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Resilience and accessibility of Swedish and Dutch municipalities

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Abstract Recent years have shown a rising popularity of the concept of resilience—both theoretically and empirically—in complex systems analysis. There is also a rising literature on resilience in the transport and spatial-economic field. The pluriform interpretation of resilience (e.g., engineering vs. ecological resilience) is related to methodological differences (e.g., stability in dynamics vs. evolutionary adaptivity). But in all cases the fundamental question is whether a complex system that is subjected to an external shock is able to recover, and if so, to which extent. The present paper [Based on presentation from cluster 6 (Accessibility) of the Nectar 2015 conference in Ann Arbour, USA.] aims to add a new dimension to resilience analysis in spatial systems, by addressing in particular the relationship between spatial accessibility at a municipality level and the resilience outcomes of the spatial system concerned. It does so by investigating to which extent accessibility of Swedish and Dutch municipalities has mitigated the local shock absorption from the recent economic recession. In our study the shock absorption capacity of municipal accessibility is estimated by analysing the relevant resilience indicators for the period concerned. In this context, conventional resilience indicators based on either multivariate complex data (in particular, the Foster Resilience Capacity Index) or employment data (in particular, the Martin Resilience-Employment Index) are confronted with spatial connectivity data based on local accessibility measures, so that geographical mobility may be regarded as one of

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the shock-mitigating factors. The empirical analysis is carried out for two countries which have both proven to be rather shock-resistant during the recent economic crisis, viz. Sweden and The Netherlands. Clearly, the geographical structure of these countries forms a sharp mutual contrast, viz. a spatially dispersed economy with a few distinct urban concentrations versus a spatially dense economy with one major metropolitan centre (the Randstad), respectively. Our experiments are carried out for the 290 municipalities in Sweden and 40 COROPs in The Netherlands. Our research findings show relevant and new insights into differences in the local recovery potential in Sweden and The Netherlands.

Keywords Resilience · Accessibility · Comparative approach · Sweden · The Netherlands

Introduction

Regions are dynamic socio-economic constituents of a country, with often a high degree of physical and virtual interaction. They are influenced by internal dynamics and external forces from either outside the region or outside the country. Such influences may be gradual in nature, but may sometimes also have a shock character. Examples of external shocks or jumps are sudden migration movements or internal economic crises. Such crisis phenomena may impact a system of regions in either a uniform or a place-specific way, depending on the robustness of the socio-economic structure of each region and the degree and nature of interregional interdependencies. In the latter case, the degree of openness of the spatial system concerned may play a critical role, in particular in relation to the spatial accessibility of the region or place concerned.

Accessibility is usually related to a long-range characteristic and functioning of a transport system, while resilience is related to response patterns after an external shock. It seems plausible to hypothesize that a favourable accessibility may create more spatial openness and hence a faster shock propagation. But in the long run a countervailing power may emerge, since a high degree of accessibility may enhance productivity rise and competitive efficiency of an area, so that then the resilience pattern will enhance a region's recovery rate. Consequently, the extent to which a system of regions or places is affected by a shock depends—in addition to its internal strength—on the accessibility factors among these regions or places. Such distance-friction or distance-mitigation forces are a standard feature in spatial interaction models (see e.g. Fotheringham and O'Kelly 1989; Reggiani et al. 2011; Reilly 1931; Wilson 1981, 2009).

It is thus evident that the (spatial) recovery from an external shock depends on the intrinsic economic power of each region and the openness or accessibility of individual regions. Consequently, spatial resilience and spatial accessibility are two interrelated phenomena. The present paper seeks to address the relationship between spatial resilience of places and spatial accessibility indicators at a municipal level.

The economic literature in the past years has shown many interesting applications of shock analyses, either for specific sectors such as financial markets (see e.g. Hommes and Iori 2015) or for countries as a whole (see e.g. Tubadji et al. 2016). There is an extant literature on statistical and econometric methods and models to study shock identification, shock propagation, or shock mitigation (see e.g. Vermeer 2015). In the field of transportation science several studies have in recent years been published on the nowadays popular concept of resilience which aims to assess the recovery potential of a complex transport system after it has been affected by an external force (see for an overview, Caschili et al. 2015a; Reggiani et al. 2015).

