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The spatial and temporal dynamics of infrastructure development disparity – From assessment to analyses

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ABSTRACT

Infrastructure development relies on the allocation of resources which is usually uneven across cities. Socioeconomic instability stems from such development disparity that consequently affects the decision processes focusing on sustainable development. This study proposes an approach to examine the temporal dynamics of infrastructure development disparity at multiple spatial scales. Starting from the selection of spatial scales, time-series and infrastructure development indicators fitting the study requirements, the Infrastructure Development Index (*IDI*) values are computed through sequential steps involving data normalization and assessment of indicator weights through analytic hierarchy process. The sectoral, *IDI* and disparity analyses are then carried out using coefficient of variance (C_v), temporal *IDI* value change, and C_v/sample *t*-test methods, respectively. The methodology was applied to a case study area, the five city districts (Faisalabad, Gujranwala, Lahore, Multan and Rawalpindi) of the province of Punjab, Pakistan, at town, city district and province scales (the province scale encompassed only the five city districts). Three time periods (2002, 2007 and 2012) and five infrastructure development indicators were considered. The results show that the development status in Lahore (provincial capital) was better compared to the other city districts. The temporal trend, however, indicated that the provision of infrastructure facilities has improved in the study area over the past years. The proposed methods performed quite well at identifying the development gaps at multiple spatial scales, though the approach can be enhanced by incorporating more indicators.

1. Introduction

Development disparity can be defined as an unequal distribution of resources with respect to an area or population, and is considered unfavorable for economic growth (Rouf & Jahan, 2007). It is seen as a pressing issue in the modern world as it promotes social injustice and environmental degradation. Infrastructure is one of the core sectors which directly or indirectly determines the socioeconomic development condition of a region (Holtz-Eakin & Schwartz, 1995). World Bank delivered evidences that infrastructure played a crucial role in urban transformation (Kessides, 1993). Moreover, substantial linkages have been found between infrastructural services and socioeconomic development (Esfahani & Ramírez, 2003; Mangone, 2016). Coordinated infrastructure projects are thus considered to offer balanced and stable regional development between urban and rural areas in terms of social welfare, economy and environment (Mangone, 2016; Shen, Jiang, & Yuan, 2012).

Urbanization is viewed as a negative thing by some researchers (Gordon & Richardson, 2000; Habibi & Asadi, 2011), while others consider it positive for regional development (Roberts & Kanaley, 2006). Rapid population rise and haphazard urban development often results in a decrease in open spaces, urban decay, increase in land prices and transportation costs, unemployment and degradation of environment (Gordon & Richardson, 2000; Jaeger, Bertiller, Schwick, & Kienast, 2010) – some researchers, however, have also identified a positive relationship between urbanization and human development (Njoh, 2003). On the other hand, metropolitans/cities are seen as embodiments of civilization and engines of economic development (Pelling, 2003), and are therefore favored over secondary cities and other urban settlements in general (Roberts, 2014). However, the important thing is to strike a balance between urban growth and quality of life.

The urban-rural divide appears to be growing as urban areas are considered more developed as compared to rural settlements across the world (Lu & Chen, 2004). However, since the development varies across space and time, the comparative development often varies even among the urban areas. This can be explained by characterizing urban centers into primary and secondary cities. A primary city can be defined

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as an area that is disproportionately larger than any other urban hierarchy, and a leading city in its country or region (Goodall, 1987). Secondary cities, on the other hand, are defined based on population size, administrative extent, political, economic, and historical importance, and are smaller than the primary cities (Roberts & Hohmann, 2014; Rondinelli, 1983). A few capital cities/metropolitans take away large amounts of budgets and resources, and the secondary cities, which are more in number, are left with fewer resources for development and maintenance. This trend shows government biasness towards certain cities with political concentration, and accumulation of wealth and resources, which eventually leads to concentrated infrastructure development in the urban centers. As a consequence, an upsurge in migration and population occurs in big cities which further increases the demand for resources. This inequality sometimes provokes public protests for fair and balanced development across regions. Although governing bodies try to enact policies to restrict inequalities, they usually fail to implement them on ground (Roberts, 2014).

Sustainable development has been a huge concern for Pakistan. The country ranked quite low in the Human Development Index (HDI), 147th out of 188 countries (UNDP, 2015). In the province of Punjab (the largest in terms of population), rapid urbanization is taking place along with lopsided and haphazard development (Mayo, 2012). To tackle this, separate Development Authorities (DAs) were set up in the large cities of Lahore, Gujranwala, Rawalpindi, Multan and Faisalabad at different times under the Development Cities Act of 1976 (Ahmad & Anjum, 2012). This Act allowed the government to grant powers to the DAs, in addition to Town Municipal Administrations (TMAs), to ensure planned urban growth through building control, and to provide infrastructure utilities in their respective areas. Moreover, the Punjab Local Government Ordinance of 2001 coined these five cities as 'city districts' and empowered the local administrations to take development initiatives (Government of Punjab, 2001). Although the goals 9 and 10 of global Sustainable Development Goals (SDGs) developed by the United Nations suggest developing resilient infrastructure and reducing inequality within countries (ICSU & ISSC, 2015), the national development plans in Pakistan are oriented more towards infrastructure development than socioeconomic growth (Rana, 2014). This calls for an immediate evaluation of the development disparity to ascertain sustainable growth in the region.

