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Economic performance of spatial structure in Chinese prefecture regions: Evidence from night-time satellite imagery

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ABSTRACT

This paper examines the causal link running from spatial structure to productivity in Chinese prefecture regions. Specifically, we investigate whether mono- or polycentricity leads to higher productivity in the context of China. We use satellite-derived data of night-time lights as a measurement of spatial structure to avoid potential measurement errors. While our descriptive statistics show that Chinese city-regions at the prefectural level have a weak tendency towards polycentricity from 2000 to 2010, regression models reveal that a more monocentric spatial structure performs better in terms of labor productivity, a result that a stricter two-stage least square estimation supports. Thus, we advise caution for urban plans and policies encouraging polycentric urban development, which may come at the loss of economic efficiency.

1. Introduction

It has long been simply taken for granted that polycentric spatial structure is an effective tool for urban planners and policy makers to enhance regions' competitiveness and environmental sustainability. While satellite/new towns and edge cities are early versions of polycentric-oriented planning concepts, ESDP, ESDPON and POLYNET are well-known polycentric development strategies in contemporary Europe. An increasing number of developing countries try to borrow this idea and follow this polycentric spatial pattern. For example, megacities in China, such as Beijing, Shanghai, and Guangzhou, have developed a series of new towns or edge cities under the guidance of polycentric development strategies in the last two decades (Liu, Derudder, & Wu, 2016; Sun, Tu, & Shi, 2013; Wen & Tao, 2015). However, the outcomes appear far from what policy actors expected. New towns lag in development and central cities continue to grow as rapidly as before. In fact, there is a lack of empirical examination of the performance of spatial structure. The few studies that do exist focus mainly on the U.S. and Europe (Cervero, 2001; Lee & Gordon, 2007, 2011; Meijers & Burger, 2010; Veneri & Burgalassi, 2011; Tresserra, 2016). At the same time, cities in developing countries, which are experiencing the most rapid urbanization and try to follow this polycentric development as they grow, have hardly been examined (Zhang, Sun, & Li, 2017; Zhao, Diao, & Li, 2017).

The first step in evaluating the impact of spatial structure is identifying spatial structure. Most measurements, especially those focused on morphology, are based on population/employment distribution based on data governments' statistical bureaus collect. Such data are prone to three measurement issues: (1) Measurement errors occurring when agencies collect population data based on arbitrary administrative boundaries, which are exacerbated when the study units are administrative areas incongruent with the actual urban agglomerations (e.g. metropolitan areas). Bounded by legal definitions, administrative boundaries may divide populations that actually co-located within an agglomeration into different subunits. This can generate arbitrary border effects, an issue related to what the literature calls the Modifiable Areal Unite Problem (MAUP), or shape-induced MAUP. Furthermore, administrative boundary changes over time as the result of jurisdictional restructuring, making contrastive analysis of different years difficult. (2) Spatial resolution of population data is limited. Compared with general statistics yearbooks, data derived from census are more accurate and reliable. Even for the latter, however, the availability of detailed population data is constrained. For example, The Chinese census still cannot provide accurate population data in county's built-up area. (3) Measurement errors may come from inaccurate and unreliable population data, which is especially serious in China's general statistics yearbooks. The most widely reported population data for provinces, prefectures, and counties in China are de jure measures of

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where people are legally registered to live under the *hukou* system, rather than measures of where they actually live. What's worse, this counting error is, proportionately, larger at finer spatial scales such as prefectures and counties.

In response to the problems in measuring spatial structure, we employ a unique and independent database: the amount of light that can be observed from outer space. A number of researchers, especially in the field of remote sensing, have begun to analyses DMSP/OLS night-time imagery to estimate population (Sutton, Roberts, & Elvidge et al., 2001; Amaral, Monteiro, & Câmara et al., 2006), or model population distribution (Bhaduri, Bright, & Coleman et al., 2007). However, most of these studies focus on describing the phenomenon without further exploring any causal relationship. Different from previous studies, we use night-time lights data to measure spatial structure to avoid the defects of demographic data, and then explore the causal link running from spatial structure to economic performance. In order to confirm this causality, we use two-stage least squares (TSLS) regressions with an instrumental variable to deal with the potential issues of endogeneity. Our main findings show that a more monocentric spatial structure performs better in terms of labor productivity in China's prefectural-level city-regions, which may serve as an important warning for urban plans and policies aiming to promote polycentric urban development.

This study contributes to the literature in at least two important ways. First, it provides robust empirical evidences on whether polycentric spatial structure is an effective tool in enhancing regions' economic productivity in the context of a typical developing country. This debate on the effects of spatial structure on productivity has not been well settled, and it is especially the case in the developing countries. The second set of contribution is methodological. We employ night-time satellite imagery as a new way to identify spatial structure, following an approach which has been used in urban remote sensing, but seldom in urban economics. A satellite-derived dataset of nighttime lights is a good way to address potential measurement issues. We also take great care of potential endogeneity problems with a historical instrumental variable.

The remainder of this paper is organized as follows. Section 2 introduces the theoretical and empirical background on the relationship between spatial structure and economic performance. The measurement of spatial structure is presented in section 3. This is followed by a discussion of the model, data and estimation strategy in section 4, after which we present our results in section 5. Section 6 concludes with our main findings and limitations.

2. Spatial structure and economic performance

There is a long-running controversial debate about monocentric and polycentric oriented spatial structure and their relationship to economic performance. The proponents of monocentric-oriented spatial structure base their argument on limited effective scope of agglomeration (Rosenthal & Strange, 2004; Veneri & Burgalassi, 2011). Agglomeration economies allow firms and individuals to take advantage of the sharing of indivisible goods such as public infrastructure facilities, the learning or spillover of local knowledge, and the better matching between employees and employers, buyers and suppliers, and so on (Marshall, 1890; Duranton & Puga, 2004). Advocates of the monocentric development argue that because the advantages of agglomeration may be confined to limited geographic area (Rosenthal & Strange, 2004), proximity is the most important determinant in preventing the attenuation of agglomeration economies: if agents are physically closer, then there is more potential for interaction (Ciccone & Hall, 1996; Ciccone, 2002; Melo, Graham, & Levinson et al., 2017). Conversely, a polycentric urban region generally implies longer travel and commodity flows (Parr, 2004; 2008), a strong shortcoming of polycentricity. These literature provide extensive empirical evidence to support the link between better economic performance and monocentricity (Brülhart & Sbergami, 2009; Vandermotten, Roelandts, & Cornut, 2007; Veneri & Burgalassi, 2011).

The monocentric view is not without its critiques, and there are good grounds for arguing that polycentric spatial layouts can perform better in terms of productivity. First of all, based on the concept of 'borrowed size' (Alonso, 1973), smaller cities within a polycentric region can take advantage of agglomeration economies without meeting the critical mass themselves. These cities can 'borrow' size from nearby, larger cities through effective and dense regional networks. Second, and more importantly, a polycentric region can enjoy agglomeration economies without incurring the same costs as a similarly sized monocentric region. Polycentricity has the potential to significantly decrease agglomeration diseconomies such as environmental pollution, crime, or high housing price, which explains their appeal (Lin, Allan, & Cui, 2015; Meijers & Burger, 2010). The advantage of polycentricity derives from agglomeration diseconomies being local issues confined largely to the scale of individual cities (Parr, 2002). When paired with the possibility of smaller cities having a greater endogenous capacity to keep social, economic, and environmental costs under control (Capello, 2000), polycentricity acquires a distinct advantage in keeping agglomeration cost down. Finally, salient research provides evidence that the positive link between spatial structure and higher labor productivity is not limited to monocentricity, empirical studies show similar results for polycentricity (ESPON 1.1.1, 2004; Meijers & Burger, 2010; Garcia-López & Muñiz, 2013; Veneri & Burgalassi, 2012; Meijers, 2013).

Based on the foregoing review, it is clear that both monocentricity and polycentricity can have positive or negative effect on regional economic performance, and it depends on which one can provide a better balance between agglomeration advantages and agglomeration disadvantages. In the remainder of the paper, we ascertain which side of the balance Chinese prefecture regions fall on.

3. Quantifying spatial structure

Spatial structure is "an abstract or generalized description of the distribution of phenomena in geographic space" (Horton & Reynolds, 1971). The 'phenomena' often refer to population or employment, and their distribution is a long-term process involving locational preferences of agents. Furthermore, the spatial structure of a particular region is multi-faceted. It can be described as sprawled, compact, decentralized/centralized or polycentric/monocentric (Anas, Arnott, & Small, 1998; Glaeser & Kahn, 2004; Meijers & Burger, 2010). This paper focuses only on the monocentricity-polycentricity dimension, which is one of the most important attributes of spatial structure and reflects the extent to which population and employment are concentrated in one city or spread over multiple cities in the wider region.

3.1. Night-time lights data

To measure regional spatial structure, or the extent of regional monocentricity/polycentricity, we first need to find an accurate and reliable population or employment data source. Considering the three problems we discuss in the introduction, we turn to the stable night lights data from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS).[1] Provided by the National Oceanic and Atmospheric Administration-National Geophysical Data Center, the DMSP-OLS data uniquely measure light on earth's surface. This dataset reports a digital number (DN) ranging from 0 to 63 for each cell, which is a record of the percent visible and near-infrared light intensity in a given location. When extracting light mosaic images to serve as a proper proxy measure for population, we must first determine a threshold value to decide what light intensity should be used. Despite the growing interest in using this type of data for studying spatial

[1] Available from http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html (Apr. 2017).