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SPATIAL ECONOMIC RESILIENCE AND ACCESSIBILITY: A JOINT PERSPECTIVE

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Abstract

In most studies of economic resilience much effort is attributed to the development of factors and measures representing economy and related resilience. In this context, a great deal of attention is paid to the role of regions and to their abilities to withstand an economic shock. Usually, however, less attention is given to the size, distribution and interaction of regions, containing the underlying statistics used in calculation of resilience factors. In this article, we argue that more attention to choosing spatial units is necessary in order to increase the potential of resilience measures. In particular, we consider a smaller spatial unit, such as the municipality level, in order to better visualize resilience's variations. In addition, by complementing measures of resilience with a measure of accessibility, we aim to depict the municipality's economic function. Experiments are carried out with reference to the system of the 290 municipalities in Sweden.

Our municipality-level analyses reveal that: a) proxies of resilience and accessibility, in general, are positively and significantly correlated, and that the estimated most resilient and accessible municipalities also are the major economic centres in Sweden; and that b) the municipality position in ranks of proxies for the resilience and accessibility is more useful for the classification of differently resilient municipalities than by classifying municipalities using resilience alone. For instance – whereas high proxy-values for resilience and high accessibility municipalities often are both job and population rich, municipalities with low resilience estimates and high accessibility can typically be depicted as suburb- and commuting municipalities in metropolitan areas. Whilst municipalities with estimates of poor resilience and poor accessibility in general can be used to categorize remote municipalities experiencing population loss, municipalities estimated to have low resilience and high accessibility are characteristics for municipalities increasing in population.

All in all, this joint analysis combining estimates of resilience and accessibility can be considered a suitable tool for providing a more complete insight into the economic investigation and measurement of resilience.

Keywords: resilience; accessibility; socio-economic indicators; Swedish municipalities

***Highlights (for review)**

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- Proxies for the measurement of resilience (in this case economic resilience) correlates with accessibility – i.e. accessible areas are often also more resilient than less accessible municipalities.
- A joint analysis of resilience and accessibility can be useful to identify municipalities that are vulnerable – since accessibility can bridge lack of resilience in municipalities close to major employment centers, and vice versa in more desolate areas.
- A joint analysis of resilience and accessibility allows for the usage of disaggregate statistics.

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**REGIONAL ECONOMIC RESILIENCE AND ACCESSIBILITY:
A JOINT PERSPECTIVE**

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Abstract

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1. Introduction

Both resilience and accessibility can be described as amenities that are highly sought-after and economically important. This because high resilience indicates that the location in question have a better chance of withstanding an economic shock, and high accessibility (in this case to surrounding jobs) means that it is possible to reach a good number of jobs within commutable times. Usually resilience is valuated measuring or estimating regional assets in

terms of diversity in industry and skills, availability to learning institutions and financial institutes, modern infrastructure, open-minded, innovative and creative workers, good health, female empowerment, integration into global economy and a lack of lock-ins and negative path dependence (see for instance Chapple & Lester, 2010; Christopherson et al., 2010; Simmie & Martin, 2010; Wilson, 2010).

The above list of factors make up a sample of typically included factors but the list is not complete. An important point to be made about the above listed and other usually used factors is that they represent counts or shares of amenities available at any local region i . However, today's economies are integrated through transactions, flows of merchandise and skilled workers and companies. This means that resilience-factors will be exchanged not only within each region, but also between. In general, measures of resilience make use of geography only as the spatial container in which studied factors are being contained. This means that size and distribution of the spatial container (region) will determine a considerable amount of how high or low the estimated resilience will become, since the borders may contain or exclude locations and flows increasing or decreasing resilience. Expanding the borders does not take away the problem, but moves it to the new borders. In addition, too large geographical units will disregard the within-region variability and resilience values, which will become more similar to national averages. On the other hand, too small geographical units will underestimate resilience due to inability to comprise spatial sorting of activities at a larger scale and cannot therefore effectively be used to study resilience. In cases where the spatial units are more restricted in size than the activity spaces of its inhabitants, high-amenity dwelling areas or areas containing major industrial plants risk being listed as non-resilient simply because all the *ingredients* needed for *cooking* a resilient region are not contained within its borders.

Using larger spatial units for analysis is commonplace in many scientific papers, usually because disaggregate statistics are not available for analysis. In economic resilience research, this becomes apparent when using statistics aggregated on Metropolitan Statistical Area (MSA)-level in the US. For instance, studies of regional economic resilience in the US suggest that several of the very largest MSAs are significantly resilient and transformative (see for instance, Chapple & Lester, 2010; Lin, 2012). However, using regions as the MSA of New York, having a population of approximately 18.9 million individuals in 2010 (US Census), for the study of regional economic resilience makes less sense. With a population almost twice as big as the population of Sweden, shocks to the economy will almost inevitable be absorbed by the sheer size of the region. However, on sub-regional level the effects may be less resilient. Similarly, results stating that the Detroit MSA is one of few positively transformative regions in the US miss the point that the Detroit MSA has a dwindling population and a staggering racial segregation (Galster, 2012). Substantial variations in economy and resilience within the Detroit region are being hidden using too aggregate levels of statistics.

As noted, a drawback in many studies of economic resilience is that spatial economics is not given enough attention (Pendall et al., 2010). For instance, at what spatial scale is resilience preferably measured – is it on a political and administrative level, urban/rural level

or county level or at some functional level denoting economic regions? Regardless of choice, choosing size and distribution of an economic region also means excluding surrounding areas from the region. A dichotomous, spatial delineation of economy has little resemblance with how economic activities are arranged spatially since it generalizes interaction within the region and disregards interaction with other regions (Östh, 2007; Amcoff, 2009). rRelated questions are: a) with what periodicity regional data should be collected?. and b) what is the consequence of using data from different scales and from different times just because they are not available for the same time and place? Questions like these indicate that comparisons between regions are difficult to conduct and that precise guidelines for the measurement of resilience will be difficult. One way of approaching these issues is to perceive of job accessibility as the glue that binds places together. By using spatially disaggregate resilience-proxy statistics in combination with accessibility estimates for corresponding spatial units, job accessibility can be seen as a means for alleviating differences in resilience between smaller and adjacent spatial units. Relationships similar to that between resilience and accessibility have been observed before. For instance, Rouwendal and Rietveld (1994) showed that there is a positive correlation between GDP and commuting distance. In addition, Östh and Lindgren (2012) showed that individuals having weaker ties to the labour market were more responsive in terms of adjusting commuting distances to changes in GDP than others. Similar responses were recorded for rural dwellers and individuals in metropolitan areas. These results suggest that spatial variation in economic resilience may be better understood if flows (accessibility) are incorporated into modelling.

Given these premises, in this paper, we will estimate RCI - a measure designed to function as a proxy of economic resilience - at the municipality level, since this spatial unit can provide analyses at a more spatially disaggregate level than enabled at conventional geographical levels such as counties or NUTS-2 & -3. Municipalities were chosen for this study because Sweden can be described as a sparsely populated country with small polycentric structures. Most Swedish municipalities consist of small to mid-sized towns with surrounding rural areas, with the exception for municipalities in the greater Stockholm region wherein some municipalities are lacking rural surroundings (Johansson, 2002). Factual economic resilience is impossible to measure since it is a compound of everything that has an effect on the economy. When a region's degree of economic resilience is estimated, measureable factors from a range of resilience-influential fields are often aggregated to a composite proxy of resilience. Included factors usually consists of the regional shares of well-educated and healthy and the local industrial mix and similar, but the statistics used is typically generated for administrative levels, a fact that flattens the geography in which the factual economic resilience is being played. As an effect of how public statistics is generated, proxies of resilience therefore measures things that are stationary and contained within administratively distinguishable borders whilst factors that are mobile (such as commuting, spread of ideas and capital etc.) are disregarded. Since commuting statistics (flows and distances) between and within municipalities are available, opening up for estimation of job accessibility we are able to explore the relationship between proxies of resilience and accessibility, answering the following research question: are the most resilient centres also the

most accessible (and vice versa)? In other words, what is the role of spatial connectivity and accessibility in enhancing resilience?