Resilience has in the past decade become a popular research concept in both the natural sciences and the life sciences, and increasingly also in the social sciences. In recent years, its popularity has clearly also risen in the spatial sciences (e.g., geography, regional economics, transportation sciences). Recent reviews on resilience in spatial systems can inter alia be found in Bailey and Turok (2016); Caschili et al. (2015b); and Modica and Reggiani (2015). In this context, Reggiani et al. (2015), in the vein of Holling (1986), made a distinction into engineering resilience and ecological resilience. Engineering resilience "*concentrates on stability near an equilibrium steady state*", while ecological resilience "*emphasizes conditions far from any equilibrium steady state, where instabilities can flip a system into another regime of behaviour, that is, to another stability domain*" (Holling 1996, p. 33).

It is clear that, next to a conceptual clarification of resilience principles, the operational definition and measurement of resilience is a major research issue. In the spatial-economic literature two main approaches can be distinguished:

- The Foster (2007) Resilience Capacity Index (RCI), which is a 'high complexity' measure, comprising a wide range of (12 equally) important factors subdivided into 3 classes: (1) economic capacity; (2) socio-demographic capacity; and (3) community connectivity capacity.
- The Martin (2012) Resilience Employment index (REI), which is essentially a 'low complexity' measure proxied by spatial labour market data in relation to the national trend data.

In particular, RCI, being more of a kind of static measure, might identify the engineering resilience; while REI, being a more dynamic measure, might qualify the ecological resilience [see also the subsequent formulas (1) and (2)]. Many of the components in the RCI composite index may also be seen as proxies for central features in agglomeration economies, where the localization of skill and industrial mix, and when combined with measurements of accessibility, also the potential for knowledge spillovers are of great importance (Rosenthal and Strange 2004; Bathelt et al. 2004). It is noteworthy that sometimes in transportation studies also related concepts such as robustness, vulnerability or reliability are being used (see e.g. Cox et al. 2010; Watling and Balijepalli 2012). As a first step in our empirical analysis, we will focus on these two resilience indicators to test the resilience of both Swedish and Dutch municipalities after the occurrence of the economic crisis shock in the years 2007–2008. Thus our study focuses on local resilience patterns.

In addition—and more importantly—our analysis addresses explicitly local accessibility conditions as a moderator variable for the recovery process after a shock in a local system (see also Östh et al. 2015). Normally, shock propagation and recovery processes are studied in terms of socio-economic indicators (e.g., employment, income), but the mitigation and shock recovery potential of spatial mobility—proxied through geographic connectivity and spatial openness based on accessibility—has not yet been given full-scale attention in the literature. Accessibility is mainly related to a long-range feature and functioning of a fine-grained local (or inter-local) transport system. Clearly, in a first stage shock propagation may proceed faster in an open spatial system, but after some time a high accessible spatial system may prompt a faster productivity rise and efficiency increase in the area concerned, so that the area's recovery rate may be faster due to geographical resilience forces.

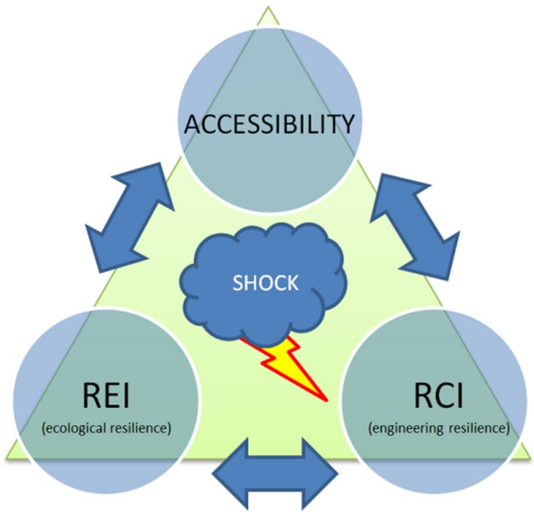

Fig. 1 The interlinked driving forces of Accessibility, RCI and REI, for identifying resilience of a local centre after a shock

Thus, the novelty of our study rests on an empirical investigation of both shock data at the municipality level (by adopting two standard regional resilience indicators) and spatial interaction data based on accessibility structures at local level (see Fig. 1). Clearly, the focus on the local recovery patterns leads to a rather low geographical granularity in spatial resilience analysis.

