DELINEATING U.S. LABOR-SHEDS FROM COMMUTER FLOW DATA: COMPARING CURRENT METHODS USING QUALITY OF FIT STATISTICS

Christopher S. Fowler
Department of Geography and the Population Research Institute, The Pennsylvania State University, 321 Walker Building, University Park, PA, 16802, USA. E-mail: csfowler@psu.edu

Leif Jensen
Department of Agricultural Economics, Sociology and Education and the Population Research Institute, The Pennsylvania State University, 106 Armsby Building, University Park, PA, 16802, USA. E-mail: ljensen@psu.edu

Danielle C. Rhubart
Department of Sociology, Anthropology and Social Work, The University of Dayton, St. Joseph Hall, 300 College Park, Dayton, Ohio 45469, USA. E-mail: danielle.rhubart@gmail.com

ABSTRACT. Labor-sheds – geographically defined areas where individuals can both live and work – are essential for regional analysis. A number of researchers and Federal agencies have delineated labor-sheds. This paper establishes a set of metrics for comparing the quality of a labor-shed delineations and subsequently compares delineations provided by several Federal agencies and research teams. None of these delineations is ideal, but our analysis indicates that the Economic Areas of the Bureau of Economic Analysis have the best 'fit' of any of the reviewed delineations and also perform the best in terms of comparisons over time.

.

Keywords: labor markets, regional analysis, commuting patterns

1. INTRODUCTION

A labor-shed is a geographically defined area where individuals can both live and work. Modeled after water-sheds, labor-sheds are meant to represent containers of economic activity with numerous interactions within their boundaries and few interactions across them. Our ability to confidently delineate and understand the bounds of labor-sheds has value for governments and researchers alike. Having an accurate labor-shed delineation can inform decisions related to government reorganization, regional development, economic planning, and regional marketing (Jones and Paasi, 2013 citing Pike, 2011; Smart, 1974; Van Nuffel, 2007; Fowler and Kleit 2014). Researchers rely on labor-shed delineations to better understand variation in earnings across industries and gender (Gibbs and Bernat, 1997; Tickamyer and Bokemeier, 1987), the relationship between education and unemployment (Killian and Parker, 1991), and factors associated with firm formation (Armington and Acs, 2010).

Motivated by the reality that standard administrative boundaries often fail to capture labor-sheds, several labor-shed delineations have been developed and used including metropolitan statistical areas, core-based statistical areas, commuting zones, labor market areas, and economic areas. These have primarily relied on population thresholds and commuter flow data as measures of economic integration (Kropp and Schwengler, 2016). County-level journey-to-work commuter flows that are regularly reported by the U.S. Census Bureau provide the building blocks for delineating labor-sheds in the U.S. and provide a means for both the public and scholarly communities to access a vital unit for measuring factors associated with economic integration.

Identifying labor-sheds is challenging and subject to valid critique. People are constrained in their choices of where to live and work, and the patterns of settlement and

employment fluctuate with preferences, technology, and a range of economic and social conditions. Cities have traditionally served as the economic cores (or nodes) of labor-sheds, but are increasingly polycentric and characterized by significant employment centers in outlying areas (Tong and Plane, 2014). In more densely populated areas such as those found in parts of the Northeast the patterns involve overlap among urban areas where the whole concept of labor-shed will necessarily function less well (Plane, 1981). Finally, the idea that commuting patterns can meaningfully define economic regions is called into question by the existence of rural areas with such light commuting as to yield faint labor-sheds with little or no meaning.

While the delineation of labor-sheds poses real challenges, their demarcation also presents opportunities. Aside from the clear advantages of having an appropriate unit of analysis for conducting regional-scale research, delineation can tell us a great deal about the spatial patterns organizing economic activity. By delineating labor-sheds for different time periods we can observe how these patterns evolve. Having a unit of economic integration through which we can assess demographic composition, economic development, job growth, and industrial change provides public and private-sector leaders a lens through which to make important policy and strategic decisions.

In this paper, we begin by describing the origins and intent of several extant labor-shed delineations; ranging from the metro-only Core Based Statistical Areas of the Office of Management and Budget to the rural-focused commuting zones of the Economic Research Service. In our review we note that these delineations, while all aiming to capture labor-sheds, had slightly different purposes. We then describe a set of ‘fit’ measures that might be usefully employed to compare and validate competing labor-shed delineations. In so doing we focus on measures that are easy to interpret by non-specialists to increase the likelihood that this

validation will be adopted. We offer a comparison of five extant methods for delineating labor-sheds; two focusing on metropolitan areas only and three that cover most of the United States. In comparing these methods we consider both the quality of labor-sheds themselves (i.e. how well they capture the ideal of a labor-shed in which people both live and work) as well as the degree of fit for counties within those labor sheds (how closely connected a county is to its assigned labor-shed as opposed to other adjacent labor-sheds). Our comparison highlights the strength of the delineation undertaken by the Bureau of Economic Analysis, although we have some reservations about the extremely large size of the units proposed in this delineation. We conclude by offering some suggestions to researchers wishing to employ these delineations.

Each of the delineations discussed here is available to the public for download at [redacted to retain anonymity] in several formats including both tabular and boundary files (ESRI shapefiles) at both county and labor-shed scale with associated fit statistics for the years 1980, 1990, 2000, and 2010. This analysis conforms as nearly as possible to current best practices in reproducible research (Gentleman and Lang 2007), and an R script reproducing the analysis presented here is also available in this location for researchers wishing to compare alternative delineations.

2. LABOR-SHEDS: HISTORY AND MOTIVATION

In the U.S., two main approaches to developing labor-sheds can be identified; a metropolitan area approach originating from the U.S. Census Bureau and a broader approach aimed at including both metropolitan and non-metropolitan areas typified by delineation of ‘commuting-zones’ (U.S. Department of Agriculture Economic Research Service, ERS hereafter). A middle ground exists, filled by ‘economic areas’ (Bureau of Economic Analysis, BEA hereafter), that focus on metropolitan cores, but extend to include both metropolitan and

rural counties. These approaches all rely on county and county equivalents (e.g. New England City and Town Areas) as their basic building blocks (OMB, 2010) for several reasons including the availability of economic data at this scale and their limited degree of change over time. However, each approach uses different criteria for connecting counties into labor-sheds. All three approaches rely heavily on commuting flow data, though some efforts to delineate labor-sheds have relied on goods and services, amenities, tourism, land productivity, and land prices (e.g. Bode, 2008). It is important to note that, while most delineations rely on commuter flows, these flows are themselves heterogeneous and vary across a range of economic, social, and demographic factors (e.g. Tigges and Fuguitt, 2003; Fuguitt, 1991; Wyly, 1998; Peck, 1989).

The metropolitan area approach has a long history at the Census Bureau. The Office of Management and Budget (OMB) has provided the Census with metropolitan statistical area (MSA) (formerly known as Standard Metropolitan Areas and Standard Metropolitan Statistical Areas) delineations since the 1950s (U.S. Census Bureau, 2016). MSAs are counties or county clusters with populations of 50,000 residents or more that are then expanded by adjacent counties that have significant "economic and social integration" (U.S. Census Bureau, 2016). In 2003, the OMB modified these delineations to develop Core Based Statistical Areas (CBSAs). CBSAs are an advancement on MSAs, most notably because they include a second set of delineations (i.e. micropolitan statistical areas) for county clusters with core populations between 10,000 and 49,999 residents (Tong and Plane, 2014). CBSAs have proven to be useful in that they provide a nationally consistent set of geographic areas to access and analyze federal data (OMB, 2010) and also allow researchers and practitioners to access data for groups of counties that they would have otherwise not had access to because of such small population sizes (Kurban and Persky 2007; Mille et al., 2013; Tong and Plane, 2014; Plane et al., 2005).