Consequently, in this work, we argue two main issues:

- a) A functional approach for the construction of a better proxy of resilience is to categorize activities as stationary (Traditional proxies of resilience) and mobile (interaction factors). We argue that by combining a resilience measure created from a spatially disaggregate dataset with a measure of accessibility on the same disaggregate level we combine stationary activities (resilience factors) with mobile activities (in particular, accessibility, since this indicator embeds interaction within and between disaggregate regions).
- b) Bringing proxies for resilience and accessibility together will have positive policy implications.

The rest of the paper is arranged as follows. In the subsequent Section 2, we define regional economic resilience and accessibility theoretically. In Section 3 we introduce the data sources used in analyses and the methods for estimating resilience and accessibility. In Section 4, results from analyses where estimates of resilience and accessibility are brought together are presented. Finally, in the concluding Section 5, our findings are summarized and discussed.

2. Defining Resilience and Accessibility

2.1 Economic Resilience

Originating from the Latin word *resilio* with the approximate meaning of *bouncing back*, the idea of resilience means to adapt to or cope with the consequences of (a sudden) change (Rose, 2009).

The concept of economic resilience stems from precedents concepts in the ecological literature, which established two main definitions. The first *conventional* definition by Pimm (1984) focusses on the property of the systems near some stable equilibrium point (*engineering resilience*). Here resilience is measured by the speed at which the system returns to equilibrium. The second definition by Holling (1973) focusses on the property of the systems further away from the stable state. The measure of resilience is here the perturbation that can be absorbed before the system converges on another equilibrium state (*ecological resilience*). In this context, it should be noted that different interpretation and measurements emerged in the spatial economic and transport literature, also with reference to the *counterpart* concepts of vulnerability and fragility (see, for a review, Reggiani, 2013).

Economic resilience came recently to the fore, as the ability to mute the influence of the external shocks (Rose, 2009). Economic resilience can analogously be understood as a nation/region/centre's ability to adapt to (sudden) changes in economic conditions. According to Martin (2012), recent works on (regional) economic resilience tend to describe resilience in

a wider sense including (amongst others) the ability to anticipate, prepare, respond to changes and recover.

In a recent review of analytical frameworks for the analysis of economic resilience, three lines of thinking emerge (Pendall et al., 2010). Economic resilience is usually either studied using a single equilibrium approach, ‘multiple equilibrium’ approach or a ‘complex adaptive system’ approach. Studying resilience using a single equilibrium approach means that the socio-economic status of a region – before an external shock – is considered as the equilibrium to which the situation should rebound upon recovery (Pimms’ view (1984)). In a ‘multiple equilibrium’ approach the system rebounds into a different socio-economic status (Holling’s view (1973)). In ‘complex adaptive systems’ the notion of shock is replaced with gradual but constant state of change. Resilience, in this view, becomes the ability to adjust to changes in prerequisites of economy (Christopherson et al., 2010; Martin, 2012; Pike et al., 2010; Simmie & Martin, 2010).

In summary, resilience turns into the continuous ability to adjust to stress, and the analysis of resilience becomes the study of how social-economics adjusts to varying stages in economic cycles (Pendall et al., 2010). The stages of economic adjustment essentially comprise stages of decline, restructuring, exploitation and conservation (Dawley et al., 2010; Simmie & Martin, 2010).

Of key importance for the study of how countries/regions/centres adapt to socio-economic conditions at various stages in the economic cycle is the choice of representative and measureable factors. Factors should preferably illustrate conditions of population composition and demographic trends, employment and human capital, industrial mix and innovation, etc. No comprehensive list of must-include factors will ever be constructed, partly because there is an endless list of potential candidates but also because factors viable in analysis today risk being useless tomorrow. A reason for the latter is the economic path dependence of each location (Massey, 1984). What proved resilient in the past may or may not be resilient tomorrow, depending on how the adjustment to tomorrow’s economic looks.

In widened context, a rich list of indicators of resilience exist in the literature, according to the objective of fostering resilience in different socio-economic sectors, such as health, security, food, communities, etc. (see, among others, Benard, 1991; Cowell, 2013; Cox et al, 2010; FAO, 2013). From these studies, it appears that resilience is strictly linked to the concepts of connectivity and accessibility (for example, if an economic sector decreases, probably other connected economic sectors decrease to), thus a multiplicity of socio-economic-environmental indicators are often considered. However, mobility in terms of a spatial interaction indicator is seldom taken into account.

Having said this, our aim is to figure out whether economic resilience can be joined – in a unified perspective – to a synthetic indicator, such as accessibility, which embeds both interaction and connectivity factors (by means of its impedance functions). In other words, we conceive resilience strictly associated to accessibility, in such a way that accessibility can strongly contribute to enhance resilience in socio-economic networks. Before showing our empirical analyses linking resilience with accessibility in Sweden (Section 4), the accessibility indicator – here adopted – will be briefly illustrated in the next section.

2.2 Defining Accessibility

The concept of ‘accessibility’ came to the fore in the last century, thanks, first, to Hansen (1959), who defined accessibility as the *potential of opportunity for interaction*, and, second, to Weibull (1980), who considered accessibility as a *property of configuration of opportunities for spatial interaction* (for a review on the accessibility concept, see also Reggiani, 2012).

In the field of spatial economics, accessibility refers to the relative ease of reaching a particular location or area. In this context, accessibility A_i emerges in its analytical form, as the potential of opportunities, as follows:

$$A_i = \sum_j D_j f(\gamma, d_{ij}), \quad (1)$$

where A_i defines the accessibility of centre i ; D_j is a measure (or weight) of opportunities/activities in j ; and $f(\gamma, d_{ij})$ is the impedance function referring to the distance d_{ij} from i to j , with γ its distance-sensitivity parameter.

Two main research questions usually concern the empirical application of accessibility formulation (1): a) the question of the ‘best’ γ -value to be introduced in expression (1); and b) which type of impedance function better fits the connectivity/economic structure associated to the system under analysis. Recent research, focusing on the solution of the above issues in Sweden, emphasized the role of the spatial unit level, as well as of the associated topological network. In particular, it has been found that: concerning issue a), a doubly constrained spatial interaction model¹ better fits the commuting network of municipalities in Sweden; and concerning issue b), the impedance function of power type shows the best fit (Östh et al., 2013).

The results emerging from the empirical applications – at municipality level in Sweden – of the accessibility indicator (1) combined with the adopted resilience indices, will be illustrated in Section 4.

¹ For the description of the doubly constrained spatial interaction model, see, among others, Fotheringham and O’Kelly (1989); Reggiani (2012).

3. Data and Method

3.1 The Data

The methods and data used to calculate resilience and accessibility are presented in the section below. Unless otherwise stated the data is drawn from the Uppsala University located PLACE database. The database contains individual level data for all Sweden residents between 1990 and 2010. All data is compiled by Statistics Sweden.

3.2 Creating a proxy for resilience

For the computation of resilience proxy we are using a nationally adopted version of RCI (Resilience Capacity Index), on the basis² of Cowell (2013). The index is a compound of in total 12 equally important factors split into three groups (A, B, and C) (see Appendix A). The three groups, with four factors each, make up a blend of economic, socio-demographic and ‘sense of community’ factors. The RCI measurement of factors can basically be described as the standardized share of the local (municipality in this case) population belonging to a category of people doing well in relationship to what is measured. After calculation, the standardized factors are summarized on municipality level by averaging the twelve factor values into a new variable denoting the local composite value of resilience. Positive RCI values indicate that the municipality is doing better than the average municipality. Detailed descriptions of how each of the factors was constructed are available in Appendix A.