In our study we address local resilience patterns in two countries, viz. Sweden and The Netherlands. Both countries belong to the wealthiest countries in Europe and both countries—though affected by the recent economic recession in 2007–2008—have shown an above average recovery rate from this crisis situation and belong at present to the group of countries with the highest happiness index. On the other hand, these countries are geographically rather different: Sweden has a low population density, while The Netherlands has a very high population density, mainly concentrated in the western part of the country. Consequently, our analysis is based on both similarities (in economic terms) and dissimilarities (in geographic terms) among these two countries. It goes without saying that given the geographic differences between these countries, the connectivity/accessibility pattern related to infrastructure is rather different (see for some empirical data Eurostat 2016). Consequently, our study does not aim to provide a full-fledged comparison of Sweden and The Netherlands, but to demonstrate the relevance and the potential of a combined accessibility—resilience study for the two countries with both similar and dissimilar economic-geographic characteristics.

In light of the above observations, the present paper has the following research aims:

- To assess the (differences in) economic-geographic resilience in both Sweden and The Netherlands, after the economic shock in the years 2007–2008.
- To address in particular the relevance of the municipality level in both countries for studying spatial resilience.
- To add in a spatial resilience analysis explicitly the importance of local accessibility (which is related to spatial openness and connectivity), so as to trace its impact on spatial resilience.

- To investigate the robustness (or 'sensitivity') of our findings by employing alternatively the RCI or REI measure for spatial resilience.

This paper is organized as follows. "Methodological framework" section will be devoted to a methodological framing of our research, in which particularly the operational measurement of resilience and accessibility will be presented. Next, "Data" section will be devoted to the data base, from both Sweden and The Netherlands. "Comparative analysis: the results" section will provide the empirical resilience results—and related accessibility results—for both countries, including detailed maps showing our findings and providing a solid base for an interpretation of the results. Finally, "Conclusions" section will offer some—retrospective and prospective—remarks.

Methodological framework

As mentioned in the "Introduction" section, the present study rests on two legs: (1) a detailed study of spatial (i.e., local) resilience based on socio-economic indicators for Swedish and Dutch municipalities; (2) the explicit consideration of economic-geographic interaction factors in the form of spatial accessibility measures in a spatial resilience context of both countries. These two constituents will now explicitly be addressed.

Measuring spatial resilience

As indicated above, two types of measures of resilience are employed in this study: a *composite* measure of regional economic resilience taking multiple factors into account and a *simple* measure using one indicator to proxy regional economic resilience. The composite measure is represented by the Resilience Capacity Index (RCI) measure (Foster 2007). The RCI is used, since it aims to provide an *all-encompassing* measure where a total of 12 equally weighted factors are combined into one single measure. These factors are subdivided into three categories representing the regional-economic, socio-demographic and community connectivity capacity. Within each of these categories four different variables are used to capture a broad profile for each category. The economic capacity category aims at describing the function of the regional labour market and contains parameters describing *income equality* (Gini), *economic diversity* (deviation from national industrial mix), *affordability* (pricing on housing market) and *business environment* (ranking of local business climate). The socio-demographic capacity category aims to depict skills and risks among members of the regional labour force and contains variables describing the regional *educational attainment* (% of aged 25 + with a bachelor's degree), 'w*ithout disability*' (share of population without need of health care), '*out of poverty*' (% population above the poverty-line) and *health insured* (share of population health insured). Finally, the community connectivity capacity category aims to describe the resilience of the community and contains variables describing the regional *civic infrastructure* (share of NGO workers), *metropolitan stability* (stability of population over time), *homeownership* (share residing in self-owned homes), and *voter participation* (share of voting people).