The development progress can be studied using a wide variety of methods. Several spatial techniques like Global Moran's I, Geary's C and Local Indicators of Spatial Association (LISA) can be used to relate indicators with space that can help ascertain spatial inequalities (Duncan et al., 2012; Gutiérrez & Delclòs, 2016). However, analyzing the spatial and temporal dynamics of infrastructure disparity at multiple spatial scales has not been carried out using these techniques. Indices, on the other hand, have been widely used and accepted – some of these have been explicitly formulated to measure inequalities and disparities (Ahmad, Ludlow, & Mahmood, 1989; Hicks, 1997; Jamal & Khan, 2007; Lee, Choi, & Im, 2013). A commonly used measure is the Gross National Product/Gross Domestic Product (GNP/GDP) per capita for assessing the economic growth which helps in comparing effective development across regions. Other indices like HDI (Anand & Sen, 1994), Gini inequality index (Dadashpoor, Rostami, & Alizadeh, 2016; Yitzhaki, 1983), Theil Index (Lee et al., 2013; Theil, Raj, & Koerts, 1992) and inequality adjusted HDI (Hicks, 1997) have also been used to compare inequalities. Quality of life has also been used to examine the development levels among settlements. Indices like physical quality of life index (Morris, 1979), World Health Organization's quality of life (The WHOQOL Group, 1998) and index of well-being (Bobbitt, Green, Candura, & Morgan, 2005) have been developed and employed. Regional inequalities and disparities have been measured in the local context by numerous authors on the basis of poverty and income (Ahmad et al., 1989), social wellbeing and quality of life (Bhatti, Tripathi, Nagai, & Nitivattananon, 2016; Nawaz-ul-Huda, Burke, & Azam, 2011), education (Ghaus & Pasha, 1996) and health (Midhet, 2004). Jamal & Khan (2007) developed HDI for each district of Pakistan to present a comparative picture of development at district level. However, limited studies have exclusively examined the infrastructure sector in the urban areas at a sub-district scale.

The selection of indicators/variables is the most critical part of defining an index (Williamson, 1965). The indicators data is normalized using data standardization techniques, whereas weighting techniques (objective and subjective) are employed to obtain the cumulative indices values (Khan, 2012; McCrea, Shyy, & Stimson, 2006). The weights can be derived through opinion of the experts and/or previous empirical studies, and represent the relative importance of each factor based on its influence on development. Decision making techniques such as analytic hierarchy process (AHP) can be used for allocation of weights (Saaty, 1980). The composite index conjugates all the heterogeneous data into one reliable source of information. Various statistical tests, such as *t*-tests and coefficient of variances, can then be applied to observe and compare the differences among regions to measure the disparity. The two main objectives of this study are to: (1) develop an approach for examining spatiotemporal infrastructure development disparity at multiple scales; and (2) examine the spatiotemporal infrastructure development disparity in the city districts of Punjab province, Pakistan through the proposed approach.

2. The approach for analyzing infrastructure development disparity

An important aspect of the proposed approach is the integration of space and time to look at the infrastructure development disparity at multiple spatial scales. Three dimensions are therefore addressed: (1) multiple spatial scales – Tier-1 (smallest units and most detailed) … to Tier-N (largest single unit); (2) space – variation across space; and (3) time – variation across time. The framework of the proposed approach is presented in Fig. 1.

The overall approach comprises three sequential phases; the first two primarily deal with the selection of spatial-temporal scales and development indicators, and computing the Infrastructure Development Index (*IDI*), whereas the final phase involves performing different analyses to examine infrastructure development disparity at multiple spatial scales (Fig. 1(a)). The dimension of space is presented as x-y plane, whereas that of time as multiple spatial layers (Fig. 1(b)). The multiple spatial scales refer to the smaller/detailed spatial units (Tier-1, Tier-2, …) and larger/general spatial unit (Tier-N), where the smaller spatial units aggregate to form the larger spatial unit (Fig. 1(c)). The quantity of spatial layers of time and spatial scales depends on the availability and level of detail of the data.

2.1. Phase 1: selection of spatial scales and time-series infrastructure development indicators

The selection of spatial and temporal scales for examining infrastructure development disparity is quite relative, and depends on factors such as the indicators being used to assess the development and availability of data. The selection of indicators itself is linked to the local development context and availability of time-series data. Table 1 presents general guidelines that can be consulted while selecting the spatial and temporal scales, and the indicators.

2.2. Phase 2: assessing the IDI values

The next step involves processing the data through three sequential steps: (1) data normalization – standardizing all the data to a common quantitative scale; (2) indicator weights computation – assessing the relative importance of each indicator; and (3) *IDI* computation – application of weights to the normalized data.

Data standardization is quite important as the quantitative scale and data sources might not be the same for all the datasets. There are a variety of methods for normalizing quantitative data such as Transformed