Figure 1 visualises the resilience results concerning the first of three RCI-groups, i.e. the A-group (economic capacity), which includes: A1) income equality (inverted Gini); A2) economic diversity; A3) affordability (housing market); and A4) business environment. Maps in Figure 1 reveal that this A-Group of resilience (economic capacity) is high (dark) in core metropolitan municipalities and in many of the more populous municipalities. In municipalities classifiable as suburbs or commuter-municipalities this A-component is considerably lower (lighter) – especially in the Stockholm and Göteborg areas. That the economic capacity varies substantially within the metropolitan areas suggests that activities related to work and residence is organized spatially different.

Figure 1. Distribution of ‘economic capacity’ index values (A-Group); darker colours indicate higher values and vice versa

In Figure 2 the sum of values from the four factors belonging to the B-Group (socio-demographic capacity) are illustrated. The darker the colour the stronger the socio-

² See also: <http://brr.berkeley.edu/rci/>. RCI was originally developed by Kathryn A. Foster at Buffalo Regional Institute, State University of New York (Cowell, 2013).

demographic capacity is. The maps indicate that higher values are clustered to major populated areas as well as to a few municipalities in Northern Sweden. The latter group of municipalities can be make an interesting case – in contrast to municipalities especially in the North-western inland – the Northern-most municipalities have an economy built around mining and public jobs requiring higher levels of education (including health facilities, military centres, as well as more ‘exotic’ labour niches including car-testing facilities and the European Space Agency). The heterogeneity of skills needed on these labour markets may contribute to the relatively high resilience values.

Figure 2. Distribution of ‘socio-demographic capacity’ index values (B-Group); darker colours indicate higher values and vice versa

In Figure 3 the sum of values from the four factors belonging to the C-Group (community connectivity capacity) are illustrated. The darker the colour, the greater the capacity is. The maps indicate that lower values are more common in the surroundings of larger metropolitan areas and in some of the remote northern municipalities. However, while Stockholm has got a high community connectivity capacity value – corresponding values for Göteborg and Malmö are considerably lower.

Figure 3. Distribution of ‘community connectivity capacity’ index values (C-Group); darker colours indicate higher values and vice versa

All in all, these three figures show the following. A-Group (economic capacity) outlines the polycentrism in Sweden formed by the three main hubs: Stockholm, Göteborg and Malmö. B-Group (socio-demographic capacity) outlines the high education regions in Sweden. Most municipalities ranked highly in this group are either university cities or major centres of high-skill jobs in industry or public sector; C-Group (community connectivity capacity) essentially highlights the municipalities of Stockholm and Göteborg and smaller high-amenity municipalities in Sweden.

From these three resilience perspectives (A-Group, B-Group, and C-Group), Stockholm seems then to emerge as the most ‘resilient’ municipality. It would be then interesting to investigate whether Stockholm – in the network of the 290 Swedish municipalities – is also the most accessible, by assuming that resilience is linked in a (non-) linear way to accessibility. Accessibility means also connectivity, thus the type of the spatial distribution of economic agents and their activities (identified by the accessibility indicator) might directly influence the resilience of the associated spatial economic network.

3.3 Modelling Job Accessibility

Accessibility to jobs on the Swedish labour market is used to represent the mobile state within and between Swedish regions. The data used in computations come from the Uppsala University based database PLACE containing records of individuals' place of residence and work for all (working) Sweden resident individuals between 1990 and 2008. Using the most recent year (2008) we first calculated the Cartesian distance between home and work, and thereafter aggregated the median commuting distance and flow of workers between and within each municipality in Sweden (290 * 290 municipalities).

Concerning the analysis of accessibility, designing a study of potential accessibility also means deciding which model – among those emerging from the family of spatial interaction models – is the most suitable for identifying accessibility, according to different spatial economic settings and constraints. For a review of the various spatial interaction models (SIMs), as basis for the accessibility formulation (1), we remind and refer to Reggiani (2012) and Östh et al. (2013). The labour market is the conventional example of the doubly-constrained SIM: an employee cannot be working on several locations and with different tasks at the same time, and he/she cannot occupy already occupied jobs (i.e. both the supply side and the demand side are fixed). Since we are modelling potential accessibility to jobs on the labour market, a doubly-constrained SIM, has been applied, first, to the commuting network of the 290 Swedish municipalities, in order to extract the γ -value to be introduced in the accessibility formulation (1). In particular, the doubly-constrained SIM showing the best γ -value embeds – in its impedance function – the following power form:

$$f(d_{ij}) = d_{ij}^{-\gamma} . \quad (2)$$

The accessibility formulation (1), incorporating the power form of type (2) has been then applied the commuting network of the 290 Swedish municipalities. The emerging results were finally clustered and compared with the resilience results (see next Section 4).

4. Estimates of Resilience and Accessibility: A Joint Perspective

Central behind the idea of bringing resilience and accessibility together is that the interplay between stationary and mobile factors can be pivotal for the development of policies aiming to alleviate negative effects of shocks to local economic systems. The idea is that high/low levels of economic resilience should be interpreted as beneficial or problematic only after considering the effects of flows between regions. As illustrated schematically in figure 4, low levels of resilience must not be viewed as problematic if that region has good access to other job-rich communities in the surrounding. In the event of a shock to the local economy (by means of a down-sizing, closing of a major plant or similar) both employers and employees

may find alternative solutions without relocating outside the community. However, if accessibility is low, similar shocks to the local economy can be devastating. In high-resilience locations, local levels of accessibility are of less importance since the local economy is better equipped to fight the shock. However, communities being both highly resilient and highly accessible are likely to be coping better with economic shocks than other types of communities – since local employers and employees have more options for how to recuperate.

Figure 4 Schematic representation of the relationship between resilience and accessibility in a 2 x 2 chart. Low resilience and low accessibility is associated with greater risks of not being able to handle an economic shock (labelled highly problematic). High levels of both resilience and accessibility are associated with smaller risks in case of an economic shock (labelled not problematic). Mixed levels of resilience and accessibility are associated with intermediate risks (labelled intermediate). Lower red sections indicate types of regions associated with higher risks in case accessibility is not considered.

What the final RCI value, resulting from the computations described above, communicates is the standardized, combined economic resilience for each municipality in Sweden. As such, the local municipality value represents nothing tangible besides the deviation from the national RCI average. It does however give us the potential to compare and rank municipalities according to their predicted economic resilience. In similar fashion, the doubly-constrained job accessibility value represents the potential pool of jobs available for commuters in each municipality. However, being a potential measure – it is just as tangible as the RCI in terms of letting each value represent ‘factual’ accessibility but just as for RCI, each municipality’s job accessibility estimate can be compared and ranked to other municipalities. Because of this we bring resilience and accessibility together by clustering the ranks of their values, and this is also the reason we do not attempt to combine proxies for accessibility and resilience into one single measure. It is important to let proxies of accessibility and resilience responsive to the spatial economic circumstances at play in the studied municipalities rather than forcing accessibility to become a fixed part of a resilience proxy. In other words, the size and economic composition of the areas studied (RCI) foster the relevant role of mobility and space (accessibility).