A similar effort originating at BEA in the late 1960s extended the metro-centric concept employed by the Census and OMB to cover all U.S. counties. The BEA effort also relies on commuting data to connect "non-nodal" (peripheral) counties to "nodal" (core) counties. This mono-nodal approach created economic areas that were used for regional projections. Since their inception in the 1960s OMB metropolitan cores have served as the base nodes for BEA's delineations. Delineations covered here were undertaken in 1977, 1995, and 2004. The most recent, 2004, delineations rely on OMB CBSAs. The BEA delineations use metropolitan cores as proxies for economic nodes, referred to as 'component economic areas' (CEAs, Johnson and Kort 2004). The remaining (non-core) counties are then assigned to CEA economic nodes based on commuting flows, and in some cases newspaper circulation data. The final step consists of aggregating CEAs into BEA economic areas through an iterative process (Johnson and Kort 2004). BEA's economic areas, with their primary purpose of acting as a geographic unit for economic projections, have had a long history in regional economic research (Beyers 1992; Harris et al., 2000; Lim 2016).

In the comparisons below we also include a delineation from the Federal Communications Commission for Partial Economic Areas (PEA's). This delineation is entirely derived from the BEA Economic Areas. The delineation is intended not to represent labor-sheds, but to identify auctionable units for the sale of communications licenses. To this end major markets are sometimes divided in the PEA delineation. While not a true labor-shed, the FCC units are retained in the comparison for the sake of completeness and to demonstrate their complete unsuitability for regional analysis purposes.

In contrast to the metropolitan-focused delineations used by the Census Bureau, and the explicitly metro-centered delineations by BEA, ERS has long-supported a series of labor-shed

delineations meant to incorporate more rural areas. Commuting zones, developed originally in the late 1980s (Tolbert and Killian, 1987) and rely on commuter flow data between counties and county equivalents, offered a complete assignment of U.S. counties into labor-sheds and provided a means for studying urban as well as rural regions. Unlike Census and BEA delineations, the ERS delineations did not begin from an assumption that labor markets would be centered on an urban core with a minimum size. The methodology, which emphasized linkages between small counties and large counties, certainly shared the same theoretical frame; that labor-sheds would extend out from large employment centers, but allowed the size of that center to vary with local commuting patterns. These delineations were subsequently updated for 1990 and 2000 commuter flow data by ERS, and for 2010 commuter flow data by Fowler Rhubart and Jensen (2016). Research employing commuting zones has a long history in regional economic analysis (Autor and Dorn, 2009; Gibbs and Bernat, 1997; Davis Connolly and Weber, 2003; Allegretto, Dube, and Reich, 2009; Tickamyer and Bokemeier, 1987).

In large measure the ERS effort to delineate commuting zones nationwide sought to bring *rural* labor markets into the broader research and policy conversation. Indeed, a key limitation of CBSAs is that they attempt to capture urban labor-sheds and subsequently exclude a large share of nonmetropolitan counties. For example, approximately 1,260 counties were excluded from the 2013 CBSA delineations. These counties were home to approximately six percent of the U.S. population and are labeled by OMB as “Outside Core Based Statistical Areas”. While CBSAs provide insight into urbanized regions, a great deal of U.S. land is also lost. BEA’s Economic Areas overcome the limitation of excluded counties, but they do so by making labor-sheds that are extremely large, perhaps too large in some cases. Commuting zones, on the other hand, also have limitations. While they are comprehensive of all rural and urban areas of the US, by

eliminating the requirement that a labor-shed be centered on a metropolitan core and deriving connection from the share of commuting flows, commuting zones appear in areas where the whole concept of labor-shed seems weakly relevant. The untested assumption of the pioneering work on commuting zones was that rural commuting zones indeed do hang together empirically. One intent of this paper is to provide an empirical assessment of this assumption.

In addition to the concerns already raised about the methods used to delineate commuting zones, economic areas and CBSAs each faces an additional challenge which is that the underlying thing that they seek to delineate varies in both time and space. Across different areas of the US each of the delineations will likely perform more or less well as populations and economic configurations vary geographically with respect to their conformance to the labor-shed model. Counties vary in size from East to West, urban areas are more or less monocentric, and populations are more densely settled on the coasts than in most other parts of the country. Each of these creates geographic variance in how well the labor-shed concept fits a regional economy. Furthermore, as economies change, the degree to which a particular method of delineation can capture the new patterns of residence and employment would also be expected to vary. Increased commuting times and distances (Kneebone and Holmes, 2015), an increased prevalence of two-earner households (Pew Research Center, 2015), telecommuting (Beers, 2000), are just a few ways in which the economic landscape of labor-sheds has changed during the time period covered here. . Metropolitan-origin commuting has historically looked very different from nonmetropolitan-origin commuting (Clemente and Summers, 1975). The rise of commuting and commuting over long distances helped fuel population de-concentration and as a result, not all non-metropolitan origin commuting is toward an urban center (Tigges and Fuguitt, 2003).

Previous studies have highlighted the spatially and temporally fluid and overlapping nature of labor-sheds (Jones and Paasi, 2013; Smart, 1974). In many ways, understanding labor sheds is most appropriately done through a social constructivist perspective (Jones and Paasi, 2013). Yet, empirical research requires that some middle ground is found between the fluid and variant nature of labor sheds and the need for delineations to represent these entities. Metrics that can differentiate among methodologies and distinguish levels of fit within given methodologies across time and space are thus essential to the ultimate utility of these delineations.

3. BUILDING BETTER LABOR-SHEDS: A DESCRIPTION OF FIT STATSITICS

The ability to accurately delineate labor-sheds is contingent on several constraints. The arrangement of work and residence varies across place and time meaning that the scale and fit of delineations will also vary geographically and temporally. Physical characteristics of the landscape and historical patterns of settlement condition the extent to which labor-sheds are distinct or overlap, furthering the variation in fit geographically. Counties, the building blocks of the delineations considered here, are also heterogeneous in size and population. Taken together these constraints insure that any labor-shed delineation is likely to vary in quality and that this variation is likely to have a spatial pattern to it. Responsible use of labor-sheds must, therefore, consider the variation in this quality and take reasonable steps to minimize its impact on analytic results. Remarkably, with very few exceptions, the delineations currently available for U.S. regions are made available to users without any reported validation, leaving analysts to assume that the delineation they are using is valid and appropriate (but see Tong and Plane, 2014).

Researchers need to balance priorities when delineating labor-sheds, and the metrics presented here are intended to permit researchers to find a balance suited to their specific analysis. To increase the share of the population living and working in the same labor-shed requires delineating larger labor-sheds. Conversely, reducing the number of counties only weakly tied to their labor-shed requires increasing the number of labor-sheds. For some analyses, culling out counties that do not truly fit into a recognizable labor-shed may be appropriate, but for others completeness will be worth the price of including marginal counties. Any delineation will require the analyst to find a balance that optimizes on the combination of these and other criteria. Table 1 summarizes the set of criteria for evaluating the quality of a given labor-shed delineation and their associated justification. Each of these is presented subsequently in the comparison of existing labor-shed delineations.

Table 1: Description of fit measures for judging the quality of labor-shed delineations

Property		Justification
Completeness		
	Number of counties covered by delineation	A delineation should cover as much of the study area or study group as possible
	Population covered by delineation	
Size and Shape		
	Range, variation, and skew in area	While land area, population size, and number of sub-units will necessarily vary because regions vary, extreme outliers may indicate problematic groupings that prevent a useful comparison of observations.
	Range, variation and skew in population	
	Range and variation in number of counties per labor-shed	
	Compactness (Iso-Perimeter Quotient)	While regions will take on a wide range of forms based on variation in the underlying sub-units, it is desirable that these shapes be as compact as possible and spatially contiguous except where sub-regions are islands.
	Contiguity	
Conformance to Labor-shed concept		
	Share of county residents who work in labor-shed (sub-region scale)	Conceptually, labor-sheds are meant to indicate regions with a common labor market such that people are expected to live and work in the same delineated area. Conformance to this ideal can be measured at the population, region, or sub-region scale. Additionally, by examining the worst-fit counties in each cluster, the measure of county residents who work in the labor-shed can also help identify delineations that inappropriately join unlike sub-regions together.
	Share of labor-shed residents who work in labor-shed (region scale)	
	Share of U.S. population that lives and works in same labor-shed (population scale)	
Other metrics		
	Number of metropolitan areas split into multiple labor-sheds	Metropolitan areas are built to represent labor-sheds. If too many metros are split into multiple labor-sheds, then the delineation probably has too many units
	Spatial clustering of labor-shed fit statistics	If a delineation performs poorly in a way that indicates a spatial pattern to performance then subsequent analyses may be biased by 'better' observations in some places than others.
	Spatial clustering of county fit statistics	

Completeness plays an important role in labor-shed delineation and represents a major point of difference across extant delineations. The labor-shed concept is easy to explain when considering the array of counties surrounding a large metropolitan area, but can become strained in remote rural areas. For this reason some delineations, like the Census' CBSAs, only include counties that are demonstrably attached to a specific metropolitan area with strong commuting flow relationships. In contrast, the ERS Commuting Zones reflect a greater interest in connectivity for rural areas and include counties that may have a very slight connection. The intent of an analysis should determine whether completeness and inclusion of rural populations is

of greater importance than conformance to the labor-shed concept. Decision metrics included here describe the number of counties, and share of the population covered.

Size and shape are relevant metrics for judging the quality of a labor-shed delineation and also convey important information about the scale of observations an analyst will be working with. Metrics describing the size and skew typical to a delineation offer a comparison of both the 'typical' labor-shed and the extremes of the delineation. While we would expect economic regions to vary significantly in size both for historical reasons and due to the functioning of economic systems (e.g. Zipf, 1949), maintaining some degree of homogeneity among observations is desirable in many analytic contexts. Compactness, here presented as an aspect of shape, has a basis in previous work on functional regions (Kropp and Schwengler, 2016). Compactness typically refers to the ratio of the area to the perimeter. The Iso-Perimeter Quotient (IPQ) is a standard measure for compactness (for a review see Li et al., 2013). The IPQ is defined as:

$$IPQ = \frac{4\pi Area}{Perimeter^2}$$

The IPQ ranges from 0 to 1 with one indicating that the shape is perfectly compact (e.g. circular). Beyond flagging delineations that result in particularly unusual combinations of counties, compactness is not a particularly useful measure in this context as it is largely determined by the shape of the constituent counties and there is little variation among the finalized delineations presented for comparison. Contiguity plays a similar role to that of compactness, as conceptually, labor-sheds should always be contiguous, but the finished delineations compared here are all composed of contiguous labor-sheds so there is no variation on this variable.

The third, and likely most important, set of criteria measure a delineation's *conformance to the labor-shed concept* with its basis in the natural phenomenon of a watershed where every

drop of rain that falls within a watershed remains there until evaporation. The idea of self-containment, is a foundational component of delineating labor-sheds (Coombes et al., 1986 p 944). Having a high degree of self-containment means that there should be many interactions within each labor-shed and minimal interactions between labor-sheds (Coervers and Hensen, 2003). In other words, labor-sheds will contain a high level of self-containment if the proportion of residents who work there and live there is high. Complementary to self-containment, labor-sheds can be measured by their commuting relationships with other areas. Ideally, a labor-shed with a high level of self-containment will have a low level of commuting relationships with other labor-sheds (Smart, 1974). While the former is operationalized here as the share of residents living and working in the same region, the latter is examined based on the share for the least contained county in each cluster. If labor-sheds include counties that are only weakly connected to the rest of the unit then self-containment can be understood to be over-emphasized in a delineation. The final measure included here, the share of the U.S. population whose commute is contained within their assigned labor shed, is essentially a population weighting of self-containment that gives a useful overview of the overall performance of the delineation. It is included here as it was a key metric used by Tong and Plane (2014) to justify their delineation as an improvement over CBSA's.

Several *other metrics* present themselves as useful diagnostics of delineation quality given the application of these proposed labor-sheds. First, metropolitan areas are understood to be the engines of most regional economies (Giuliani, 2007; Katz and Bradley, 2013; Krugman, 1991; Partridge et al., 2007; Sole and Viladecans-Marsal, 2004). While the definition of metropolitan area has changed considerably over time (appropriately given the changed spatial structure and morphology of urban areas), having metropolitan areas split into multiple labor-

sheds does not make sense for most applications. In some places this may be a necessary outcome of using counties as sub-regions; as in the Northeast where metropolitan areas are substantially overlapping and certainly do not conform to county boundaries (Plane, 1981). In general, however, it will be desirable to minimize the number of metro areas that are split. Here we use decade-appropriate metropolitan boundaries and identify the number of times that those boundaries contain counties assigned to more than one labor shed. Finally, spatial clustering of high containment and, more importantly, low containment regions poses serious problems for analysis. If 'bad' observations are clustered in space then subsequent analyses employing these observations will need to consider the implications of using these delineations, particularly if the analysis intends to make an argument about a spatially variant process. The metrics employed here are operationalized as a Moran's *I* (Moran, 1950) to indicate the degree to which results are clustered both at the region and county level.

4. DATA

This paper compares delineations of labor-sheds from the U.S. Census Bureau, ERS, BEA, and also includes modifications of these delineations by the FCC, Tong and Plane (2014) and Fowler et al. (2016). All of the delineations described here for each decade 1980 through 2010 are assembled with complete metadata and documentation at <web site redacted to retain anonymity in review process>. The Census delineations include definitions for Combined Metropolitan Statistical Areas (CMSA) and Metropolitan Statistical Areas (MSA) for 1980 and 1990 and Core Based Statistical Areas (CBSA) for 2000 and 2010 (U.S. Census Bureau 2017a). ERS delineations for 1980, 1990 and 2000 were initially accessed through the ERS web site (Economic Research Service, 2017). The 2010 delineation is based on a replication of the ERS methodology completed by Fowler et al. (2016). BEA Economic Areas and FCC Partial Economic Areas were initially accessed via the FCC web site (Federal Communications

Commission, 2017) and conform to delineations by the Regional Economic Analysis Division, Bureau of Economic Analysis. Additional BEA delineations for 1977 and 1995 were obtained as a spreadsheet in the context of personal communication with a BEA employee. The delineations by Tong and Plane were made available by the authors. A full description of their method of linking counties in a way that accounts for polycentricity in urban form is the focus of their 2014 paper.

As its primary focus is establishing fit statistics for previously released delineations of labor-sheds, this paper follows previous research and uses county-to-county commuter flow data made available through the American Community Survey (ACS) and Decennial Census long form. We use data from the 1980, 1990, and 2000 Census long form to provide base data for our analyses in these decades and 2008-2012 data from the ACS for our 2010 analysis. Until 2000, commuting data had been collected using the Census long form questionnaire (question 22 in both 1990 and 2000 surveys) that asks "at what location did this person work LAST WEEK?" (U.S. Census Bureau 2000 emphasis in the original). Beginning in 2003, this question was moved to the ACS. Whereas this question was previously asked of five percent of the entire population every ten years, it is now asked of only 2% of individuals and is administered continuously so estimates are developed over multiple years. Because of collection methods, ACS data also capture seasonal employment trends and economic cycles. In addition, the question changed slightly to ask the respondent to provide the location of the place where they worked the most hours last week including the address, county, and state. The Census then geocodes this response to the 'place' level and ultimately to the block level (McKenzie, 2013). We exclude cases for Puerto Rico and other outlying U.S. territories.

Data on commuting flows for 1990, 2000, and 2010 were available from the Census Bureau web site (United States Census, 2017b), but 1980 data were not available from that source. For 1980 we utilized a file produced by the BEA in the mid-1980s. While the Census Bureau defined 3,137 counties or county equivalents in 1980, from the BEA data came with a number of counties combined together[i]. In all cases these combinations fell within the same metropolitan boundaries for the Census Bureau definition, and the same Economic Areas for the BEA delineation. In all but two cases these counties were also placed in the same labor-shed in the 1980 ERS delineation so very few discrepancies occurred in calculating descriptive or fit statistics. The two exceptions are Kalawao County, HI which is joined here with Maui County, HI, and Martinsville City, VA which is joined here with Henry County, VA. In both cases the connection used by BEA in 1980 is mimicked in the ERS delineation for 1990. When all exclusions and combinations were completed the final dataset has 3096, 3141, 3141, and 3,143 county and county equivalencies for the decades 1980 through 2010, respectively.

5. DESCRIPTIVE COMPARISON OF DELINEATIONS

Table 2 conveys a range of descriptive statistics meant to highlight the differences in coverage, typical unit size, and compactness for the delineations considered here. The intent of these statistics is not to judge the quality of the delineation, but to highlight the differences in intent that are visible from this type of comparison.

Completeness

The ERS, BEA, and FCC delineations cover all 50 states.[ii] Only the Census Bureau CBSA delineation includes outlying territories such as Puerto Rico or Guam. While it includes a broader set of counties in its set of potential labor-sheds, by intent it defines labor sheds for a much smaller set of counties overall. The Census Bureau designation and its close relative suggested by Tong and Plane (2014) do a surprisingly good job of covering the vast majority of

the country's population (94%) even though they omit a substantial number of counties. Census definitions for CMSA's include 761 counties in 1980 and 854 in 1990, while the more comprehensive CBSA boundaries for 2000 and 2010 include 1764 and 1808 counties, respectively. The Tong and Plane delineation, which covers only 2010, includes 1196 metropolitan counties and 701 micropolitan counties for a total of 1897 included counties. Given the population coverage of these delineations, many researchers may find the simplicity of the Census Bureau CBSA delineation appealing for analyses based on 2000 data or later. The limitation of the CBSA definition lies primarily in its single time-frame, and its omission of many rural counties. The Census Bureau has distributed a closely related delineation in previous decades (e.g., CMSA's, MSA's) but those delineations do not utilize the same criteria. A retroactive application of the CBSA definition is certainly possible, but it is based on an assumption that metropolitan areas are extremely broad that has debatable relevance for earlier decades.

Size (of population, land area, and number of counties)

Table 2 also describes the variation in size of the labor-sheds delineated in each methodology. The most significant point to draw from this comparison is that the delineations are remarkably similar along the range of these metrics except for the BEA Economic Areas which are much larger units. Put another way, a diverse range of techniques for dividing up the country into labor-sheds have led to substantially similar units in terms of population, area, and number of counties suggesting some degree of robustness in the labor-shed concept. While the CBSA delineations are missing some of the low-end labor-sheds in population terms (the smallest population CBSA was approximately 13,000 individuals as compared to 1,000 for the 2010 ERS delineation) they are otherwise remarkably similar. The average Economic Area, by

comparison, has three to five times the population of the other delineations and the largest Economic Area has more than twice as many counties as the largest CBSA and more than three times as many counties as the largest ERS commuting zone. This decision to group more counties together will make sense for some research applications where the priority is on not separating connected regions, but it will likely prove too large for other applications where grouping unlike counties into the same labor-shed is a more pressing concern. Additionally, the huge size of some of the BEA units may lead to concerns about the number of observations available for analysis and about coherence of the amalgamated observations. The FCC Partial Economic Areas, which have a higher N, than the Economic Areas retain at least a few exceptionally large population areas and exhibit a skew that is much higher than all but the combined Tong and Plane delineation with its intentional mixing of large and small regions.

Compactness

Table 2 also measures the average compactness of the delineations using the IPQ method described in Li et al. (2013). There is very little variation in this metric across delineations. This suggests that it has little role to play in choosing among them, and that the underlying methods for delineating labor-sheds produce geographic forms that are roughly equivalent.

Table 2 Descriptive Statistics

				Population (000's)					Area (000's of km2)					
Delineation	**Year**	**N**	**Complete**	*Included*	*Min.*	*Mean*	*Max.*	*Kurtosis*[e]	*Min.*	*Mean*	*Max.*	*Kurtosis*[f]	*Compactness*[g]	*Min*
ERS[a]	1980	765	Yes	100%	0.5	296	11,787	0.15	0.2	11	282	205.5	0.46	1
	1990	741	Yes	100%	1.3	336	14,545	-0.02	0.2	11	140	40.45	0.45	1
	2000	709	Yes	100%	1.2	397	16,393	0.08	0.2	11	140	38.36	0.45	1
ERS Mod.[b]	2010	625	Yes	100%	1.0	494	17,877	0.05	0.3	13	133	24.72	0.49	1
ERS Rep.[b]	2010	658	Yes	100%	1.0	469	17,877	0.1	0.3	12	172	43.23	0.50	1
BEA[c]	1980	183	Yes	100%	110	1,238	17,899	0.43	2.9	44	282	6.91	0.38	2
	1990	172	Yes	100%	60	1,446	23,919	0.31	6.8	47	282	5.7	0.35	1
	2000	179	Yes	100%	83	1,572	22,315	-0.09	7.0	45	286	7.34	0.35	1
	2010	179	Yes	100%	80	1,725	23,154	-0.16	7.0	45	286	7.34	0.40	1
FCC	2010	410	No	99.6%	5.9	750	25,237	0.68	0.7	20	229	24.67	0.40	1
Census CBSA's	2010	917	No	94%	13.5	316	19,567	1.24	0.3	5	71	30.38	0.45	1
Tong and Plane[d]	2010	933	No	94%	12.1	310	18,897	1.32	0.3	5	71	29.47	0.59	1
--Metro only	2010	363	No	84%	55.3	712	18,897	0.89	0.4	7	71	20.44	0.52	1
--Micro only	2010	570	No	10%	12.1	54	243	-0.02	0.3	3	55	47.84	0.63	1

Notes:

a.Original ERS delineations

b. Delineations completed by Fowler et al. (2016). Mod. Represents a modification meant to replicate the intent of the ERS analysis while Rep. is an exact replication of the ERS methodology.

c. BEA Economic Areas were delineated in 1977, 1995, and 2004 The 1977 delineation is used with the 1980 flows, the 1995 delineation is used with 1990 flows, and the 2004 delineation is used with both 2000 and 2004 f

d. Delineations based on Tong and Plane (2014)

e. Kurtosis of Population calculated on log of population as we expect functional regions to be distributed on an exponential scale (Zipf 1949).

f.Kurtosis of Area calculated on area in 1000's of square kilometers

g. Mean compactness based on IPQ method as described in Li et al. 2013.

