Resilience, Network Connectivity and Regenerative Economy:

A Study in the Western Balkans

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Extended Abstract

Objective

This study explores economic resilience and network connectivity in the Western Balkans within the framework of a regenerative economy. Economic resilience is the capacity of a system to absorb shocks or recover from shocks by reaching new equilibria. However, 'too strong absorbing states' could lock-in people or actors in pattern behaviours precluding any positive evolution. Thus, the 'optimum' resilience is still an open research question (Reggiani et al., 2002). Regenerative economy is a wider 'umbrella', since it relates to the ability of a system to remake or renew itself continuously. Regenerative economy can revitalize resilience. In this regard, network connectivity seems to play a significant role, which is worth examining. Consequently, the objective of the present work is on understanding the role of network connectivity and accessibility not only in the evolution of resilience but also in the development of regenerative economic structures in urban areas.

From the measurement viewpoint, traditional measures, by analysing resilience at the regional/national level, omitting spatial interaction effects, often fail to capture the relationship between economic resilience and network connectivity. This study proposes a novel approach using open-source geospatial and population data to analyze resilience at the urban level, and regenerative economies quantified by the availability of green amenities in Balkan cities where data is limited. Methodological links between resilience, network connectivity, and the

regenerative economy are examined. Urban variation in resilience is influenced by network connectivity and accessibility, as the effects of a shock can either be mitigated or amplified.

Demographic changes are studied over ten-year periods from an intra-and inter-urban perspective, with population data available for two time points, roughly from 2012 to 2022. Although each Balkan city has slightly different periods of data availability due to national census schedules, this timeframe provides a basis for analyzing long-term trends in resilience. In contrast, OpenStreetMap (OSM) data is cross-sectional, representing a snapshot of the current distribution of amenities. In this paper, regenerative economies are understood as the presence of sustainability-related infrastructure, such as green amenities, renewable energy stations, environmental monitoring stations, and waste recycling facilities in Balkan cities. We analyze the impact of this infrastructure on resilience.

Variables

A new approach is tested to facilitate the study of resilience and networks in urban contexts where data is scarce, such as in the Balkan areas. Long-term economic resilience is analyzed through the over-time population change. Longitudinal census data is used to generate datasets that capture urban development across different countries. Open Street Map and equivalent sources provide transport network data connecting different urban areas. Additional variables describing urban features and economic opportunities are generated using open map resources. Network connectivity is measured by distance between all pairs of origins and destinations, combined with data on population at destinations. It allows the estimation of potential accessibility from all origins to all included destinations. Accessibility, considered as 'potential accessibility' (Hansen, 1959), is used for weighting network connectivity. Population change, interpreted as socio-economic resilience, is used as a dependent variable, with contextual variables generated from open data for both origin and destination.

Methods

Weighted Least Squares (WLS) regression is applied to study the relationship between population change over time within and between cities, network structure measured by road network with a decay factor, and contextual variables. Since mobility data is unavailable for the Balkans, asymmetries in population change between cities serve as a proxy measure. Network connectivity is defined using real road networks between cities, with a decay function that ensures interaction decreases with distance. The decay factor is calculated using half-life models as detailed in Östh et al. (2016). Spatial decay can be represented in various ways, including cost, time, and metric distance between features. While distance decay parameter is often estimated using observed flows, this study employs mathematical functions instead. Since flow data between OD pairs is unavailable, mathematical specifications of distance decay are used in three forms: negative exponential, log-normal, and inverse distance. The negative exponential function estimates opportunity in the destination using a form suited for short to medium commuting distances. The log-normal function is used for regional travel and migration and follows a similar structure to a power function.

Data

Data is derived from Eurostat, Open Street Map (OSM), and national census statements (2012 and 2022). OSM describes infrastructure and points of interest (POI), which include locations such as schools, banks, cafés, and playgrounds. The dataset contains approximately two million POIs in the Western Balkans. The obtained datasets are used to generate key variables. Population change is expressed as the percent change between two census years, which most often represent 2011 and 2021, but may also include 2011 or 2023, depending on the census dates in each country.

To incorporate regenerative economies into our analysis, we will employ OpenStreetMap (OSM) data to identify and map key green amenities, including renewable energy stations, environmental monitoring stations, and waste recycling facilities. These variables will allow us to assess the role of sustainable infrastructure in urban resilience and network interactions. By integrating these factors into our spatial models, we aim to examine whether cities with stronger regenerative economic structures exhibit greater socio-economic resilience.

Destination population gravity is estimated between each origin-destination pair using three specifications of network connectivity (exponential, log normal and inverse distance). Distance decay parameters are specified under the assumption that median mobility distance can be approximated. A median distance of 50,000 meters is suggested, following the calculation methods in Östh et al. (2014, 2016).

Using Open Street Map data, kernel density functions estimate the concentration of various urban features such as culture, hospitality, financial establishments, and child-rearing facilities. Values for each city are estimated at the city midpoint. Population census functions classify relationships between origin-destination pairs based on language similarity. Line density is determined by summing infrastructure within a 5 km radius from midpoints of urban areas to establish a measure of infrastructure density as a proxy for urban density.

Results

Since mobility data is unavailable for the Balkans, asymmetries in population change between cities serve as a proxy measure. Network connectivity is defined using real road networks between cities, with a decay function that ensures connectivity decreases with distance. Negative exponential, log-normal, and inverse distance functions are tested to compare different specifications. The related results will provide city rankings also in terms of resilience.

The estimated distance decay parameters reflect the assumed median mobility distance, with results indicating that accessibility to urban features such as financial institutions, cultural centers, and childcare facilities influences population change over time.

The relationship between infrastructure density, green amenities as proxies of regenerative economies and population change suggests that urban areas with higher connectivity and accessibility both in general and from a regenerative sense tend to exhibit greater economic resilience. The weighted regression models highlight the significance of destination accessibility and most importantly in shaping urban development patterns.

All in all, the models used in this study apply importance weighting in the regressions, with variables defined for both origin (home) and destination cities. Different model specifications are employed to examine the relationship between network characteristics, accessibility, and resilience. Cultural amenities, financial institutions, child-rearing facilities, and road network density are considered in relation to population change over time. The analysis specifically incorporates proxies for regenerative economies, including green amenities, renewable energy stations, environmental monitoring stations, and waste recycling facilities, to assess their role in resilience. Variations in findings across model specifications highlight differences in how distance influences network connectivity. When using a negative exponential function, shorter distances have a stronger effect, influencing the role of cultural amenities and accessibility. The inverse distance specification produces results that align closely with the lognormal specification, reinforcing the overall patterns observed in the study.

Preliminary Conclusions

We have proposed a method integrating data generation with spatial models for analyzing resilience, network connectivity and regenerative economies in urban areas where data is scarce. The data used in this study is derived from open sources or national and EU censuses. Network connectivity is often analyzed using flow data, but by employing an alternative formulation, we estimate interaction without direct flow observations. Our findings indicate that a log-normal functional form best describes network connectivity decay. Additionally, the method performs reasonably well in explaining long-term population changes in the Western Balkans.

Regenerative economies emphasize circular resource use and environmental resilience (Velenturf and Purnell, 2021). By integrating proxies such as green amenities, renewable energy stations, environmental monitoring stations, and waste recycling facilities, we assess how urban network structures correlate with regenerative economy. In particular, our results suggest that these features enhance socio-economic resilience, reinforcing the role of regenerative economies in shaping long-term urban development.

Finally, in addition to the analyses described above, we aim to examine the relationship between "optimal resilience" and regenerative economies using a quantile regression framework. These results will pave the way for the analysis of new methodological perspectives on resilience, network connectivity, and regenerative economy.

Keywords: Population Dynamics, Urban Resilience, Network Connectivity, Spatial Analysis, Regenerative Economics

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