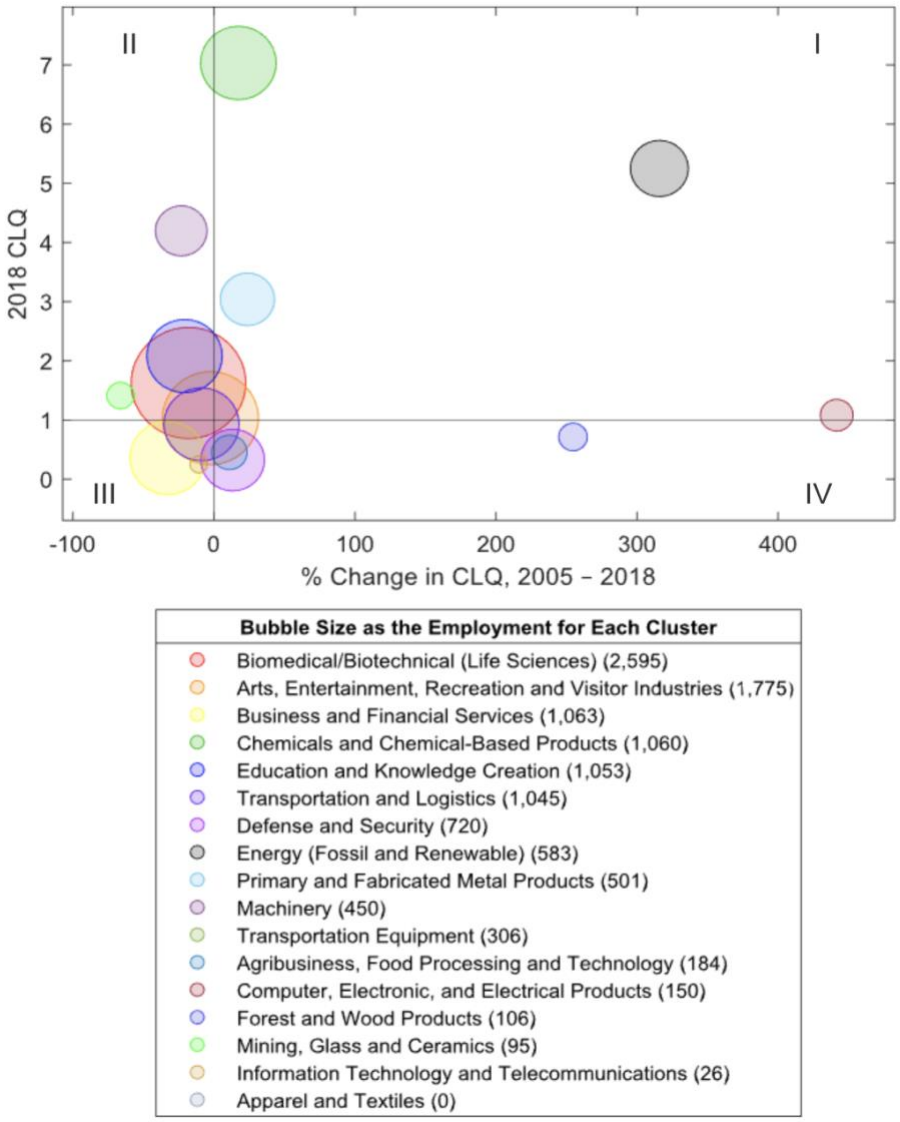
From this table, which provides a summary view of the region's industrial structure, we can identify easily which clusters are becoming more and which are becoming less concentrated, thereby playing greater or lesser roles in the fortunes of the regional economy. In this case, the three largest clusters have fallen somewhat, though not dramatically, in regional concentration. The Energy cluster, in contrast, has grown substantially more specialized relative to the national average between 2005 and 2018. The data identified two clusters that reported no employment in 2005. One of these, the Transportation Equipment cluster, added 306 employees, ultimately reaching a level of relative regional concentration, as indicated by its 2.67 2018 CLQ.

It is often helpful to present statistics like these graphically. To assist in visualizing the cluster characteristics and dynamics, each region-specific chapter also includes a CLQ bubble chart companion to the Cluster Concentrations table. In this chart, the vertical axis measures the 2018 CLQ value, the horizontal axis measures the change in CLQ from 2005 to 2018, and the size of the bubble is proportional to cluster share of regional employment. By adding a vertical line at zero change and a horizontal line at CLQ equal to 1.0, we create a four-quadrant chart, as shown in Figure 1, below. Clusters in quadrant I – Star clusters – are those that are relatively specialized in the region and have become more so during the 2005 to 2018 study period. Hence, Star clusters are both dynamic and well-suited to the region. Clusters in quadrant II – Mature clusters – are those that remain specialized but less so now than in 2005. Clusters in quadrant IV – Emerging clusters – exhibit no regional concentration, but their employment shares relative to national counterparts have increased during the study period. Clusters in quadrant III – Transition clusters – revealed no relative specialization in 2005 and even less in 2018.

The greatest value of the chart is to assist in identifying those clusters that are in some sense outliers, because the bubbles that center near the horizontal and vertical axis origins (0,1) are neither notable in terms of concentration nor in terms of recent dynamic behavior. The order of entries in the legend is determined by the size of the cluster, with the largest cluster listed first. Therefore, the first legend entry, Business and Financial Services, identifies the largest cluster bubble, making it easily identifiable in the chart. The 2018 cluster employment from Table 2 is also repeated in the legend as a visual aid for associating cluster names with bubbles in the chart. Labeling each chart bubble resulted in less rather than more clarity for most regional charts and was thus eliminated.

In many cases, readers will be generally interested to see at a glance which quadrant the largest clusters occupy. In the example chart below, we can confirm that all the largest industries are declining in concentration. Also, attention is quickly drawn to the green, gray, and maroon bubbles in quadrant I and farthest from the origin. These are clusters that are both concentrated and become more so, but which clusters are they? The green cluster is the one with the largest CLQ, so we easily see that it is the Chemicals and Chemical-Based Products cluster. The maroon bubble has a position on the horizontal axis (nearly 500%) that indicates that it has almost quintupled in relative concentration. With a CLQ slightly above 1.0 value horizontal origin line in the graph, identifying it as the Computer, Electronic, and Electrical Products industry is straightforward. The gray bubble has roughly tripled in concentration and has the second largest 2018 CLQ, clearly identifying it as the Energy Cluster. Thus, cross-referencing between the chart and Table 2 should clarify any ambiguities in identifying the outliers visually.

[Sample] Figure 1. Bubble Chart



Regional Analysis Table 3 Content: Anchors, Clusters, and Employment

Regional Analysis Table 3 begins the display of the CADS analysis results. For every identified anchor industry, the industry and cluster names are displayed along with 2005 and 2018 industry employment. The anchors are listed in the order in which they were selected according to the rules of the algorithm, so clusters to which anchors belong can appear consecutively or separated by other industries in other clusters. Anchor industries will appear only once, but because there can be more than one anchor industry selected from the same cluster, clusters can appear more than once. A Regional Analysis Table 3 consistent with the examples above is reproduced below.

[Sample] Regional Analysis Table 3. Anchors, Clusters, and Employment

Cluster #	Cluster Name	Anchor #	Anchor Industry Name	Anchor Emp. 2005	Anchor Emp. 2018
6	Chemicals and Chemical-Based Products	43	Rubber Product Manufacturing	204	451
17	Transportation Equipment	81	Motor Vehicle Parts Manufacturing	0	306
10	Energy (Fossil and Renewable)	10	Support Activities for Mining	65	509
16	Transportation and Logistics	99	Truck Transportation	264	399
15	Primary and Fabricated Metal Products	55	Architectural and Structural Metals Manufacturing	162	208

These tables present the anchor industries, the clusters to which each belongs, and the anchor industry employment in 2005 and 2018. The order in which these anchors appear in the table corresponds to the order of their selection as anchors. Industry 6, in this example, was the industry with the largest anchor dominance value that also met the remaining anchor selection criteria.

Regional Analysis Table 4 Content: Anchor Industry Statistics

Regional Analysis Table 4 provides additional information for the anchor industries of Regional Analysis Table 3. The LQ, the RS, and regional and national industry growth rates, along with Anchor Strength (AS) and Anchor Dominance (AD) values are listed for every anchor candidate selected by the CADS algorithm. Larger LQ values indicate greater regional specialization in the anchor industry. The RS shows the growth in number of employees from 2005 to 2018 after accounting for overall national trends and trends in the industry at the national level. Industries with positive RS are those identified as having some comparative advantage relative to the national economy. In regions with multiple anchors, it will be apparent that the only anchor metric that always decreases monotonically is AD, reflecting its role as the primary selection variable. AD and AS values range from 0 to 1, and anchors with larger values indicate more dominant and better supported industries, respectively, than anchors with smaller values.

[Sample] Regional Analysis Table 4. Anchors, Location Quotients, Regional Shift, and Growth Rates

				Industry Growth Rate (%)	Industry Growth Rate (%)		
Anchor #	Anchor Industry Name	LQ	RS	National	Regional	AS	AD
43	Rubber Product Manufacturing	33.97	282	-17.19	121.20	0.75	0.08
81	Motor Vehicle Parts Manufacturing	5.35	306	-11.56	N/A	0.65	0.08
10	Support Activities for Mining	15.17	410	52.54	683.08	0.79	0.08
99	Truck Transportation	2.46	132	1.19	51.14	0.83	0.04
55	Architectural and Structural Metals Manufacturing	5.51	48	-1.47	28.40	0.77	0.03

The average AD value is 0.009, which, while small, is nearly twice the size of the average industry share of the economy (1/181 = 0.0055). The small average value is somewhat misleading, however, because the corresponding population of AD values includes all industries in all regions and there are numerous industries with zero or very small numbers of employees in most regions. The maximum industry AD value for any region is no smaller than 0.086 and no larger than 0.791, with an average of 0.234 and a median of 0.190.

A sample Regional Analysis Table 4 consistent with prior examples above is reproduced below. The AS values for each of these anchor industries is well above the 0.55 average, indicating that these industries are already quite well supported in the region, and that we might not expect to see substantial direct and indirect input material deficits identified in the CADS analysis results. The first three anchors identified also each have AD values roughly eight times the overall average, indicating that they are substantial drivers of regional economic activity. In theory, these five anchors could account for as much as 31% of the region's industrial production.[5]

Remaining Regional Analysis Tables: Deficit Industries by CADS Analysis Phase

The remaining Regional Analysis tables provide information on which industries are underrepresented in anchor industry or industries supply chain(s). These underrepresented industries are those whose expansion would most strengthen the regional anchor industry or industries in terms of supply chain requirements. Phase 1 results identify employment deficits by industry for the first anchor operating at existing levels of production.[6] If a second anchor is identified, i.e., if there is a second industry in the residual economy that results after extracting the first anchor and its associated regional supply chain, then Phase 2 results identify deficit industry output and employment for the first *two* industries combined, operating at their existing levels of production. If a third anchor is identified, then Phase 3 results identify deficit industry output and employment for the first *three* industries combined, operating at their existing levels of production, and so on for the addition of each new anchor. The Employment column of the phase results tables are cumulative.[7] Hence, a value of N/A appearing in deficits tables indicates that although it will take on a value in subsequent phases, as of the reported phase the corresponding industries are not in deficit.

[5] The AD values correspond to the proportion of the anchor's direct and indirect requirements that could, in theory, be locally (regionally) sourced. Considerations such as product mix mismatch within each of the 181 industries likely lowers the actual regional supply proportion. To clarify, consider industry 81, which has more than one subsector. Subsector 81A might produce metal motor vehicle parts while subsector 81B might produce plastic motor vehicle parts, and subsector 81C all other motor vehicle parts. The presence of a manufacturer in subsector 81A will be recorded in industry 81 without distinguishing its subsector. Thus, there is some uncertainty inherent in the industry classification scheme that implies a greater than actual ability to meet the demands for output from industry 81.

[6] Employment deficit values are based on the IO generated output deficits and output per employee averages. Average output per employee values by industry are based on national averages because comparable estimates for BLS industries for the Appalachian region are unavailable.

[7] Although the results for successive analysis phases are cumulative, the results for anchors assessed sequentially are not strictly additive because in the independent sequential analyses, only one industry's activity (output) levels are exogenously specified, whereas in subsequent phases, each anchor's output levels are fixed.

At each phase, we select no more than the top ten deficit industries (there could be fewer if there are fewer than ten deficit industries for an analysis Phase) to add to the potential set of reported industries at each phase. To aid in interpretation and focus on results of appreciable size, we eliminate from the potential set those small-deficit industries whose employment deficits are less than ten in the final analysis phase. Results for industries remaining in the reporting set are reported in the results for all phases. Sample deficit tables are shown below.

[Sample] Regional Analysis Deficits by Phase Tables

Based on the results in Sample Table 5 below, the industry least well positioned to support the region's first anchor, industry 43 (Rubber Product Manufacturing) is industry 26 (Textile Mills and Textile Product Mills). After adding the second anchor industry (81 Motor Vehicle Parts Manufacturing) to the anchor set, the supply chain support deficit in industry 26 shown in Sample Table 6 increases by only 5 employees to output that could be produced by 41 Textile workers, based on national average output per worker in this industry. Because we also know from the last column in Sample Table 6 that the largest addition to deficits is actually observed in industry 59. Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing. Indeed, for the support of these two industries combined, the largest support deficit corresponds to industry 59, which would need a combined total of 47 new workers to satisfy the two industries' total direct and indirect supply chain input requirements.

[Sample] Table 5. Phase 1 Deficits for Anchor Industry 43

Rubber Product Manufacturing

Industry #	Industry Name	Employment
1	Crop Production	-15
3	Forestry and Logging	-18
26	Textile Mills and Textile Product Mills	-36
27	Apparel, Leather and Allied Product Manufacturing	-1
52	Foundries	-1
53	Forging and Stamping	-4
59	Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	-5
60	Coating, Engraving, Heat Treating, and Allied Activities	-7
72	Semiconductor and Other Electronic Component Manufacturing	-11
104	Warehousing and Storage	N/A
129	Management, Scientific, and Technical Consulting Services	N/A
133	Management of Companies and Enterprises	-13

Whether the values in the Added to Deficit column of Table 6 are large or small depends on the region's industrial structure. When there are substantial added deficits for phase results, the largest (negative) values are associated with the industries that are least able to supply the direct and indirect input requirements of the newly identified industry anchor. When the added deficits are relatively small, we learn that the added anchor industry is already well-supported by the region's industrial structure.

[Sample] Table 6. Phase 2 Deficits Adding Anchor Industry 81

Motor Vehicle Parts Manufacturing

Industry #	Industry Name	Employment	Added to Deficit
1	Crop Production	-18	-2
3	Forestry and Logging	-19	-1
26	Textile Mills and Textile Product Mills	-41	-5
27	Apparel, Leather and Allied Product Manufacturing	-12	-11
52	Foundries	-31	-30
53	Forging and Stamping	-18	-14
59	Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	-47	-42
60	Coating, Engraving, Heat Treating, and Allied Activities	-17	-10
72	Semiconductor and Other Electronic Component Manufacturing	-37	-26
104	Warehousing and Storage	-10	-25
129	Management, Scientific, and Technical Consulting Services	-7	-10
133	Management of Companies and Enterprises	-43	-29

6. Summary

Developing a strong foundation for economic development planning and programs requires a thorough and comprehensive understanding of the region's economy. Which activities are dominant? Which regional industries are growing, and which are in decline? Is my region's industrial base specialized or diverse? What is the industrial structure in my region? Which clusters are important to the region, and which are becoming more and less so? How strongly linked are my regions' industries? How well are regional industries supplied by other regional industries, both directly and indirectly, and which depend on other regions for their direct and indirect supply chain support? Are the regional anchor industries specialized within a single cluster, or are the region's clusters diversified? Where the region is less than self-sufficient, which industries are responsible for the deficits? How do regional supply surpluses and deficits change as additional anchor industries are identified and added to the analysis? In which industries would further development most strengthen intraregional linkages in the region's key clusters and anchor industries?

The region-specific analyses in the four Supplemental Documents that accompany this report address each of these of these questions. Each report begins with a description of one of the micro- or metropolitan regions fully within the Appalachian Region. We describe the area and population of the region and present some fundamental employment trend statistics. We identify the region's largest employers by industry and report the 2018 Coefficient of Specialization to characterize overall regional specialization. The top ten growth industries are identified and presented along with their location quotients and regional shift measures. Next, we describe the industrial structure of the region by presenting statistics for 17 industry clusters. We report 2005 and 2018 cluster location quotients along with 2018 cluster employment levels. Then, to assist in identifying outliers, we also present cluster traits graphically. The bubble chart provides a visual representation of which clusters have the largest shares of regional employment, which clusters have higher concentrations of employment than their national counterparts, and which clusters have grown or declined during the period of analysis.

A CADS analysis completes each regional analysis. CADS is used to reveal the region's cluster anchor industry or industries, and to identify potential supply-chain bottlenecks. The bottlenecks occur in industries that can represent development potential for the regional economy, depending on the location theoretic requirements of the bottleneck industries. In this sense, the deficit industries become candidate industries for economic development.

Analyses based only on secondary data are only rarely sufficient foundations for policy decisions. Analysts familiar with the data presented in this report understand that within industry clusters and even within industries there can be substantial variation in goods and services produced, and that additional detail in the form of often unquantifiable knowledge of local economies will almost surely be needed for informed decision making. As one example, while many industries with identified supply deficits will be candidates for regional development, many will not be for a variety of location theoretic reasons. As one example, CADS for an economic region that specializes in fabricated metals manufacturing might well identify the Iron and Steel Mills and Ferroalloy Mfg industry as being in deficit, but for reasons of access to transportation, electrical, and other local infrastructure requirements there are only a handful of

viable locations for this industry. Likewise, industries like Metal Ore Mining can only be developed where there are supporting ore deposits.

For a substantial set of regions, however, the identification of deficit industries can prove to be quite useful. When a deficit industry whose location appears to be a viable option to explore, the compendium of relevant structural economic information in the regional analyses, including its local and national growth rates, its regional shift, and its measures of dominance and strength can prompt local Chambers of Commerce, Metropolitan Planning Organizations, Local Development Districts, or other similar groups and organizations to approach business leaders with a list of deficit industries and a request for help in first confirming the deficit, and then in identifying more detailed descriptions of precisely which sub-industry level suppliers in the identified deficit industries might be most beneficial to the anchors in strengthening their local supply chain linkages. With the compendium of regional data from these analyses, decision-makers will be able to make fully informed decisions as they work with specific businesses within the anchor industries to identify with greater precision which specific types of businesses in the deficit industries might be most beneficial to the regional industrial structure. Likewise, business leaders also can be helpful in pointing to important location theoretic reasons as to why some deficit industries might not be viably located within a given region. Some underlying location-theoretic impediments that contribute to comparative disadvantages might even be remediated as a result of such discussions, in turn leading to development in industries that had previously seen them as barriers to development in the region.[8]

One disadvantage to the preparation of extensive reports like these that implement identical sets of rules for a large number of regions is that the results will inevitably be more useful for some regions than for others. While we have attempted to codify a set of procedures and decision parameters that will generate the most useful results for the largest number of regions, the algorithms employed can be modified and tailored to produce deeper analytical insights for specific regions. Intensive cluster analysis for a given regional economy can accommodate a wider array of decision rules and can provide analysts with the ability to specify industry and cluster specific goals and parameters to inform a range of what-if hypothetical scenarios, including those that assess the consequences of expanding production levels in one or more industries.[9]

Despite the need for such additional steps when formulating development policies, programs, or decisions, the information provided in the region-specific analyses provides a wide range of otherwise unavailable and important contextual information and descriptions of supply chain relationships and regional economic structure that can be used to guide regional decisions effectively and efficiently.

[8] Examples of such location-theoretic impediments might include access to high voltage electricity, a lack of rail spurs serving regional industrial development sites, or specialized or higher capacity waste management facilities.
[9] Readers interested in pursuing more intensive, region-specific analyses are encouraged to contact this report's corresponding author. In intensive analyses, industries can be evaluated in isolation, more complete supply-chain requirements can be enumerated, cluster definitions can be modified, combinations of anchor industries and hypothetical (as opposed to observed) activity levels can be specified exogenously, and automated anchor selection criteria can be customized.

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Appendix A. Measures and Metrics

Growth Rates

Industry growth rates for the region and the nation are $\dot{e}_\iota = \frac{e_i^t}{e_i^{(t-1)}}$ and $\dot{E}_\iota = \frac{E_i^t}{E_i^{(t-1)}}$, respectively, where e refers to regional employment, E is national employment, subscript i refers to industry i, and superscripts t and $t-1$ refer to 2018 and 2005 respectively. The overall national growth rate is E^t/E^{t-1}, where $E = \sum E_i$.

Location Quotients

The formula for industry location quotients is $\mathrm{LQ_i} = \frac{\mathrm{e_i}/\mathrm{E_i}}{\mathrm{e/E}} = \frac{\mathrm{e_i}/\mathrm{e}}{\mathrm{E_i/E}}$, and for cluster location quotients is $\mathrm{CLQ_k} \frac{\sum_{\mathrm{i}\epsilon\mathrm{k}} \mathrm{e_i}/\sum_{\mathrm{i}\epsilon\mathrm{k}} \mathrm{E_i}}{\mathrm{e/E}}$.

Coefficient of Specialization

The coefficient of specialization is the sum of the absolute differences between regional and national industry shares multiplied by industry employment. Each industry's contribution to the COS is the absolute value of its employment surplus or deficit relative the national average.

$$COS = \mathrm{e_i}|(e_i/e) - (\mathrm{E_i/E})|$$

The COS values for Appalachian regions average 30.93 and vary from a minimum of 13.85 to a maximum of 55.33.

Regional Shift

Regional shift for an industry is defined as $RS_i = e_i^{t-1}(\dot{e}_\iota - \dot{E}_\iota)$, and for the regional summary, $RS = \sum e_i^{t-1}(\dot{e}_\iota - \dot{E}_\iota)$.

Anchor Strength

Anchor industry j strength, S_j, quantifies regional industries' ability to support anchor industry j, if industry j was the region's only anchor.

Let g_i be observed regional industry i output and let g_i^j be industry i output needed to support anchor industry j. The initial value of $\mathrm{g_i^j}$ is the $\mathrm{i^{th}}$ row from the industry-support solution with only observed $\mathrm{g_j}$ exogenous. Define the share of industry j support from industry i that could be supplied by regional industries as

$$s_{ij} = \begin{cases} g_i / g_i^j & \text{for } g_i < g_i^j \\ 1 \text{ for } g_i \geq g_i^j \end{cases}$$

Define anchor industry j strength as

$$S_j = \frac{\sum_{i \neq j} \min (g_i^j, g_i)}{\sum_{i \neq j} g_i^j} = \frac{\sum_{i \neq j} g_i^j s_i^j}{\sum_{i \neq j} g_i^j}$$

Anchor Dominance

Regional anchor industry dominance is the share of regional output that could be devoted to supporting anchor *j* if it was the region's only anchor.

Define the share of regional industry *i* output that is required to support anchor industry *j* as

$$d_{ij} = \begin{cases} g_i^j / g_i & \text{for } g_i > g_i^j \\ 1 \text{ for } g_i \leq g_i^j \end{cases}$$

$$D_j = \frac{\sum_i \min (g_i^j, g_i)}{\sum_i g_i} = \frac{\sum_i g_i d_i^j}{\sum_i g_i}$$

Input Requirements Determination[10]

To identify the input requirements for supporting our anchors, we partition the input-output (IO) accounting framework according to anchor and non-anchor industries.[11] Mathematically, let

$$\begin{bmatrix} q_r \\ \hline q_s \end{bmatrix} = \left[\begin{array}{c|c} A_{rr} & A_{rs} \\ \hline A_{sr} & A_{ss} \end{array}\right] \begin{bmatrix} q_r \\ \hline q_s \end{bmatrix} + \begin{bmatrix} f_r \\ \hline f_s \end{bmatrix} \qquad (1)$$

be a partitioned system where *q* is an appropriately dimensioned outputs vector and *r* refers to the anchor industry or industries being evaluated, and *s* refers to all other industries from which the anchor industries can draw support. The values in q_r are set to the observed anchor industry output values (demand for which is *revealed)*. *A* is a partitioned, household exogenous matrix of (input-output) *technical coefficients*, and f is a partitioned vector of exogenous final demands. The solutions for supporting sector output vector, q_s, and constrained sector final demand are:

10 This section draws heavily from Jackson (2015).

11 This approach is derived from a parallel version of this framework developed by Davis and Salkin (1984) to estimate the economic impacts of industry-specific supply constraints.

$$q_s = \left(I - A_{ss}\right)^{-1}\left(A_{sr}q_r + f_s\right)$$

The q_s equation includes the f_s term for the sake of completeness, but since the objective is an estimate of a normative distribution where exogenous demand for non-cluster anchor sectors is zero by definition, the second right-hand-side term reduces to $A_{sr}q_r$.

Because the q_s equation uses technical and not regional trade coefficients, the requirements from supporting sectors are technical requirements, irrespective of where the required inputs are produced. They represent the direct and indirect supporting sector output required to support anchor industry production. The requirements solution depends on the number and production levels of all anchor industries.

Each industrial distribution derived from this approach provides a normative reference against which a region's actual industrial structure can be compared. Industries with output surpluses are able to satisfy additional endogenous or exogenous demand, and deficits potentially form the basis for exploring import substitution possibilities subject to other location theoretic concerns.

Appendix B. Industries and Parent Clusters

#	Cluster Name	#	Cluster Name
1	Agribusiness, Food Processing and Technology	10	Energy (Fossil and Renewable)
2	Apparel and Textiles	11	Forest and Wood Products
3	Arts, Entertainment, Recreation and Visitor Industries	12	Information Technology and Telecommunications
4	Biomedical/Biotechnical (Life Sciences)	13	Machinery
5	Business and Financial Services	14	Mining, Glass and Ceramics
6	Chemicals and Chemical-Based Products	15	Primary and Fabricated Metal Products
7	Computer, Electronic, and Electrical Products	16	Transportation and Logistics
8	Defense and Security	17	Transportation Equipment
9	Education and Knowledge Creation	0	No Cluster

Parent Cluster	Industry Number	Industry Name	NAICS_2017	Avg AD
1	2	Animal production	112	0.00
1	3	Forestry and Logging	1131, 1132,1133	0.00
1	4	Fishing, hunting and trapping	114	0.00
1	5	Support activities for agriculture and forestry	115	0.00
10	6	Oil and gas extraction	211	0.01
10	7	Coal mining	2121	0.02
14	8	Metal ore mining	2122	0.00
14	9	Nonmetallic mineral mining and quarrying	2123	0.00
10	10	Support activities for mining	213	0.01
10	11	Electric power generation, transmission and distribution	2211	0.04
10	12	Natural gas distribution	2212	0.00
0	13	Water, sewage and other systems	2213	0.00
0	14	Construction	23	0.06
1	15	Animal food mfg	3111	0.01
1	16	Grain and oilseed milling	3112	0.00
1	17	Sugar and confectionery product mfg	3113	0.00
1	18	Fruit and vegetable preserving and specialty food mfg	3114	0.01
1	19	Dairy product mfg	3115	0.01
1	20	Animal slaughtering and processing	3116	0.03
1	21	Seafood product preparation and packaging	3117	0.00
1	22	Bakeries and tortilla mfg	3118	0.00
1	23	Other food mfg	3119	0.01

1	24	Beverage mfg	3121	0.01
1	25	Tobacco mfg	3122	0.00
2	26	Textile mills and textile product mills	313, 314	0.02
2	27	Apparel, leather and allied product mfg	315, 316	0.00
11	28	Sawmills and wood preservation	3211	0.01
11	29	Veneer, plywood, and engineered wood product mfg	3212	0.00
11	30	Other wood product mfg, including wood tv, radio and sewing machine cabinet mfg	3219	0.01
11	31	Pulp, paper, and paperboard mills	3221	0.01
11	32	Converted paper product mfg	3222	0.01
5	33	Printing and related support activities	323	0.00
10	34	Petroleum and coal products mfg	324	0.04
6	35	Basic chemical mfg	3251	0.03
6	36	Resin, synthetic rubber, and artificial synthetic fibers and filaments mfg	3252	0.02
6	37	Pesticide, fertilizer, and other agricultural chemical mfg	3253	0.00
6	38	Pharmaceutical and medicine mfg	3254	0.01
6	39	Paint, coating, and adhesive mfg	3255	0.00
6	40	Soap, cleaning compound, and toilet preparation mfg	3256	0.01
6	41	Other chemical product and preparation mfg	3259	0.00
6	42	Plastics product mfg	3261	0.02
6	43	Rubber product mfg	3262	0.01
14	44	Clay product and refractory mfg	3271	0.00
14	45	Glass and glass product mfg	3272	0.00
14	46	Cement and concrete product mfg	3273	0.00
14	47	Lime, gypsum and other nonmetallic mineral product mfg	3274, 3279	0.00
15	48	Iron and steel mills and ferroalloy mfg	3311	0.02
15	49	Steel product mfg from purchased steel	3312	0.00
15	50	Alumina and aluminum production and processing	3313	0.00
15	51	Nonferrous metal (except aluminum) production and processing	3314	0.01
15	52	Foundries	3315	0.00
15	53	Forging and stamping	3321	0.01
15	54	Cutlery and handtool mfg	3322	0.00
15	55	Architectural and structural metals mfg	3323	0.01
15	56	Boiler, tank, and shipping container mfg	3324	0.00
15	57	Hardware mfg	3325	0.00

15	58	Spring and wire product mfg	3326	0.00
15	59	Machine shops; turned product; and screw, nut, and bolt mfg	3327	0.01
14	60	Coating, engraving, heat treating, and allied activities	3328	0.00
15	61	Other fabricated metal product mfg	3329	0.01
13	62	Agriculture, construction, and mining machinery mfg	3331	0.01
13	63	Industrial machinery mfg	3332	0.00
13	64	Commercial and service industry machinery mfg, including digital camera mfg	3333	0.00
13	65	Ventilation, heating, air-conditioning, and commercial refrigeration equipment mfg	3334	0.00
13	66	Metalworking machinery mfg	3335	0.00
13	67	Engine, turbine, and power transmission equipment mfg	3336	0.01
13	68	Other general purpose machinery mfg	3339	0.01
7	69	Computer and peripheral equipment mfg, excluding digital camera mfg	3341	0.00
7	70	Communications equipment mfg	3342	0.00
7	71	Audio and video equipment mfg	3343	0.00
7	72	Semiconductor and other electronic component mfg	3344	0.00
7	73	Navigational, measuring, electromedical, and control instruments mfg	3345	0.00
7	74	mfg and reproducing magnetic and optical media	3346	0.00
7	75	Electric lighting equipment mfg	3351	0.00
7	76	Household appliance mfg	3352	0.00
7	77	Electrical equipment mfg	3353	0.00
7	78	Other electrical equipment and component mfg	3359	0.01
17	79	Motor vehicle mfg	3361	0.04
17	80	Motor vehicle body and trailer mfg	3362	0.01
17	81	Motor vehicle parts mfg	3363	0.05
8	82	Aerospace product and parts mfg	3364	0.00
17	83	Railroad rolling stock mfg	3365	0.01
17	84	Ship and boat building	3366	0.00
17	85	Other transportation equipment mfg	3369	0.00
11	86	Household and institutional furniture and kitchen cabinet mfg, excluding wood tv, radio and sewing machine cabinet mfg	3371	0.01
11	87	Office furniture (including fixtures) mfg	3372	0.00
11	88	Other furniture related product mfg	3379	0.00

4	89	Medical equipment and supplies mfg	3391	0.00
11	90	Other miscellaneous mfg	3399	0.00
16	91	Wholesale trade	42	0.06
0	92	Motor vehicle and parts dealers	441	0.02
0	93	Food and beverage stores	445	0.01
0	94	General Merchandise stores	452	0.02
0	95	All other retail	442-4, 446-8, 451, 453-4	0.06
16	96	Air transportation	481	0.00
16	97	Rail transportation	482	0.00
16	98	Water transportation	483	0.00
16	99	Truck transportation	484	0.02
16	100	Transit and ground passenger transportation	485	0.00
16	101	Pipeline transportation	486	0.00
16	102	Scenic and sightseeing transportation and support activities for transportation	487, 488	0.00
16	103	Couriers and messengers	492	0.00
16	104	Warehousing and storage	493	0.01
9	105	Newspaper, periodical, book, and directory publishers	5111	0.01
5	106	Software publishers	5112	0.00
3	107	Motion picture, video, and sound recording industries	512	0.00
3	108	Radio and television broadcasting	5151	0.00
3	109	Cable and other subscription programming	5152	0.00
12	110	Wired telecommunications carriers	517311	0.01
12	111	Wireless telecommunications carriers (except satellite)	517312	0.01
12	112	Satellite, telecommunications resellers, and all other telecommunications	5174, 5179	0.00
12	113	Data processing, hosting, and related services	518	0.00
9	114	Other information services	519	0.00
5	115	Monetary authorities, credit intermediation, and related	521, 522	0.04
5	116	Securities, commodity contracts, fund, trusts and other financial investments and vehicles and related activities	523, 525	0.01
5	117	Insurance carriers	5241	0.01
5	118	Agencies, brokerages, and other ins related activities	5242	0.01
5	119	Real estate and Owner-occupied Dwellings	531	0.07
5	120	Automotive equipment rental and leasing	5321	0.00
0	121	Consumer goods rental and general rental centers	5322, 5323	0.00

5	122	Commercial and industrial machinery and equipment rental and leasing	5324	0.00
5	123	Lessors of nonfinancial intangible assets (except copyrighted works)	533	0.00
5	124	Legal services	5411	0.01
5	125	Accounting, tax preparation, bookkeeping, and payroll svcs	5412	0.00
5	126	Architectural, engineering, and related services	5413	0.01
5	127	Specialized design services	5414	0.00
5	128	Computer systems design and related services	5415	0.00
5	129	Management, scientific, and technical consulting services	5416	0.00
9	130	Scientific research and development services	5417	0.01
5	131	Advertising and related services	5418	0.00
5	132	Other professional, scientific, and technical services	5419	0.00
5	133	Management of companies and enterprises	55	0.02
5	134	Office administrative services	5611	0.00
5	135	Facilities support services	5612	0.00
5	136	Employment services	5613	0.01
5	137	Business support services	5614	0.01
3	138	Travel arrangement and reservation services	5615	0.00
8	139	Investigation and security services	5616	0.00
5	140	Services to buildings and dwellings	5617	0.01
5	141	Other support services	5619	0.00
5	142	Waste management and remediation services	562	0.00
9	143	Elementary and secondary schools	6111	0.02
9	144	Junior colleges, colleges, universities, and professional schools	6112, 6113	0.03
9	145	Other educational services	6114-7	0.00
4	146	Offices of physicians	6211	0.03
4	147	Offices of dentists	6212	0.01
4	148	Offices of other health practitioners	6213	0.00
4	149	Outpatient care centers	6214	0.01
4	150	Medical and diagnostic laboratories	6215	0.00
4	151	Home health care services	6216	0.00
4	152	Other ambulatory health care services	6219	0.00
4	153	Hospitals	622	0.07
4	154	Nursing and residential care facilities	623	0.02
0	155	Individual and family services	6241	0.01

0	156	Community and vocational rehabilitation services	6242, 6243	0.01
0	157	Child day care services	6244	0.00
3	158	Performing arts companies	7111	0.00
3	159	Spectator sports	7112	0.00
3	160	Promoters of events, and agents and managers	7113, 7114	0.00
3	161	Independent artists, writers, and performers	7115	0.00
3	162	Museums, historical sites, and similar institutions	712	0.00
3	163	Amusement parks and arcades	7131	0.00
3	164	Gambling industries (except casino hotels)	7132	0.00
3	165	Other amusement and recreation industries	7139	0.00
3	166	Accommodation	721	0.01
3	167	Food services and drinking places	722	0.05
0	168	Automotive repair and maintenance	8111	0.01
0	169	Electronic and precision equipment repair and maintenance	8112	0.00
0	170	Commercial and industrial machinery and equipment (except automotive and electronic) repair and maintenance	8113	0.00
0	171	Personal and household goods repair and maintenance	8114	0.00
0	172	Personal care services	8121	0.00
0	173	Death care services	8122	0.00
0	174	Drycleaning and laundry services	8123	0.00
0	175	Other personal services	8129	0.00
0	176	Religious organizations	8131	0.00
0	177	Grantmaking and giving services and social advocacy organizations	8132, 8133	0.00
0	178	Civic, social, professional, and similar organizations	8134, 8139	0.00
0	179	Private households	814	0.00
0	180	Postal Service	491	0.00
8	181	Government and unclassified	92, 99	0.07

Appendix C. Regional Statistics

Region	COS	Maximum AD	Average AS	RS
Albertville, AL	39.9	0.468	0.598	-2454.1
Alexander City, AL	41.7	0.361	0.414	-1702.7
Altoona, PA	32.1	0.097	0.646	-9688.9
Anderson, SC	37.1	0.218	0.660	1803.6
Anniston-Oxford, AL	29.0	0.180	0.596	-10025.0
Asheville, NC	28.2	0.113	0.833	5826.1
Ashtabula, OH	39.4	0.283	0.606	-6562.5
Athens, OH	36.5	0.144	0.464	-5877.0
Athens, TN	42.5	0.396	0.499	-538.7
Beckley, WV	34.0	0.336	0.464	-4641.8
Binghamton, NY	29.1	0.110	0.700	-20517.8
Birmingham-Hoover, AL	23.4	0.111	0.907	-51969.4
Blacksburg-Christiansburg-Radford, VA	33.7	0.475	0.640	-13989.2
Bloomsburg-Berwick, PA	45.0	0.226	0.576	-4973.5
Bluefield, WV-VA	33.4	0.123	0.543	-10562.7
Boone, NC	39.0	0.294	0.467	-3627.2
Bradford, PA	40.4	0.576	0.461	-4469.2
Brevard, NC	34.8	0.138	0.404	-900.9
Calhoun, GA	48.4	0.498	0.441	258.9
Cambridge, OH	40.7	0.115	0.477	-2300.6
Cedartown, GA	50.8	0.262	0.309	-1849.9
Charleston, WV	21.5	0.117	0.725	-32132.9
Chattanooga, TN-GA	25.9	0.129	0.882	-35363.3
Chillicothe, OH	40.4	0.572	0.459	-739.9
Clarksburg, WV	28.8	0.249	0.522	-226.9
Cleveland, TN	38.4	0.197	0.600	307.9
Columbus, MS	34.0	0.214	0.584	-1524.1
Cookeville, TN	32.9	0.205	0.585	-102.9
Corbin, KY	42.5	0.132	0.387	-2294.2
Corinth, MS	43.1	0.199	0.429	-386.4
Cornelia, GA	43.1	0.236	0.378	-1696.1
Corning, NY	38.3	0.157	0.521	-3572.1
Cortland, NY	36.4	0.149	0.494	-1378.8
Coshocton, OH	46.3	0.170	0.458	-3425.8
Crossville, TN	38.8	0.125	0.472	-744.5

Cullman, AL	37.2	0.170	0.568	-3205.6
Cumberland, MD-WV	35.1	0.166	0.541	-5229.0
Dalton, GA	47.9	0.524	0.538	-9242.7
Decatur, AL	33.8	0.280	0.693	-7109.1
DuBois, PA	37.8	0.095	0.581	-7257.7
East Liverpool-Salem, OH	37.8	0.092	0.666	-7659.9
East Stroudsburg, PA	35.4	0.236	0.627	-8659.7
Elmira, NY	31.3	0.128	0.572	-6899.3
Erie, PA	32.8	0.177	0.813	-21474.5
Fairmont, WV	34.5	0.296	0.453	-5754.9
Florence-Muscle Shoals, AL	33.1	0.141	0.690	-2944.2
Forest City, NC	34.3	0.101	0.507	-5014.1
Fort Payne, AL	41.1	0.114	0.469	-866.3
Gadsden, AL	37.9	0.130	0.524	-4778.3
Gaffney, SC	48.7	0.421	0.471	-116.0
Gainesville, GA	35.5	0.317	0.698	13179.8
Greeneville, TN	43.4	0.163	0.543	-6308.1
Hagerstown-Martinsburg, MD-WV	30.4	0.111	0.715	-3454.8
Harriman, TN	49.0	0.187	0.396	-2542.4
Huntingdon, PA	32.5	0.197	0.384	-1682.9
Huntington-Ashland, WV-KY-OH	33.6	0.329	0.767	-24051.4
Huntsville, AL	30.0	0.132	0.791	13243.8
Indiana, PA	34.8	0.171	0.505	-7394.7
Ithaca, NY	44.9	0.335	0.567	-7860.6
Jamestown-Dunkirk-Fredonia, NY	32.6	0.144	0.652	-12309.1
Johnson City, TN	35.6	0.114	0.683	-5956.7
Johnstown, PA	30.9	0.091	0.698	-15320.9
Kingsport-Bristol-Bristol, TN-VA	30.3	0.512	0.817	-16403.4
Knoxville, TN	24.5	0.127	0.927	-12393.2
La Follette, TN	37.8	0.119	0.343	-2010.1
Lawrenceburg, TN	41.4	0.518	0.386	-2674.2
Lewisburg, PA	35.5	0.147	0.412	-1826.1
Lewistown, PA	43.2	0.124	0.488	-1924.3
Lock Haven, PA	38.2	0.321	0.466	-837.4
London, KY	41.4	0.142	0.437	-1014.5
Martinsville, VA	38.6	0.172	0.494	-5889.8
McMinnville, TN	42.3	0.402	0.412	-2475.4
Meadville, PA	38.6	0.108	0.635	-3634.6

Middlesborough, KY	47.4	0.255	0.335	-3140.7
Morgantown, WV	35.5	0.217	0.590	9822.1
Morristown, TN	39.1	0.293	0.591	-4202.1
Mount Airy, NC	36.0	0.188	0.504	-5714.5
Mount Sterling, KY	43.9	0.228	0.469	-2031.2
New Castle, PA	33.0	0.117	0.614	-6432.7
New Philadelphia-Dover, OH	34.8	0.086	0.699	-3494.9
Newport, TN	47.5	0.133	0.312	-1492.1
North Wilkesboro, NC	39.3	0.392	0.400	-7517.8
Oak Hill, WV	35.5	0.278	0.318	-4176.5
Oil City, PA	39.4	0.329	0.543	-7151.5
Olean, NY	33.7	0.192	0.525	-6250.2
Oneonta, NY	40.8	0.204	0.492	-4287.4
Parkersburg-Marietta-Vienna, WV-OH	29.3	0.327	0.731	-15864.9
Pittsburgh, PA	22.8	0.098	0.946	-128615.0
Point Pleasant, WV-OH	42.4	0.316	0.460	-5734.8
Portsmouth, OH	40.6	0.233	0.443	-6491.0
Pottsville, PA	39.0	0.099	0.605	-6323.9
Richmond-Berea, KY	36.9	0.258	0.503	666.8
Rome, GA	38.8	0.140	0.678	-5902.0
St. Marys, PA	51.3	0.490	0.470	-2359.4
Sayre, PA	43.3	0.181	0.450	-2820.2
Scottsboro, AL	47.0	0.251	0.412	-1089.1
Scranton--Wilkes-Barre, PA	27.9	0.106	0.851	-34456.7
Selinsgrove, PA	43.8	0.166	0.406	-1068.2
Seneca, SC	39.5	0.268	0.575	28.2
Sevierville, TN	50.0	0.306	0.553	4023.1
Somerset, KY	35.2	0.220	0.488	-3631.5
Somerset, PA	31.2	0.165	0.562	-5580.8
Spartanburg, SC	33.8	0.648	0.813	16695.7
Starkville, MS	40.1	0.223	0.443	405.3
State College, PA	32.5	0.172	0.676	10461.7
Steubenville-Weirton, OH-WV	36.3	0.230	0.583	-13780.9
Summerville, GA	56.4	0.393	0.230	-863.0
Sunbury, PA	39.5	0.134	0.565	-7927.2
Talladega-Sylacauga, AL	45.5	0.791	0.533	-2309.9
Toccoa, GA	40.6	0.142	0.367	-1578.4
Tupelo, MS	38.7	0.164	0.604	957.9

Tuskegee, AL	55.5	0.252	0.147	-1958.6
Valley, AL	46.6	0.357	0.300	-2758.6
Warren, PA	45.9	0.623	0.483	-3025.2
West Point, MS	44.3	0.251	0.274	-3308.4
Wheeling, WV-OH	29.4	0.186	0.666	-8314.7
Williamsport, PA	30.2	0.098	0.648	-5858.7
Winston-Salem, NC	28.0	0.192	0.812	-18839.2
Youngstown-Warren-Boardman, OH-PA	29.1	0.163	0.851	-64076.7
Zanesville, OH	37.5	0.126	0.543	-7097.9