Table 3: Fit statistics

Delineation	Year	Metros Split[e]	Labor-shed Fit Metric[f] Min.	Mean	Max.	I^g		County Fit Metric[h] Min.	Mean	Max.	I^g		Share of Flows Considered	Cont
ERS[a]	1980	26	63%	94%	100%	0.18	***	57%	93%	100%	0.23	***	100%	
	1990	33	61%	91%	99%	0.20	***	45%	90%	100%	0.25	***	100%	
	2000	38	49%	89%	100%	0.16	***	41%	88%	100%	0.23	***	100%	
ERS Mod.[b]	2010	36	52%	89%	100%	0.20	***	39%	88%	100%	0.27	***	100%	
ERS Rep.[b]	2010	43	42%	87%	100%	0.30	***	39%	87%	100%	0.34	***	100%	
BEA[c]	1980	3	92%	97%	100%	0.28	***	37%	96%	100%	0.23	***	100%	
	1990	1	92%	96%	100%	0.21	**	63%	95%	100%	0.31	***	100%	
	2000	0	91%	96%	100%	0.12	**	64%	94%	100%	0.30	***	100%	
	2010	4	90%	96%	100%	0.14	***	51%	93%	100%	0.29	***	100%	
FCC	2010	108	47%	86%	99%	0.09	***	18%	87%	100%	0.26	***	99.6%	
Census CBSA's	2010	0	37%	84%	100%	0.21	**	36%	85%	100%	0.24	***	94%	
Tong and Plane[d]	2010	66	33%	83%	99%	0.22	***	33%	84%	99%	0.24	***	94%	
--Metro only	2010	49	49%	90%	99%	0.21	***	46%	88%	99%	0.20	***	84%	
--Micro only	2010	34	56%	93%	100%	0.21	***	33%	77%	99%	0.39	***	7%	

Notes:

a. Original ERS delineations

b. Delineations completed by Fowler et al. (2016). Mod. Represents a modification meant to replicate the intent of the ERS analysis while Rep. is an exact replication of the ERS methodology.

c. BEA Economic Areas were delineated in 1977, 1995, and 2004 The 1977 delineation is used with the 1980 flows, the 1995 delineation is used with 1990 flows, and the 2004 delineation is used with both 2000 and 2004 f

d. Delineations based on Tong and Plane (2014)

e. Metropolitan definitions are based on Census categories for that decade. CBSA's in 2000 and 2010, CMSA's in 1980, and 1990

f. Share of labor-shed residents who also work in labor-shed

g. Moran's *I*. Neighbors based on 5 nearest neighbors to avoid contiguity problems with some delineations. Significance based on pseudo p-value from 999 simulations (Cliff and Ord 1981). *** signifies p-value of less thar signifies value less than .01

h. Share of county residents who work in the labor-shed to which their county is assigned

i. The portion of total flows considered in the delineation and the share of those flows that do not cross a region boundary

6. FIT STATISTICS

Fit statistics for labor-sheds

Table 3 compares delineations based on the measures of fit proposed in Table 1. The table describes fit in three different contexts: the labor-shed, the county, and the population. Labor-shed metrics describe the quality of each individual labor-shed and are the primary metric considered here. However, the county-level metric describes the level of fit for individual counties and is used here to describe the minimum fit case for a given delineation. For researchers seeking to refine one of these delineations for a specific use, the county fit statistics provide a convenient method for doing so. A valid critique of the labor-shed concept is that it ends up including counties in labor-sheds that, by virtue of having limited out-of-county commuting or scattered commuting patterns, do not really belong in *any* labor-shed. Using the county fit statistic as a guide researchers could eliminate counties from their analysis that have weak connections to their assigned labor-shed. Finally, the population-level metric replicates the standard used in Tong and Plane (2014) and conveys a very intuitive number that gives greater weight to fit in populous labor-sheds than it does to less populous ones. Given the heterogeneity in population documented in Table 2, this is a valuable metric for comparing the overall quality of different delineations.

The *number of CBSA areas split* is the first metric described in Table 3 and points to significant differences in the intent of the delineations. The BEA delineations begin from the CBSA delineation and only rarely split these areas resulting in very low scores on this metric. Tong and Plane's methodology was intended as a critique of the CBSA delineation and is notable for including a similar number of counties and a similar number of delineated labor-sheds, while at the same time splitting Census Bureau defined labor-sheds at a very high rate.

The data for ERS indicate a slightly increased tendency to split metropolitan areas in later decades, but generally falls in the middle of the pack. The FCC delineation is a special case, as it was designed to break the country up into auctionable units for the allocation of broadcast rights, it intentionally breaks up some of the larger markets and ends up splitting a large number of metro areas.

The second metric for consideration in Table 3 is *minimum labor-shed fit*, documenting the labor-shed in a given delineation with the lowest share of residents who also work in the labor-shed. The BEA delineations being much larger in size and number of counties than the others, have much higher values here; at or exceeding 90% in all years. This is perhaps one of the strongest recommendations for the BEA delineations as it indicates that there is little variation among observations in terms of how they function as labor-sheds. In contrast, the effort to include all counties in a labor shed without making any individual labor-shed too large results in some poorly fitting labor-sheds in the ERS analysis, a characteristic that gets worse over time from 1980 onward. The metro-focused delineations have lowered values in this category as well, but this is more a design feature than a limitation, as these delineations seek to cut off counties that are only marginally connected to the metro area at the cost of inclusiveness. The FCC delineation is again a special case; by intentionally splitting up large metropolitan areas for auction it ends up deviating significantly from the labor-shed concept.

The *mean labor-shed fit* score is most notable for the generally high values obtained. Again, the metro-only delineations are lower by design, but not nearly as different as they were for the minimum fit score. The results comparing ERS and BEA delineations should, in general, give confidence to users of these delineations that the typical labor shed largely conforms to the conceptual model they are intended to represent.

Figure 1 offers a closer look at the distribution of fit scores for the 2010 labor-sheds covered in Table 3. Figure 1 is a 'violin plot' and conveys the probability density function for fit scores within each distribution as well as a box plot showing median, and interquartile range (Hintze and Nelson, 1998). The BEA delineation has a clear advantage over the other delineations with higher mean and median than alternatives and none of the outliers that plague other attempts.

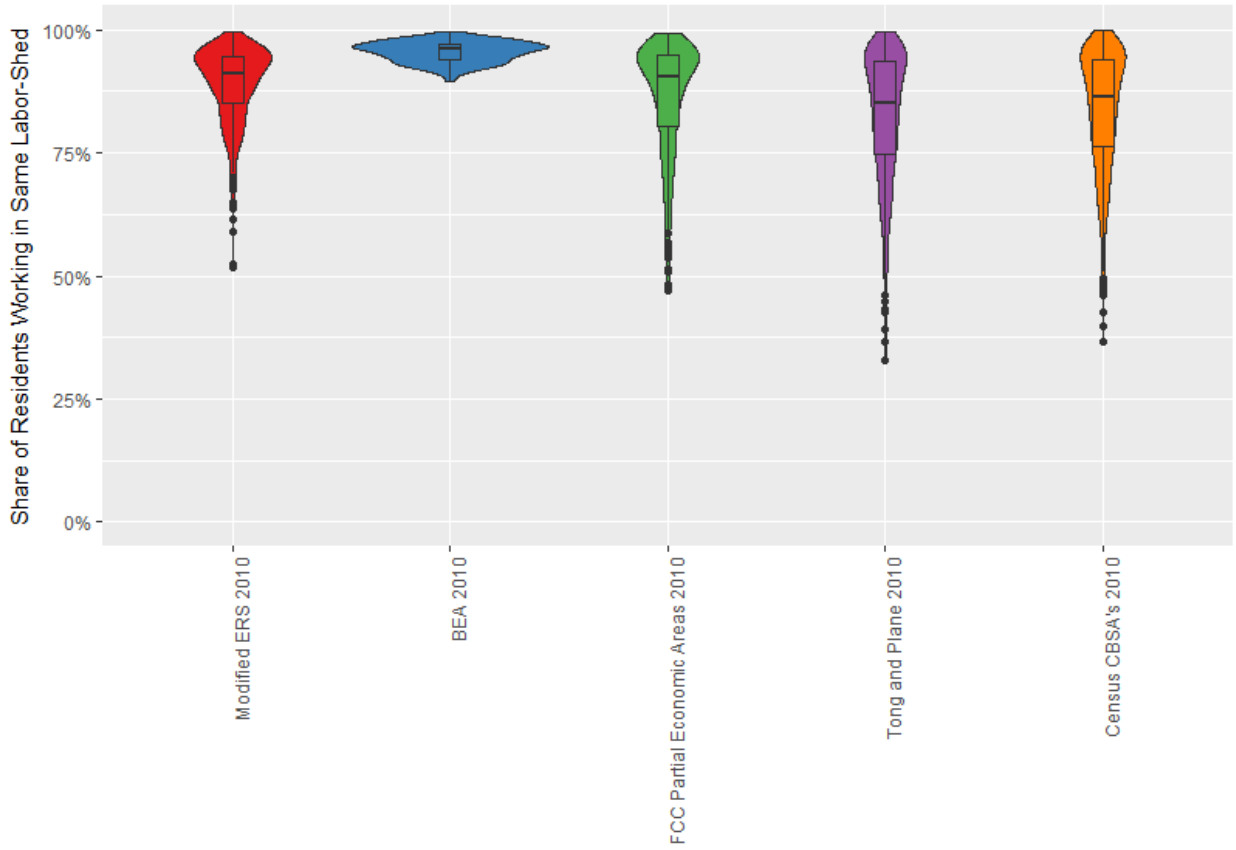

Figure 1*: Comparing the distribution of self-containment across delineations for 2010.*

Fit Statistics for Counties

The *county fit metrics* in Table 3 provide critical additional information about the delineations being considered as they offer insight into the internal structure of labor-sheds. The ERS labor-sheds have a consistent decline in both the minimum fit and average fit of counties within the delineation over time, likely associated with a decreased emphasis on expert knowledge in shaping the final delineation over time[iii]. The BEA delineation shares the decline in average fit, although it is much less than for the ERS delineation. This shared pattern suggests that at least part of the change may reflect changing patterns in the structure of employment more broadly, with workers increasingly traveling longer distances for work and two-earner households finding compromise locations between employment opportunities in different labor-sheds. While a more thorough analysis of the changing structure of labor-sheds over time exceeds the scope of this paper, these metrics suggest that an analysis of this type would be fruitful.

A second key point from the county fit metrics is that the metro-only delineations do not perform as well as their design suggests they should. Lower labor-shed fit metrics were to be expected since these delineations are meant to exclude counties that are not clearly connected to the core area of the labor-shed. However, by this same logic, weakly attached counties should be excluded from these delineations. Both the minimum county fit and mean county fit metrics indicate that on average these delineations perform no better than the more complete delineations, and in the worst cases, perform less well. Given these findings, analysts wishing to use the CBSA delineations to represent labor-sheds should consider eliminating weakly connected counties from CBSA's perhaps by setting a minimum commuting share at a higher threshold like 50% or even 70% of commuters living and working within the CBSA.

Figure 2 offers the converse analysis to Figure 1. While the former focuses on how well labor-sheds contain flows, Figure 2 looks at the degree to which relatively weakly connected counties are attached to labor-sheds where they do not belong. Surprisingly, given the larger sizes of its units, the BEA fit again exceeds that of its alternatives, and it is the only delineation where all of the counties have at least a 50% share of their commuters living and working within the same labor-shed; an important intuitive benchmark for the labor-shed concept. The violin plot further shows that the relatively weak performance of the metropolitan-only delineations is consistent across the entire set of counties and is not purely a function of one or two outliers pushing down minimum and average values.

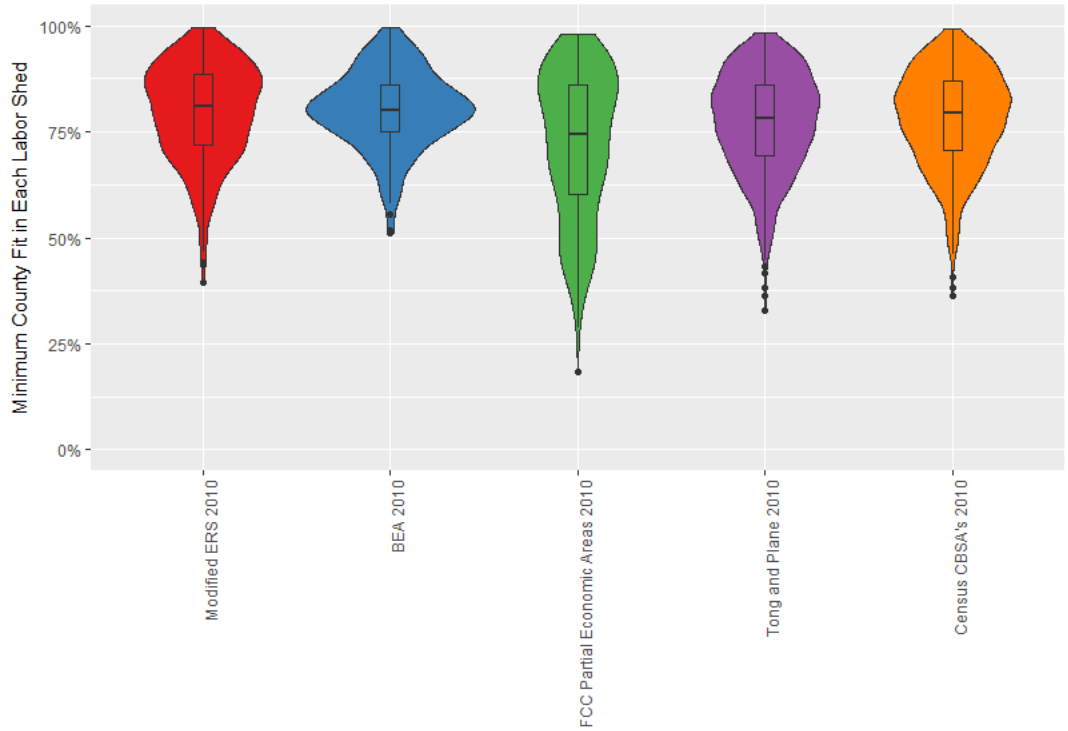

Figure 2: Distribution of fit for least-fitting county in each labor-shed for 2010 delineations

The results conveyed in Table 3 and in Figures 1 and 2 strongly convey the advantages of the BEA Economic Areas as a method for delineating labor-sheds in the United States. Some

researchers may have valid concerns about the size of the regions being too large but the fact that these delineations outperform the others in terms of labor-shed fit and county fit within labor-sheds indicates a clear reason to prefer them.

Fit Statistics for Populations

The final grouping of fit statistics indicates the share of the population that lives and works in the same labor-shed. Rather than providing an average across labor-sheds or across counties as in the previous category, this metric takes the population as its denominator and thereby values the fit of larger labor-sheds over smaller. Each of the delineations performs well on this metric with only small gaps between them. The generally high values in the last column of Table 3 offer significant support for the applicability of the labor-shed concept and its use in regional analysis. While some counties and labor-sheds may not conform well to the theoretical model of a labor-shed it is possible to assign 9 out of 10 people nationwide to a labor shed where they live and work. In the best delineations that number goes up to 98 out of 100.

Geographic Variation in Labor-Shed Quality

Table 3 also provides metrics indicating the degree to which labor-shed fit and county-within labor-shed fit are clustered geographically. Moran's *I* values for labor-shed fit are positive and significant, indicating clustering of like values, but the degree of clustering is not exceptionally high and varies little among the delineations. This result likely indicates that the measure reflects the structural variation in how well the labor-shed concept actually fits population behavior in different parts of the country rather than a difference in the quality of specific delineations (i.e. each of the delineations performs less well in some parts of the country).

While clustering metrics do not provide much of a basis for distinguishing among delineations, a simple choropleth map presented in Figure 3 shows the share of residents who work in a labor-shed, offers clear reasons to prefer the BEA delineation over the others. Figure 3 also provides evidence that at least for the ERS delineation poor fit is not distributed evenly (in geographic terms), it is only that the pattern was at a regional scale and therefore missed by the Moran's *I* metric which focused on only the five nearest neighbors.

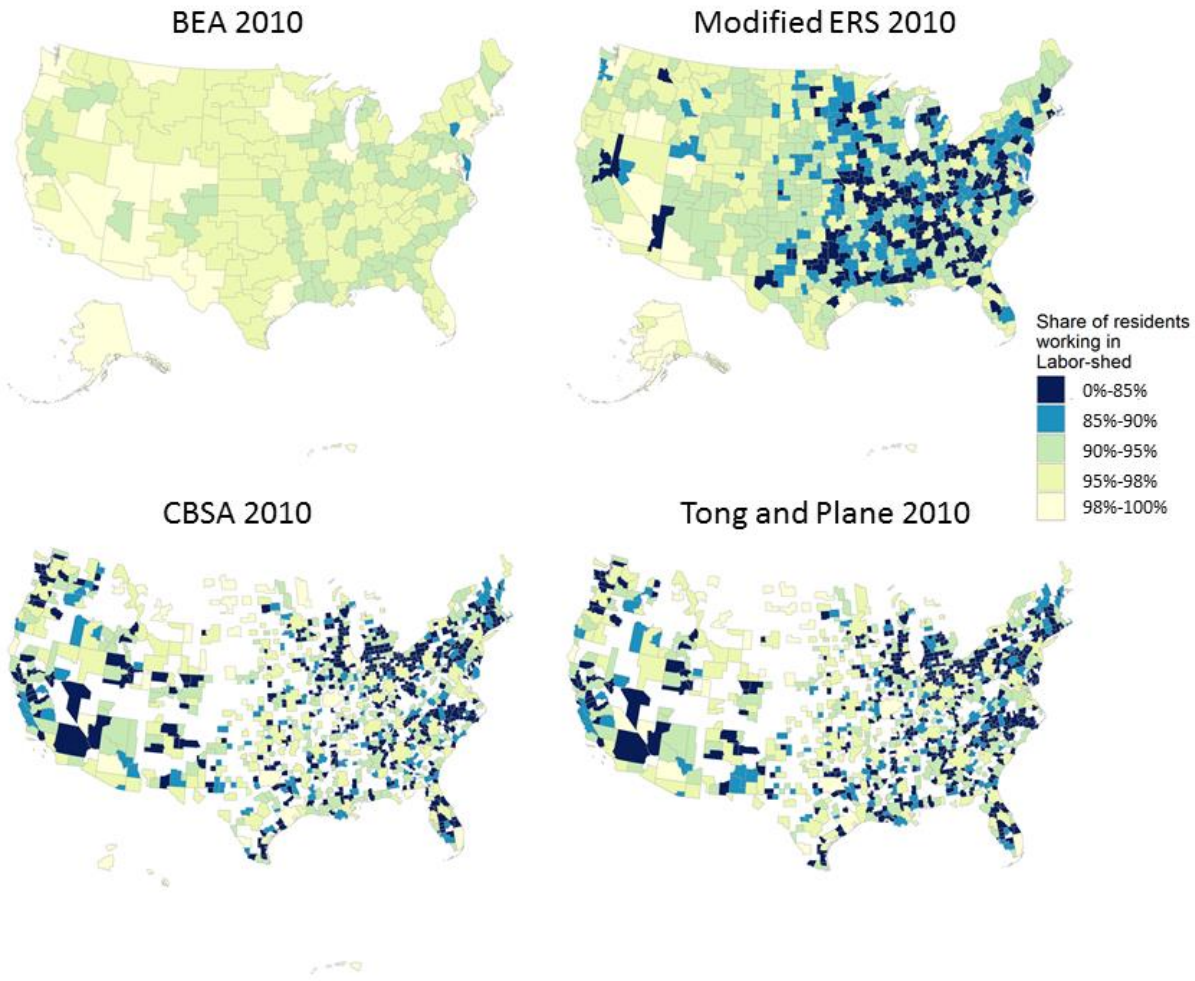

Figure 3: Choropleth map showing the share of residents who work in a labor-shed

7. CONCLUSION

Ultimately, the analysis suggests that researchers should strongly prefer the BEA delineations for regional analysis in the U.S. The effort to exclude less connected, non-metro counties from CBSA delineations causes these units to diverge from the labor-shed concept by not capturing residents with similar commuting patterns and it does not manage to exclude counties where connectivity is low. The exception to this rule may occur when researchers wish to use units with smaller populations. In this case the ERS delineation might serve well. The similarly sized FCC delineation, though meant to be just a smaller version of the BEA Economic Areas, diverges so far from the labor-shed model that it is inappropriate for this type of analysis. Alternatively, if a cross-national comparison is desired, the ERS approach benefits from an easily replicated methodology while the BEA areas with their inclusion of newspaper circulation patterns may be difficult to extend to other locations.

Questions remain as to whether the county is an appropriate unit of analysis for creating labor-sheds. Counties vary tremendously in population and size and their function as sub-units for building labor-sheds must also vary. Census tracts or even block groups might be better suited for this purpose, offering small sub-units and complete coverage of the U.S. population. Future work will explore the differences that emerge when labor-sheds are built from smaller sub-units, but their shortcomings in terms of the amount of economic information made available, mutability of boundaries over time, and limitations in the availability and quality of data, particularly for years prior to 2010 make counties the best choice for regional analysis for most cases.

REFERENCES

Allegretto, Sylvia, Arindrajit Dube, and Michael Reich. 2009. "Spatial Heterogeneity and Minimum Wages: Employment estimates for teens using cross-state commuting zones." Institute for Research on Labor and Employment: Working Paper Series. http://escholarship.org/uc/item/1x99m65f

Armington, Catherine, and Zoltan J. Acs. 2010. "The Determinants of Regional Variation in New Firm Formation," *Regional Studies*, 36(1), 33-45.

Autor, David and David Dorn. 2009. "This Job is 'Getting Old:' Measuring Changes in Job Opportunities Using Occupational Age Structure," *American Economic Review*, 99(2), 45–51.

Beers, Thomas. 2000. "Flexible Schedules and Shift Work, Replacing the 9 to 5 Workday?," *Monthly Labor Review*, 123, 33–40.

Beyers, William. 1992. "Producer services and metropolitan growth and development." in E.S. Mills, J.F. McDonald, and M.L McLean (eds.), *Sources of metropolitan growth.* CUPR/Transaction, pp.125-146.

Bode, Eckhardt. 2008. "Delineating metropolitan areas using land prices," *Journal of Regional Science*, 48, 131–163.

Clemente, Frank and Gene F. Summers. 1975. "The Journey to Work of Rural Industrial Employees," *Social Forces*, 54(1), 212-219.

Cliff, Andrew D. and John K. Ord. 1981. *Spatial Processes,* London: Pion.

Coervers, Frank and Maud Hensen. 2003. "The Regionalization of Labour Markets by Modelling Commuting Behaviour" in 43rd Congress of the European Regional Science Association: "Peripheries, Centres, and Spatial Development in the New Europe", 27th - 30th August 2003, Jyväskylä, Finland.

Coombes Michael. G, Albert E. Green and Stan Openshaw. 1986. "An efficient algorithm to generate official statistical reporting areas: the case of the 1984 travel-to-work areas revision in Britain," *Journal of the Operational Research Society*, 37, 943–953.

Davis, Elizabeth E., Laura S. Connolly and Bruce A. Weber. 2003. "Local Labor Market Conditions and the Jobless Poor: How much does local job growth help in rural areas," *Journal of Agricultural and Resource Economics*, 28(3), 503-518.

Economic Research Service. 2017. "Commuting Zones and Labor Market Areas" Available at https://www.ers.usda.gov/data-products/commuting-zones-and-labor-market-areas/ (Accessed 20 July 2017).

Federal Communications Commission. 2017. "FCC Areas" Available at https://www.fcc.gov/oet/maps/areas (Accessed 20 July 2017).

Fowler, Christopher S., and Rachel Garshick Kleit. 2014. "The Effects of Industrial Clusters on the Poverty Rate," *Economic Geography*, 90(2), 129–154.

Fuguitt, Glenn V. 1991. "Commuting and the Rural-Urban Hierarchy," *Journal of Rural Studies*, 7(4), 459-466.

Gentleman, Robert and Duncan T. Lang. 2007. "Statistical Analyses and Reproducible Research," *Journal of Computational and Graphical Statistics*, *16*(1), 1–23.

Gibbs, Robert M., and G. Andrew Bernat. 1980. "Rural Industry Clusters Raise Local Earnings," *Rural Development Perspectives*, 12(3), 18–25.

Giuliani, Elisa. 2007. "The selective nature of knowledge networks in clusters: evidence from the wine industry," *Journal of Economic Geography*, 7(2), 139-168.

Harris, Thomas R., J. Scott Shonkwiler, George E. Ebai, and Peter Janson. 2000. "Application of BEA Economic Areas in the Development of the Great Basin Fiscal Impact Model," *Journal of Regional Analysis and Policy*, 30(1), 77-94.

Hintze, Jerry L., and Ray D. Nelson. 1998. "Violin plots: A box plot-density trace synergism," *The American Statistician, 52*(2), 181-184.

Huang, Jingnan, Xi X. Lu, and Jefferey M. Sellers. 2007. "A global comparative analysis of urban form: Applying spatial metrics and remote sensing," *Landscape and Urban Planning*, 82, 184-197.

Johnson, Kenneth P. and John R. Kort. 2004. "2004 redefinition of the BEA economic areas," *Survey of Current Business*, *84*(11), 68-75.

Jones, Martin and Anssi Paasi. 2013. "Regional world(s): advancing the geography of regions," *Regional Studies*, 47, 1–5.

Katz, Bruce and Jennifer Bradley. 2013. "The metropolitan revolution: How cities and metros are fixing our broken politics and fragile economy," Brookings Institution Press.

Kaufman, Leonard and Peter J. Rousseeuw. 2009. *Finding groups in data: an introduction to cluster analysis*. New York: John Wiley & Sons.

Killian, Molly and Timothy S. Parker. 1991. "Higher education no panacea for weak rural economies," *Rural Development Perspectives*, 7(1), 2-7.

Kneebone, Elizabeth and Natalie Holmes. 2015. "The growing distance between people and jobs in metropolitan America," The Brookings Institute: Metropolitan Policy Program.

Kropp, Per, and Barbara Schwengler. 2016. "Three-Step Method for Delineating Functional Labour Market Regions," *Regional Studies*, 50(3), 429-445.

Krugman, Paul. (1991) *Geography and Trade*. MIT Press, Cambridge, MA.

Kurban, Haydar, and Joseph Persky. 2007. "Do metropolitan areas with rich central cities experience less sprawl?," *Economic Development Quarterly* 21(2), 179-184.

Li, Wenwen, Richard L. Church, and Michael F. Goodchild. 2013. "An Efficient Measure of Compactness for 2D Shapes and its Application in Regionalization Problems," *International Journal of Geographical Information Science*, 27(6), 1-24.

Lim, Up. 2016. "Regional income club convergence in US BEA economic areas: a spatial switching regression approach," *The Annals of Regional Science* 56(1), 273-294.

Mille, Norman, Vivek Sah, Michael Sklarz, and Stefan Pampulov. 2013. "Is there Seasonality in Home Prices—Evidence from CBSA's," *Journal of Housing Research*, 22(1), 1-15.

Moran, Patrick A.P. 1950. "Notes on Continuous Stochastic Phenomena," *Biometrika*. 37(1), 17–23.

Office of Management and Budget. 2010. "Federal Register: 2010 Standards for Delineating Metropolitan and Micropolitan Statistical Areas," 75 FR 37245, 37245-37252.

Partridge, Mark, M. Rose Olfert, Alessandro Alasia. 2007. "Canadian Cities As Regional Engines of Growth: Agglomeration and Amenities," *Canadian Journal of Economics*, 40, 39–68.

Peck, Jamie. 1989. "Reconceptualizing the local labor market: Space, segmentation and the state," *Progress in Human Geography*, 13, 62–98.

Pew Research Center. 4 November 2015. "Raising Kids and Running a Household: How Working Parents Share the Load." http://www.pewsocialtrends.org/2015/11/04/raising-kids-and-running-a-household-how-working-parents-share-the-load/ (Accessed July 20, 2017).

Pike, Andy, ed., 2011. *Brands and Branding Geographies*, Cheltenham: Elgar.

Plane, David A. 1981. "The Geography of Urban Commuting Fields: Some Empirical Evidence from New England," *The Professional Geographer*, 33(2), 182-188.

Plane, David A., Christopher J. Henrie, and Marc J. Perry. "Migration up and down the urban hierarchy and across the life course." *Proceedings of the National Academy of Sciences* 102.43 (2005): 15313-15318.

Smart, Michael W. 1974. "Labour market areas: uses and definition," *Progress in Planning*, 2, 239–353.

Sole-Olle, Albert and Elisabet Viladecans-Marsal. 2004. "Central cities as engines of metropolitan area growth," *Journal of Regional Science*, 44(2), 321-350.

Tickamyer, Ann and Janet Bokemeier. 1987. "Sex Differences in Labor-Market Experiences," *Rural Sociology*, 53(2), 166–89.

Tigges, Leann M. and Glenn Fuguitt. 2003. "Chapter 12: Commuting: A Good Job Nearby?" in D. Brown and L. Swanson (eds.) *Challenges for Rural America in the Twenty-First Century*. University Park: The Pennsylvania State University Press

Tolbert, Charles, and Molly S. Killian. 1987. *Labor Market Areas for the United States.* Washington D.C.

Tong, Daoqin and David Plane. 2014. "A New Spatial Optimization Perspective on the Delineation of Metropolitan and Micropolitan Statistical Areas," *Geographic Analysis*, 46, 230-249.

United States Census Bureau. 2016. "About Metropolitan and Micropolitan Statistical Areas." Available at http://www.census.gov/population/metro/about/ (Accessed 13 Jan 2017)

---. 2017a. "Geographies" Available at https://www.census.gov/geographies/reference-files/time-series/demo/metro-micro/delineation-files.html (Accessed 20 July 2017)

---. 2017b. "Commuting (Journey to Work" Available at https://www.census.gov/hhes/commuting/data/commutingflows.html (Accessed 20 July 2017).

Van Nuffel, Nathalie. 2007. "Determination of the number of significant flows in origin – destination specific analysis: the case of commuting in Flanders," *Regional Studies*, 41, 509–524.

Wyly, Elvin. 1998. "Containment and Mismatch: Gender Differences in Commuting in Metropolitan Labor Markets," *Urban Geography*, 19(5), 395-430.

Zipf, George K. 1949. *Human Behaviour and the Principle of Least Effort*. Reading, MA: Addison-Wesley.

---

[i] Acquired via personal communication with an ERS employee, and accessed from a CD originally produced by BEA

[ii] Versions of the BEA delineation acquired from the FCC web site appear not to include Alaska and Hawaii, but subsequent delineations provided by BEA do include these areas but grouped into state-wide Economic Areas.

[iii] ERS employee Calvin Beale played a prominent role in adjusting the original 1980 and 1990 delineations, but did not participate in the 2000, or 2010 efforts.