The 290 municipalities in Sweden all have estimated values representing their economic resilience and accessibility situating them comparatively to each others. By clustering municipalities based on their resilience and accessibility ranks, categories of municipalities having similar ranks resilience and accessibility can be created. Using a *K*-means cluster technique we constructed four clusters describing four distinct categories of municipalities having similar counts of municipalities in each. The four clusters each represent a unique combination of high or low accessibility and resilience, making it possible to categorize municipalities as doing either well or poor or mixed in terms of accessibility and resilience. In Table 1 the 4 clusters are described statistically. In particular, Table 1 illustrates the *K*-means cluster classification of ranks (low numbers = high ranks) of resilience and accessibility. In Cluster 1, municipalities having both high resilience and high accessibility are categorized. To Cluster 2, municipalities with high resilience but low accessibility are

classified. Cluster 3 contains low resilience and high accessibility municipalities, and finally Cluster 4 contains low resilience and low accessibility municipalities. Ranks for mean, 25%, median and 75% rank positions are listed in Table 1. Total N indicate the count of municipalities belonging to each cluster.

Table 1. *K*-means cluster classification of ranks (low numbers = high ranks) of resilience and accessibility in Sweden

In Figure 5, the spatial distribution of resilience, accessibility, and the four clusters can be viewed. In particular, Map a) displays (with same rule of coloration as Map b) the spatial distribution of resilience (RCI). Map b) displays the spatial distribution of doubly constrained job accessibility, where brown (earth colours) indicate high (good) accessibility and blue (sky colours) indicate low (poor) accessibility. Coloration intervals in Maps a) and b) are determined by quintiles. Map c) displays the spatial outcome of *K*-means clustering of resilience and accessibility, where Maps c1)-c3) display outcomes in the three metropolitan areas: c1) Stockholm, c2) Göteborg, and c3) Malmö. The clustering highlights areas with high-high, high-low, low-high and low-low levels of resilience and accessibility. Mesh-layer imposed on top of cluster layer display municipalities losing population.

Figure 5. Clustering of resilience and accessibility in Sweden

The spatial distribution of resilience and accessibility indicate that whilst higher accessibility is concentrated to the especially the three major metropolitan areas, and lower accessibility is found in less densely populated areas in the north of Sweden; resilience seems to be much less concentrated to specific parts of the country. The distribution of *k*-means clusters is as follows: all municipalities having both high resilience and high accessibility are categorized into Cluster 1 (dark green in map). The spatial distribution of Cluster 1-municipalities is concentrated to larger job-dense areas. Municipalities with high resilience and low accessibility are categorized to Cluster 2 (yellow in map). Cluster 2 municipalities are widespread throughout most of the rural parts of Sweden. Cluster 3 (light green in map) contains municipalities having low resilience and high accessibilities. These categories are almost entirely located to the southern parts of Sweden and usually in proximity to larger urban areas. Finally, Cluster 4, containing the low resilience and low accessibility municipalities are with some exceptions concentrated to the most remote parts of the country. In the cluster map an overlay mesh illustrate the spatial distribution of municipalities that decreased in population between January and December 2012. Though the distribution of population decrease does not validate the accuracy of the clusters, it points to demographic trends observable in the four types of municipalities. In fact, 89% of the cluster 1 municipalities gained population; corresponding percentages for the remaining clusters were

44% for cluster 2, 56% for cluster 3 and 25% for cluster 4. Doing the same for four groups of resilience (quartiles of highest to lowest resilience) rendered 79% in group 1, 51% in group 2, 44% in group 3 and 44% in group 4. Regression results confirm these findings, in table A1 (Appendix C) four logistic regressions (using RCI ranks, Accessibility ranks, RCI-weighted accessibility (ranked) and *k*-means cluster belonging) indicate that the population increase patterns are better depicted using a combination of RCI and accessibility than just RCI. In fact, results in model 1 and model 3 indicate that accessibility seems to be of greater importance for determining patterns of population increase than is RCI alone (Model 2). The latter is to a great extent the effect of migration to suburb and commuting oriented municipalities in the outskirts of the Swedish metropolitan areas. Though jobs might be scarce locally, these municipalities can offer more affordable homes, proximity to ‘raising family’ amenities and a big labour market within commutable distances. In model 4 the jobs in each destination D_j are weighted by the destination’s RCI-value before accessibility to jobs in municipality j from municipality i is estimated and aggregated³. Since model 4 has an explanatory power that excels over the other models it is reasonable to assume that accessibility to jobs in more resilient municipalities is more important than accessibility to just any jobs.

The spatial interrelationship between municipalities is not considered in the clustering of accessibility and RCI. However, due to the nature of the factors included in measuring resilience and especially accessibility – spatial interrelationship is inevitably part of what is being shown. Consequently, spatial clusters of high/low RCI and accessibility ranks will certainly form. One way of locating these clusters is to subject the cluster results to a local Moran’s I analysis (Anselin, 1995).

In Figure 6, outputs from local Moran’s I analyses are illustrating in what parts of the country high/low RCI and accessibility clusters are statistically more or less common⁴. It is central to note that spatial clustering in this case only is conducted to find spatial concentrations of municipalities with the same *k*-means cluster-belonging and not to reassess the relationships between RCI and accessibility.

Figure 6. Spatial clustering (local Moran’s I) maps illustrating four *k*-means clusters of RCI and accessibility, and one map of spatial clustering of RCI alone

The spatial clustering patterns are easy to identify; high RCI /high accessibility clusters are significantly clustered around the three metropolitan areas and the major cities located near to the metropolitan areas (i.e. Uppsala, Västerås, Helsingborg, etc.). Outliers represent major but remotely located job rich municipalities. Clusters of high RCI/low accessibility municipalities are primarily located in less populated areas, but compared to low RCI/low accessibility/ municipality spatial clusters, both population counts and job are more plentiful. Concentrations of low RCI/high accessibility municipalities can be described as suburb or commuting municipalities often located between the metropolitan areas and nearby major

³ $A_i = \sum_j D_j RCI_j f(\gamma, d_{ij})$,

⁴ Local Moran’s I was ran using default settings in ArcGis 10.0 (www.ESRI.com).

cities. The rightmost map in Figure 6 illustrates the spatial clustering using only RCI ranks. The results are difficult to interpret: favourable RCI-values are clustered to substantially different kinds of regions (Central parts of the Stockholm region and four relatively remote and sparsely populated municipalities in Northern Sweden). The clustering of poor RCI municipalities makes better sense, but picks up fewer candidates compared to the *k*-means cluster alternative.

The spatial clustering-patterns confirm the hypothesized relationships between RCI and accessibility. High RCI and high accessibility areas are usually found in larger more populous areas while high RCI and low accessibility municipalities are spread over different types of areas. Spatial clusters of low levels of RCI may or may not be problematic depending on the geographic location of the municipality. Low RCI in high accessibility regions could be seen as natural adjustments to the organisation of jobs and homes in the local labour market region – it may on the other hand also be highly problematic if accessibility to jobs is low.

5. Conclusions

Estimating resilience by bringing proxies of resilience and accessibility together in combined measures has two major advantages. First it takes the effects of stationary activities (RCI) and mobile activities accessibility – i.e. interaction within and between disaggregate regions into account. Secondly, it enables and emphasises the use of disaggregate spatial units in analysis since accessibility bridges areas with different levels of RCI.

In particular, this joint analysis (RCI and accessibility) – developed at the municipality level in Sweden – showed the following findings:

- Even though different interpretations of how to proxy economic resilience exists in the literature, economic resilience appears to be linked to accessibility. Consequently, it seems from our experiments that, in general, the most resilient centres (having greater RCI) are also the most accessible (and vice-versa).
- Some suburb and commuting municipalities in close proximity to major metropolitan had low RCI values. These municipalities all have high accessibility values suggesting that sorting of residential areas and work areas may take place on between-municipality level in case accessibility levels are high enough to alleviate negative effects of poor resilience locally.
- The municipality level in Sweden appears to be a very suitable level of analysis, giving the possibility of showing inherent variations.

All in all, this joint analysis of proxies for resilience and accessibility can be considered a suitable tool for providing a more complete insight into the economic investigation and measurement of resilience. From the policy viewpoint, we might then argue that improvement of accessibility is fundamental for the development of resilient economic networks. Further studies on the relationship between resilience and accessibility, as well as on transferability of

results, could constitute the final challenge in a future research agenda devoted to exploring simple indicators which map out the resilience of the spatial economy.

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Appendix A. The Economic Resilience Indicators in Sweden

In this Appendix, the twelve economic resilience indices, adopted in the present study in order to construct the global RCI in Sweden are described, on the basis of Cowell (2013). These twelve components are derived from three main indicators: A) Spatial Economic Capacity; B) Socio-Demographic Capacity; and C) Community Connectivity Capacity. Most components are calculated for year 2010 – however, components A4 and B2 make use of statistics drawn from a collection of years spanning from 2007 to 2012.

A) Economic Capacity

A1) Income Equality is measured as the inverse Gini coefficient in each municipality. Gini is calculated using individual level registers of disposable income cumulated to municipality level. High values of Gini indicate that wealth is unevenly distributed while low values indicate the opposite. To fit the RCI modelling framework where higher values are more resilient than lower ones – the (standardized) inverse Gini coefficient is used to calculate RCI-index. The Swedish specification is identical to the original specification.

A2) Economic Diversification. Local economies depending too strongly on a handful of industries are generally more vulnerable than other economies this because also moderate shifts in business cycles may have large impacts on the local economy. In the index the vulnerability is expressed as the local deviation from the national industrial mix in terms of number of employees in manufacture, service and public sectors. The standardized inverse share of deviation is used to calculate RCI-index. The Swedish specification is identical to the original specification.

A3) Affordability. In the original specification, affordability is measured as the share of the regional population spending less than 35 percent of their income on housing. This kind of statistics is unavailable in Sweden. The alternative specification used in this article uses median disposable income at municipality level and average price for single-family homes, also at municipality level. By dividing the median disposable income with the average housing price the affordability can be assessed. Resulting values are higher in areas with greater affordability. The standardized quota is used to calculate this component of the RCI-index. The Swedish specification is similar but not identical to the original specification.

A4) Business Environment. The Confederation of Swedish Enterprise (Svenskt Näringsliv) annually ranks the business climate in Swedish municipalities (Företagsklimat, 2013). The rank is based on a broad range of sub-variables comprising factors such as local taxes, communications and skill-matching. By combining rank-statistics for all years between 2007 and 2012 an indicator similar to the original |Economic Dynamics| indicator can be constructed. The standardized municipality over-time average is used to calculate this component of the RCI-index. The Swedish specification is similar but not identical to the original specification.

B) Socio-Demographic Capacity

B1) Educational Attainment is measured as the percentage of individuals aged 25+ having an education equal or higher than a bachelor's degree divided by the percentage of individuals aged 25+ having no upper secondary school education. Resulting values are high if the share of higher educated is larger than the share of lower educated and vice versa. The standardized quota is used to calculate this component of the RCI-index. The Swedish specification is identical to the original specification.

B2) The Without Disability indicator measures the share of the civilian non-institutionalized population that report no disabilities. Using statistics from The National Board of Health and Welfare the share of individuals aged 65+ being dependent on care arranged either as home-care or as care in nursing homes is used to construct a disability indicator. The standardized share of individuals aged 65+ per municipality not in need of care, is used as indicator. The Swedish specification is similar but not identical to the original specification.

B3) The Out of Poverty indicator measures the municipality share of the population having a greater annual income than what is defined as the poverty line. Within the European Union, the poverty line is defined as having a disposable income less than 60% of the median disposable income in the country. This means that the standardized share of individuals having disposable incomes greater than the poverty line is used to express the 'Out of Poverty' indicator in the RCI-index. The Swedish specification is similar but not identical to the original specification.

B4) Since the Swedish health care system is tax funded and offered to all Swedish citizens with no additional cost, the original Health-Insured indicator makes little sense in the Swedish context. However, if the focus is changed from the population's ability to afford healthcare to the population's costs in relation to ill-health, an alternative indicator can be constructed. Being on sick leave from work always means losing income. During the first day of sick leave, no sickness benefit is paid and during subsequent days a lower-than-wage benefit will/can be paid. Frequency of sick leave among workers varies between municipalities and between sectors. These variations may be results of variation in stress, working conditions or similar. Aggregated to municipality level, the standardized share of the working population not receiving sickness benefit on an annual basis is used to calculate RCI-index. The Swedish specification is not similar to the original specification.

C) Community Connectivity Capacity

C1) Civic Infrastructure is a measure of the density of civic organization employees in a region. The share of all employees in any municipality employed by civic organizations classified, according to NACE-2, as being either political, religious, sports-oriented or other (including, but not being limited to organizations focusing on folklore, literature, music and arts, societies, horticulture etc.) are used as an indicator of civic infrastructure. The specification differs from the original in that the number of civic organization employees per 1 000 inhabitants is used rather than the number of organizations per 10 000 inhabitants. The standardized share is used to calculate RCI-index.

C2) Metropolitan Stability is measured as the share of population that remains as residents in the municipality over a five year period. The greater the share of over-time stayers – the greater is the collective knowledge on how to cope with shocks locally. The Swedish specification is identical to the original specification. The standardized share is used to calculate this component of the RCI-index.

C3) Homeownership is measured as the share of population residing in owner-occupied housing per municipality. The Swedish specification of the indicator is identical to the original specification. The standardized share is used to calculate this component of the RCI-index.

C4) Voter Participation is measured as the share of the voter-eligible population that voted in the last (national) election. Voting participation data is drawn from the national election authority (Valmyndigheten). The Swedish specification of the indicator is identical to the original specification. The standardized share is used to calculate this component of the RCI-index.

Appendix B. Classification of municipalities according to activity

Figure A1. Maps show an aggregate version of the SALAR 2011 classification of municipalities in Sweden. Orange colours point out larger urban areas. Economically these areas have high concentrations of public jobs including health, education and national to regional governing. Blue areas are classified as commuting oriented where service oriented private and public jobs are common. Green areas are dominated by production in agriculture, forest or industry sectors or by tourism-oriented activities. Yellow areas are mostly scarcely populated and mixed in terms of economic activities. Full classification list of economic activities is available on www.skl.se

Appendix C. Population Increase Vs. Resilience and Accessibility

Table A1. Logistic regressions showing the relationship between the dependent variable *_population increase_* (coded 1=increase|0=decrease) and *k*-means cluster belonging (Model 1), RCI rank (Model 2), RCI and Accessibility ranks (Model 3) and RCI-weighted accessibility (ranked). Ranks are arranged so that low ranks indicate high resilience or accessibility (and vice versa). Regression results represent: Odds (Standard Error) significance. *** = significant on 99.9% level, ** = 99% level and * = 95%. Symbol _ _ indicate that variable is not included in that model.

Digital version = all colour
Printed version = figures 5-6 in colour

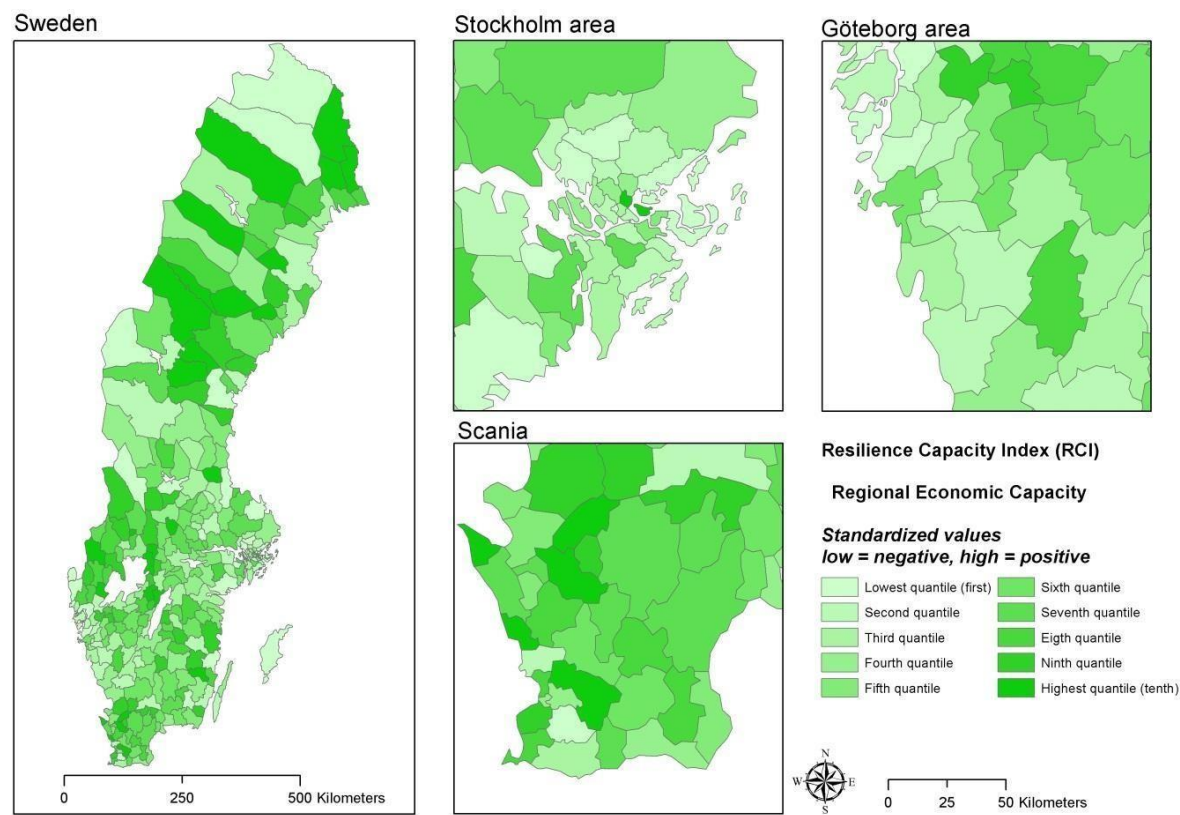


Figure 1. Distribution of ‘economic capacity’ index values (A-Group); darker colours indicate higher values and vice versa

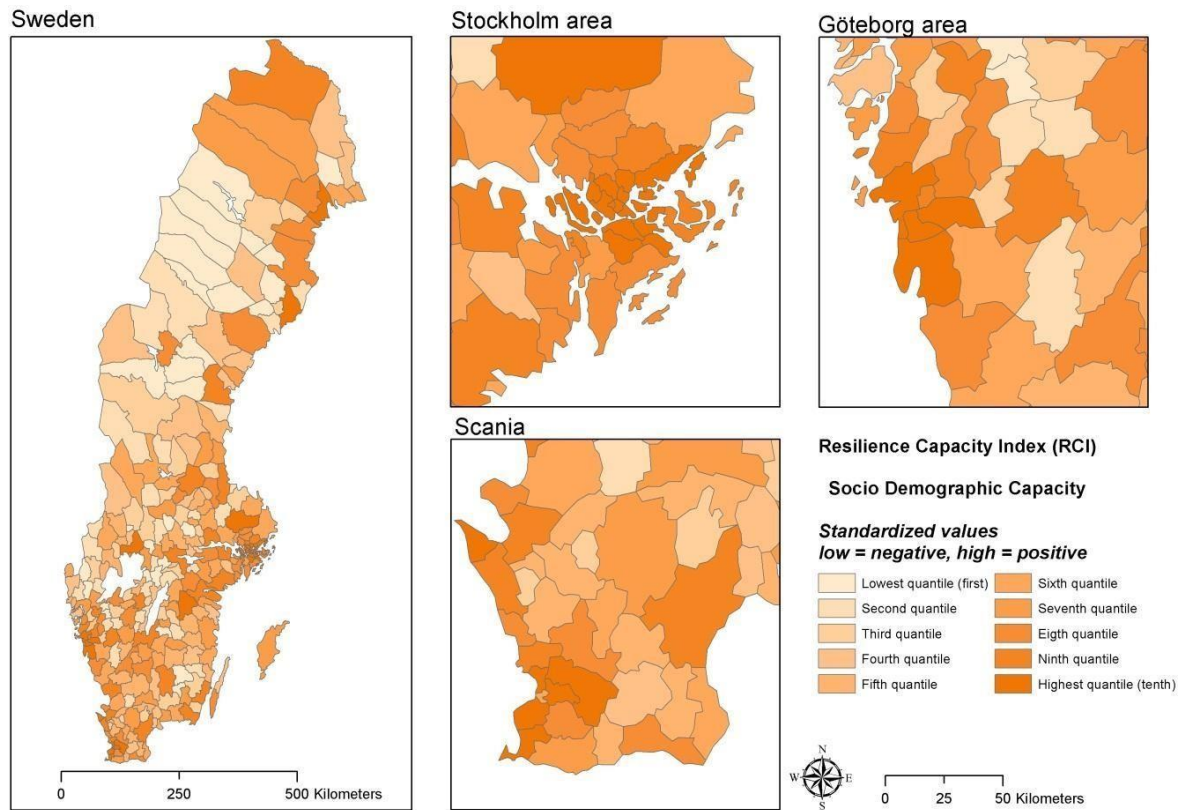


Figure 2. Distribution of ‘socio-demographic capacity’ index values (B-Group); darker colours indicate higher values and vice versa

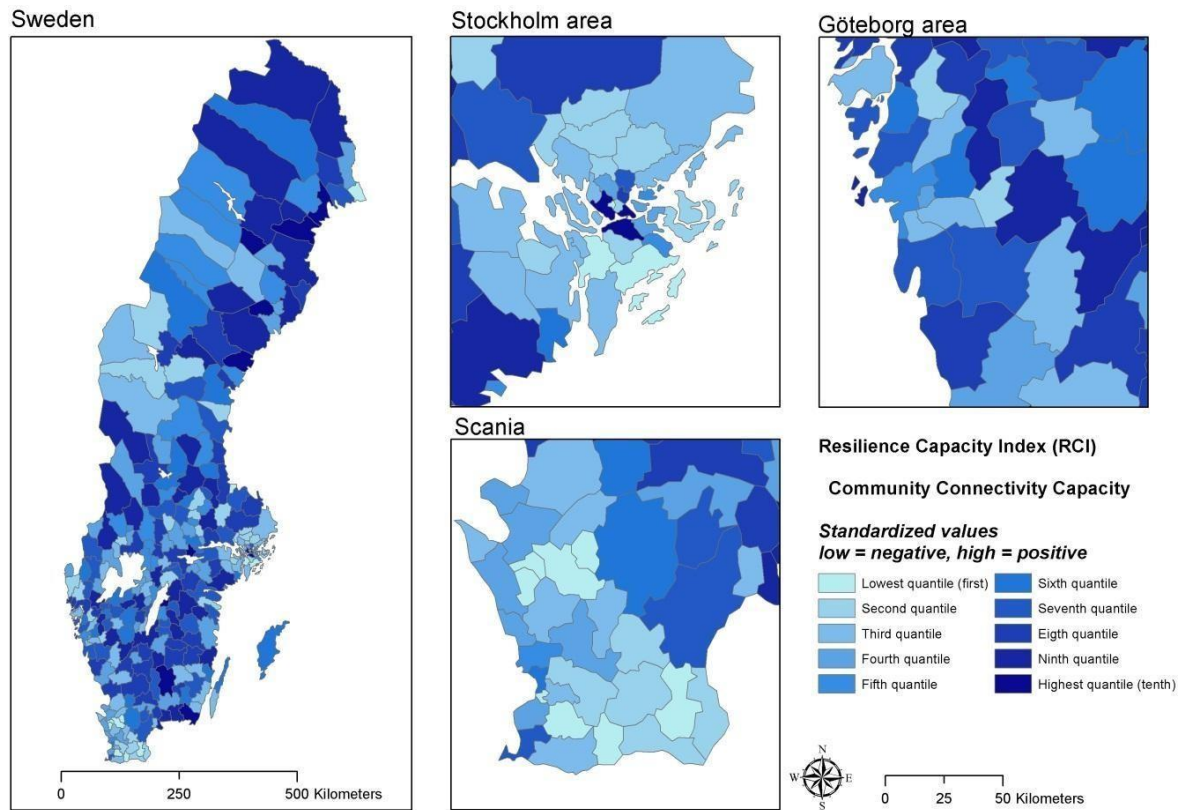


Figure 3. Distribution of ‘community connectivity capacity’ index

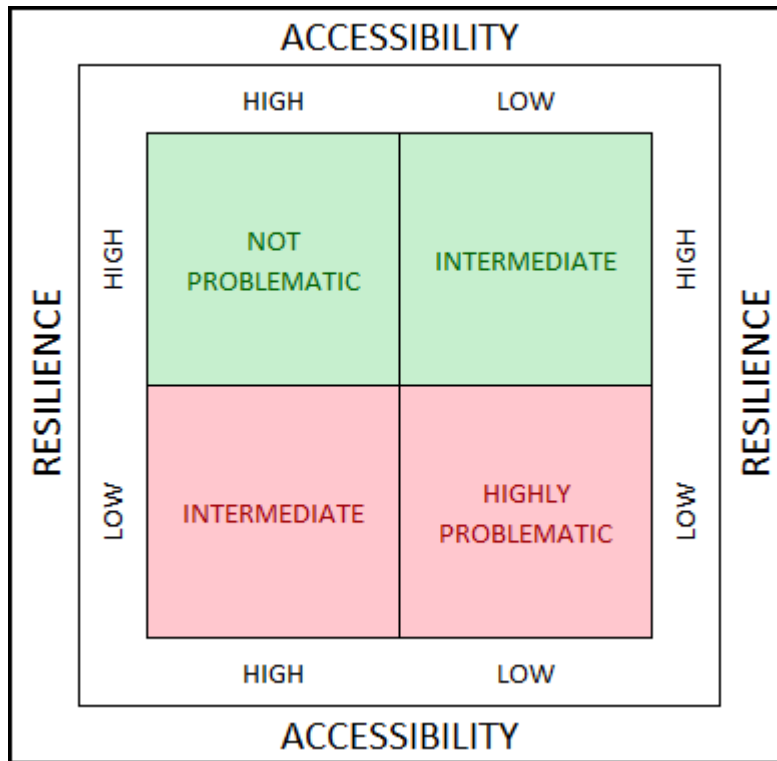


Figure 4 Schematic representation of the relationship between resilience and accessibility in a 2 x 2 chart. Low resilience and low accessibility is associated with greater risks of not being able to handle an economic chock (labelled highly problematic). High levels of both resilience and accessibility are associated with smaller risks in case of an economic chock (labelled not problematic). Mixed levels of resilience and accessibility are associated with intermediate risks (labelled intermediate). Lower red sections indicate types of regions associated with higher risks in case accessibility is not considered.

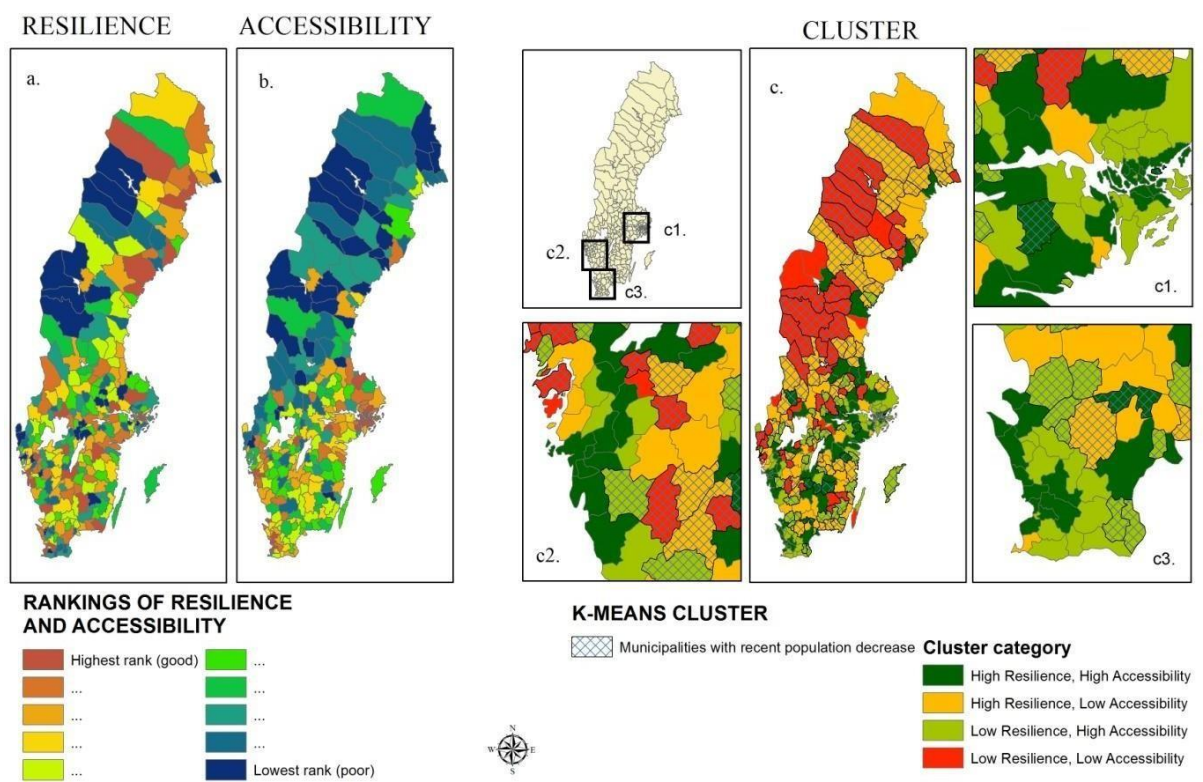


Figure 5. Clustering of resilience and accessibility in Sweden

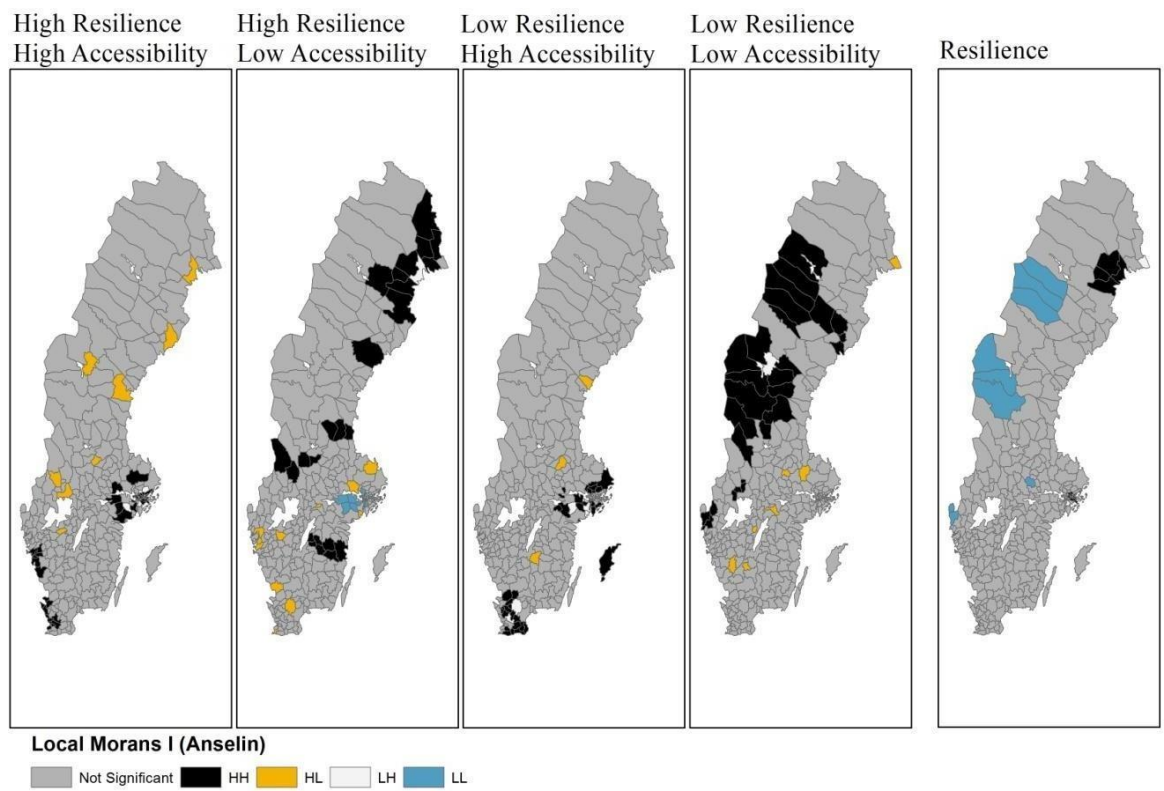


Figure 6. Spatial clustering (local Moran's I) maps illustrating four *k*-means clusters of resilience and accessibility, and one map of spatial clustering of resilience alone

Appendix B. Classification of municipalities according to activity

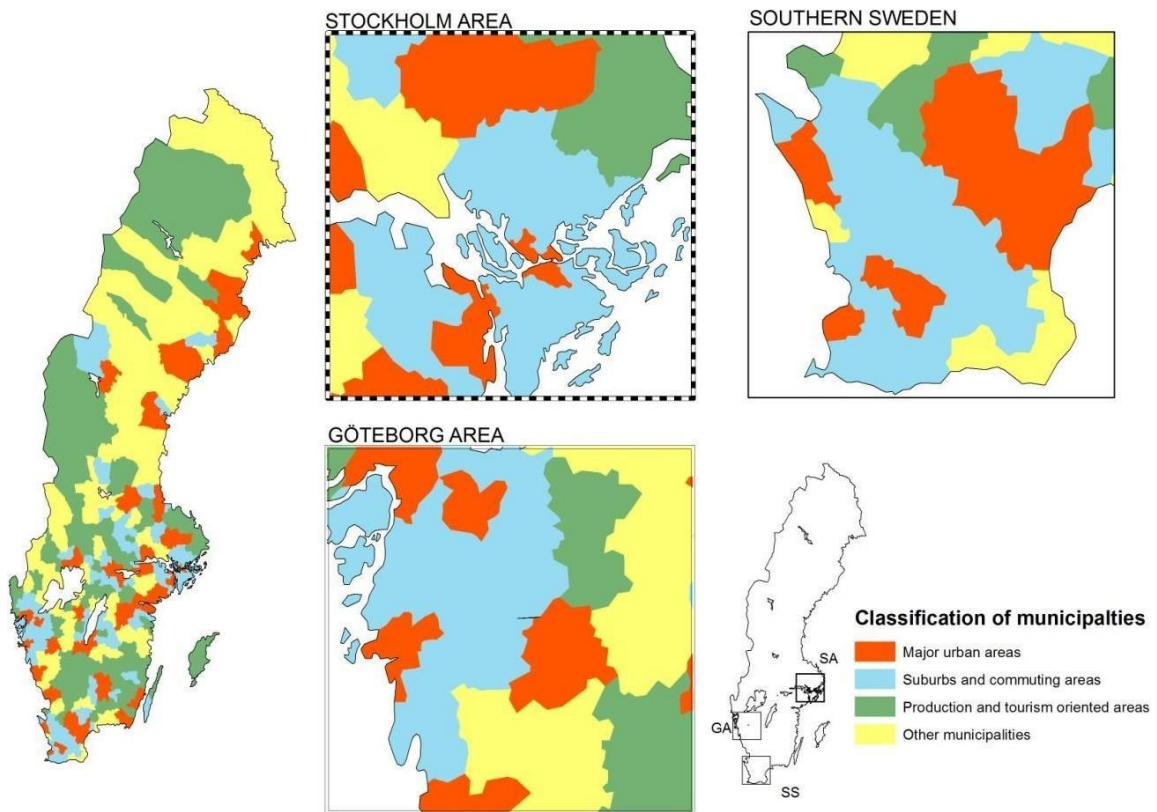


Figure A1. Maps show an aggregate version of the SALAR 2011 classification of municipalities in Sweden. Orange colours point out larger urban areas. Economically these areas have high concentrations of public jobs including health, education and national to regional governing. Blue areas are classified as commuting oriented where service oriented private and public jobs are common. Green areas are dominated by production in agriculture, forest or industry sectors or by tourism-oriented activities. Yellow areas are mostly scarcely populated and mixed in terms of economic activities. Full classification list of economic activities is available on www.skl.se

Table 1. *K*-means cluster classification of ranks (low numbers = high ranks) of resilience and accessibility in Sweden

	Cluster 1		Cluster 2		Cluster 3		Cluster 4	
	High Resilience High Accessibility		High Resilience Low Accessibility		Low Resilience High Accessibility		Low Resilience Low Accessibility	
	RCI Rank	ACC. Rank	RCI Rank	ACC. Rank	RCI Rank	ACC. Rank	RCI Rank	ACC. Rank
Mean	57	63	96	211	215	90	230	235
25%	23	28	69	179	181	53	202	203
50%	52	59	98	209	215	93	227	238
75%	88	99	131	243	251	129	266	272
Total N	72 municipalities		81 municipalities		80 municipalities		57 municipalities	

Appendix C. Population Increase Vs. Resilience and Accessibility

Table A1. Logistic regressions showing the relationship between the dependent variable ‘*population increase*’ (coded 1=increase/0=decrease) and *k*-means cluster belonging (Model 1), RCI rank (Model 2), RCI and Accessibility ranks (Model 3) and RCI-weighted accessibility (ranked). Ranks are arranged so that low ranks indicate high resilience or accessibility (and vice versa). Regression results represent: Odds (Standard Error) significance. *** = significant on 99.9% level, ** = 99% level and *=95%. Symbol ‘-’ indicate that variable is not included in that model.

	Model 1	Model 2	Model 3	Model 4
Low Res / Low Acc	1	-	-	-
Low Res / High Acc	3,949 (0,381) ***	-	-	-
High Res / Low Acc	2,457 (0,38) *	-	-	-
High Res / High Acc	24,571 (0,485) ***	-	-	-
RCI rank	-	0,994 (0,002) ***	0,994 (0,002) ***	
Accessibility rank	-	-	0,987 (0,002) ***	
RCI-weighted Accessibility (rank)	-	-	-	0,981 (0,002)***
Constant	0,326 (0,308) ***	3,132 (0,256) ***	18,725 (0,416) ***	21,474 (0,371)***
-2 Log likelihood	334,721	379,834	321,037	282,690
Cox & Snell R Square	,200	,065	,237	,331
Nagelkerke R Square	,267	,087	,316	,443

Deviation between old and new version

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