The variables are designed as shares and do as such assume values between 0 and 1, where higher values are always better. By standardizing (Z-score) each variable and by taking the mean of all standardized values on a municipal level, each municipality can be arranged according their estimated level of resilience. Information on the contents of these variables is available in the "Appendix". Detailed presentation of relevant RCI indicators[1] can be found inter alia in Östh et al. (2015). In Eq. (1), the specification of RCI is given. The $Z(n_i)$ ($n = 1,\ldots,12$) value indicates the standardized score representing one of 12 indicators, while i stands for municipality i:

$$RCI_i = \frac{\sum (Z1_i, Z2_i, \ldots Z12_i)}{12} \tag{1}$$

It should be noted that RCI is interesting due to the rich scope of the various indicators, but is also a somewhat static measure, indicating a sort of 'resilience capacity/potential'. In other words, RCI might be suitable for measuring the 'engineering resilience'. It may also be seen as a proxy for economic contexts in agglomeration economies.

In contrast, the simple measure expressed by the Martin index (Martin 2012; Lagravinese 2015) is more 'dynamic', being based on the growth rate of employment over time, and thus more suitable for identifying the 'ecological resilience' [see Eq. (2)].

In Eq. (2), the Martin index for place i ($\mathrm{REI_i}$) is formulated, on the basis of Lagravinese (2015), where Δ indicates the change over time $t - t + 1$, and Er and EN represent employment levels at local and national levels, respectively:

$$REI_i = \frac{(\Delta \mathrm{Er}/\mathrm{Er}) - (\Delta \mathrm{EN}/\mathrm{EN})}{|\Delta \mathrm{EN}/\mathrm{EN}|}. \tag{2}$$

This index is constructed as a kind of 'elasticity' or shift-share index, where regional employment levels are related to the national trend. By relating the regional trend in employment to the national employment trend, a value close to 1 indicates a labour market situation similar to the national case, while greater (lower) values indicate a more favourable (less favourable) outcome. The greater the value the better the place performs in relation to the national trend. The degree to which a place is actually performing is used as a proxy for the local economic resilience. The spatial level in our study will be represented by municipalities for both Sweden and The Netherlands.

It should finally be noted that none of these two spatial resilience indicators takes into account geographic interaction/mobility factors. In order to analyse the role of mobility/connectivity patterns versus resilience, we have, as explained above, introduced and analysed here a third indicator, viz. accessibility. We compared this indicator next with the two resilience indicators. Accessibility is in the present context a more appropriate indicator than connectivity, since it weighs connectivity by means of socio-economic variables impacting resilience.

Measuring spatial accessibility

Accessibility is in this study perceived as potential accessibility following the tradition set out by Hansen (1959) and others. Accessibility at a location i is formulated in a general form as described in Eq. (3):

$$Accessibility_i = \sum_{i \in j} D_j f(\gamma, d_{ij}), \tag{3}$$

[1] See the original website: http://brr.berkeley.edu/rci/.

where D_j represents an amenity at any destination D and with a distance deterrent function where d_{ij} represents distance d between locations i and j, and where γ represents a distance decay function. Potential accessibility can be modelled differently including different models for the depiction of spatial interaction as well as the functional form of the decay of interaction. In this study we make use of a half-life-model specification of distance decay and use an unconstrained accessibility model for spatial interaction. The unconstrained model is favoured in our study, since we are less interested in potential accessibility being a result of competition between both supply and demand (or supply or demand depending on modelling assumptions), but rather in the *free* potential accessibility from any location i. This is because an unconstrained model provides a picture of the maximum potential accessibility from any location (since no competition is considered), while a doubly constrained specification depicts more likely flow patterns where the sum of accessibility between all i and j is restricted by demand. Earlier studies have shown that changes in *GDP* tend to affect national and regional commuting behaviour in both The Netherlands and Sweden, creating new commuting time equilibria (Rouwendal and Rietveld 1994; Östh and Lindgren 2012). This means that an unconstrained accessibility pattern will be able to better capture the potential for adaptation to a new spatial economic situation than would corresponding constrained models.

We will employ here an exponential decay function, since the exponential function has a functional form that depicts commuting well, in the presence of a socio-economic homogeneous network (De Vries et al. 2009; Fotheringham and O'Kelly 1989; Reggiani et al. 2011; Wilson 1981). The decay parameters used in the accessibility estimations for The Netherlands and Sweden are determined using a half-life modelling approach (see, for instance, O'Kelly and Horner 2003; Östh et al. 2014). A recent study on job accessibility in Sweden has shown that decay parameter estimates become more accurate (commuting estimates are more similar to observed commuting patterns) using half-life models compared to regression models (Östh et al. 2016). In Eq. (4) the unconstrained, exponential potential accessibility function is described:

$$Accessibility_i = \sum_{i \in j} D_j \exp(-\beta d_{ij}), \tag{4}$$

where D_j represents jobs at each location J, and d_{ij} represents network distance between population weighted midpoints in each municipality in Sweden and The Netherlands. β is a decay parameter that is determined using the half-life modelling approach formulated in Eq. (5):

$$\beta = \frac{\ln(0.5)}{m}. \tag{5}$$

The m value represents the median commuting network distance.[2]

[2] Commuting distances between municipalities are available as network distances for the Netherlands (CBS) and Sweden (Network calculations in GIS using Road Networks). Through aggregation the Dutch data has been adapted for COROP levels. Commuting distance within each municipality is in The Netherlands estimated to be equal to sqrt((area/2)/π). In the Swedish case, coordinates of residence and workplace are known from micro-data making it possible to calculate Cartesian distances to be used to proxy for within-municipality commuting distances.

Data

In the present section, the data used for setting up measures of resilience, accessibility and testing of how resilience and accessibility play out spatially in The Netherlands and in Sweden will be described. Collecting statistics that can be used to generate equivalent and consistent variables in both The Netherlands and in Sweden has in this case proven to be feasible. In both countries rich statistical resources are available as digital online information. In addition, researchers may acquire highly disaggregate statistical data material for scientific use; clearly, regulations and means for use of and access to these data bases vary between the two countries (NL Stat and SE Stat).

The Swedish data has been drawn from five sources: PLACE (research database located at Uppsala University, individual level database compiled by Statistics Sweden), the Swedish Electoral Authority (Valmyndigheten), the National Board of Health and Welfare (Socialstyrelsen), the Confederation of Swedish Enterprise (Svenskt näringsliv) and online datasets from Statistics Sweden (Statistiska CentralByrån or SCB). Dutch statistics have been collected from the StatLine tool available from CBS (Centraal Bureau voor de Statistiek). Details on the way the Swedish data were collected can be found at length in Östh et al. (2015). The primary spatial unit of analysis in our study for both countries is based on municipalities.

These units are chosen in order to visualize the effect of mobility interaction/accessibility on spatial resilience, and also because policy efforts to prevent vulnerabilities and to increase resilience are typically conducted on a local to regional level, having municipalities as key stakeholders in the process. However, we should be aware that, at present, official data at regional level are more abundantly available than data at municipal level (see, e.g., Eurostat 2016). In this framework, our experiments aim also to outline the relevance of getting/using data at municipal levels for analysing the dynamics of socio-economic interaction effects. In addition, Swedish municipalities were reorganized from multiple smaller and functionally different areas during the 1960s and early 1970s according to Christaller's (1933) inspired administrative areas consisting of a central place and the rural areas in the vicinity (see Fig. 2 for an illustration). This means that most Swedish municipalities function as self-sustaining service and job markets, since they contain a *full spectrum* of relevant economic functions. In the Dutch case, municipalities are much smaller, while cross-border commuting is considerably more common compared to the Swedish case. This also means that sorting of functions often takes place at spatial scales greater than municipalities, increasing variations between municipalities. To make comparison to the Swedish case feasible we make use of aggregated statistics on COROP (NUTS3) level that are more similar in size to Swedish municipalities than Dutch municipalities.[3] COROPs have also, in contrast to Dutch municipalities, the advantage of being geographically stable over time.

Year is the unit of time in this analysis, where the REI and accessibility variables are constructed using data from 2003 to 2014 in Sweden and 2006–2014 in the Netherlands (differences due to availability). Since REI is computed using over-time change, REI can be calculated for year 2004–2014 in Sweden and 2007–2014 in The Netherlands. Job accessibility is estimated for years 2004–2014 in Sweden and years 2007–2014 in The

[3] Average size of COROPS are 2769 km^2, Equivalent size for Swedish municipalities is 1475 and 84 km^2 for Dutch municipalities (Values derived from GIS computations).

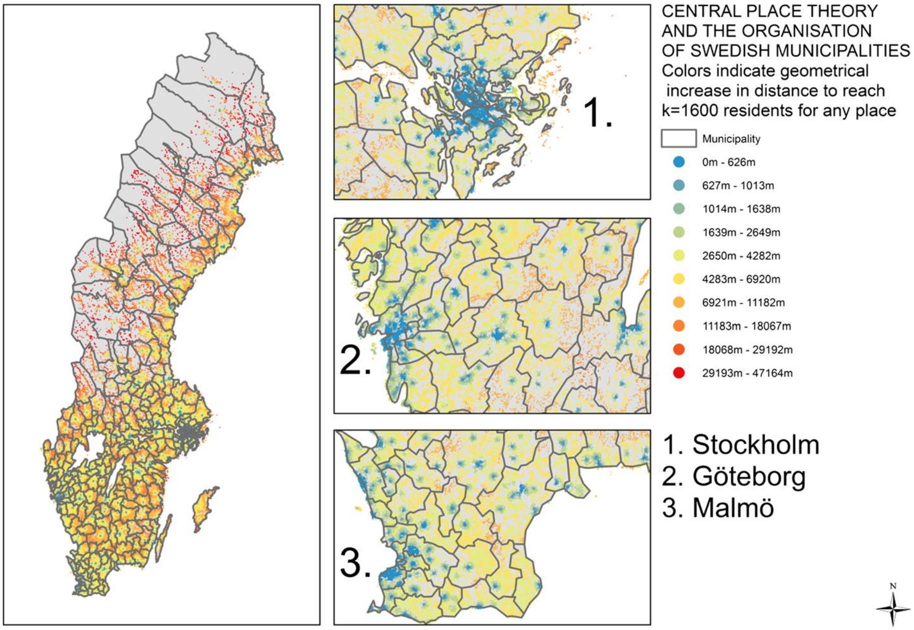

Fig. 2 Density map indicating the number of meters needed to reach $k = 1600$ nearest neighbours from any inhabited location in Sweden. Blue colour indicates short distances typical for urban areas. Administrative borders representing municipalities show how the central place ideal is used to for the formation of an administrative centre and the area nearest the central place is assigned to the central place

Netherlands. The RCI is by design constructed to be steady over time (RCI can for reasons such as election-participation not be calculated annually) and rendered values are used as constants in regressions.

Comparative analysis: the results

Resilience and accessibility of Swedish and Dutch municipalities

The present paper aims to investigate the relationship between geographical accessibility and regional economic resilience. Of key importance in this study is a comparative analysis where we study the extent to which and the direction in which a varying degree of complexity in measuring resilience in comparison to accessibility in two countries with entirely different demographic and economic density patterns may evolve. In order to retain comparability between the models and the countries and/or places, the estimations of both economic resilience and accessibility should be analysed with great care. This concerns especially the analysis of REI [see Eq. (2)]. Since here only one parameter is used for the calculations, the REI indicator may become sensitive to the geographical scale and the timeframe in that too small areas and too short time spans risk to suffer from local, short term volatilities on the labour market that affects the REI value dramatically. However, by employing a panel design, over-time changes in REI can be used to see how variation in job accessibility affects the outcome. RCI is, on the other hand designed for over-time stability, and is less suitable for studies of fluctuations.

In other words, losing or generating a few jobs in a small municipality may relatively correspond to losing or generating several thousands of jobs in a larger municipality, a fact which in turn means that the very negative and very positive values are likely pointing towards municipalities in less dense populated areas or to municipalities in datasets where only shorter time spans are studied.

In order to control for this scale problem, we have created panel datasets that caters for the volatile fluctuations making use values for several years but also, in the Dutch case, making use of aggregated data to prevent problems attributable to small population and job counts. