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# A Computational Approach for Defining Metropolitan Employment Centers: Polycentric Urban Form & the p-Regions Problem

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Recent work has suggested a departure from the familiar monocentric city model popularized into a polycentric urban form defined by multiple employment centers that form along regional transportation corridors. Importantly, these studies have demonstrated the ways in which the forces of localization and agglomeration can work together to define a pallette of well-defined employment centers that may specialize in certain industries but nonetheless increase the economic performance of firms that choose to locate inside Despite the important advances in polycentric research, we know little about the properties of these employment centers across the range of metropolitan regions, since the existing research has been constrained to a handful of large metropolitan regions. Thus, in this paper, we employ a novel modification of the max-p algorithm by extending it to incorporate two threshold constraints (satisfying both total employment and density thereof) and applying our method to every metropolitan region in the United States. By leveraging the max-p algorithm we uncover the polycentric urban form in each of America's metropolitan regions and describe the size, shape, and composition of the resulting employment centers. Using these results, we describe how the identified employment centers can be leveraged as the basis of economic development, sustainability, and equitable transportation planning.

## INTRODUCTION

Over the last several decades, American metropolitan regions have borne witness to major economic restructuring as the American economy has shifted from manufacturing and XXX to a service and knowledge-based economy. Concurrent with these trends is a less severe but equally important restructuring of the *spatial structure* of American employment, as certain industries have begin gravitating toward more suburban locations to be nearer to their employment bases, whereas other industries are flocking to inner cities. These trends suggest a critical reckoning for the study of agglomeration economies that provides the foundation of modern urban economics and regional science. Recent work has suggested a departure from the familiar monocentric city model popularized by Muth (1969) into a polycentric urban form defined by multiple employment centers that form along regional transportation corridors (Knaap et al. 2016; Giuliano and Small 1991). Importantly, these studies have demonstrated the ways in which the forces of localization and agglomeration can work together to define a pallette of well-defined employment centers that may specialize in certain industries but nonetheless increase the economic performance of firms that choose to locate inside. Furthermore, more recent evidence has demonstrated that these employment centers also provide a range of benefits for achieving global sustainability such as reduced transportation costs and lower trip durations.

Despite the important advances in polycentric research, we know little about the properties of these employment centers across the range of metropolitan regions, since the existing research has been constrained to a handful of large metropolitan regions. Existing work often adopts a relatively simple definition of an employment center: a set of contiguous spatial units whose combined total employment and employment density meet some pre-defined thresholds. But this process of identifying employment centers is prohibitively laborious, since it requires the tedious and iterative process of aggregating spatial units, testing whether each constraint is met, then re-aggregating and testing again. Luckily, over the last decade, a family of "regionalization" algorithms has grown from the tradition of spatial optimization which excels at identifying the maximum number of $p$-distinct regions (Duque, Church, and Middleton 2011) in a spatial dataset. Thus, in this paper, we employ a novel modification of the max-p algorithm by extending it to incorporate two threshold constraints (satisfying both total employment and density thereof) and applying our method to every metropolitan region in the United States (Duque, Anselin, and Rey 2012)

As a result, we identify a set of American employment centers at a national

scale. By leveraging the max-p algorithm we uncover the polycentric urban form in each of America's metropolitan regions and describe the size, shape, and composition of the resulting employment centers. Using these results, we describe how the identified employment centers can be leveraged as the basis of economic development, sustainability, and equitable transportation planning.

## SPATIAL STRUCTURE AS A VEHICLE FOR URBAN POLICY

Large portions of urban planning, regional science, and economic geography research are devoted to understanding how spatial patterns like development intensity and the separation of land uses influence social and economic activities. Part of this work is focused on patterns like urban sprawl, and the effect they have on GHG emissions, housing prices, and social welfare. Another–much older–portion of this work focuses on measuring form to understand the optimal location of resources to maximize economic output

Regardless of the perspective, the literature from across the many disciplines makes clear that urban policy measures are often designed to reshape urban form explicitly, or to make the most of existing form to capitalize on the social, economic, and environmental benefits.

### *The Monocentric Model*

von thunen, muth, mills, brueckner; agglomeration as a foundation of urban economic and economic development policy.

public transportation and transportation efficiency more generally

### *Polycentric Urban Development*

More recently, especially in newer cities like LA, polycentrism rather than monocentrism is the norm. Giuliano & small show this works well for economic development. On the other hand public transportation is notoriously difficult in LA because its so spread out. (More rencnt eamples of it working??)

In DC, and Baltimore, polycentrism seems to work for both economic development *and* transportation, with cascading environmental benefits as a result Knaap et al. (2016)

So polycentrism is not only an important and useful model for encouraging both growth and sustainability, but it also may be emerging as the dominant urban form in the US and across the world.

## URBAN SPATIAL STRUCTURE AS A *P*-REGIONS PROBLEM

the p-regions problem Duque, Church, and Middleton (2011)

max-p is a particular version of the problem Duque, Anselin, and Rey (2012)

recently a number of extensions to max-p have been explored She, Duque, and Ye (2017) Duque, Vélez-Gallego, and Echeverri (2018)

Li, Church, and Goodchild (2014) the p-compact-regions problem for urban economic modeling

Here, we propose a novel extension of the max-p regions *idea*. In this case, the modification is

## MODIFYING MAX-P TO IDENTIFY URBAN POLYCENTERS

In the original formulation of the p-regions problem, a study area is comprised of a set of polygons that must be aggregated to form the largest number of aggregate regions, subject to certain constraints. Here, every unit in the study area should be assigned to a particular region until the study space is partitioned fully. In the case of identifying employment centers, however, the original p-regions formulation requires two important extensions. First it is not appropriate to partition the entire study space

In the classic max-p problem, regions are identified by (1) satisfying a threshold constraint, and (2) optimizing some objective function, which is typically multivariate similarity among the enclave's attributes. When identifying employment centers, however, this objective function assumes the form of a second constraint; here the alogirthm must satisfy the total employment constraint within the region, but also must satisfy an employment density criterion.

If we take employment density as the objective to optimize

## POLYCENTRIC URBAN FORM IN AMERICAN METROPOLITAN REGIONS

*Quantity, Shape, and Configuration*

- radial centers around a central blob (i.e. new centers along transportation corridors extending from an original mono center a la baltimore)?
    - long and extended along transpo lines? (like I-270)
    - round and compact in walkable dense nodes? (like bethesda)

- distinct subnodes without an original center (a la LA?)
- relationship between city size, population size, or econommy size and number of centers?

*Composition*

*Evolution over time* ???

(this would be really cool but would extend the scope a lot)

## DISCUSSION & POLICY IMPLICATIONS

## CONCLUSION

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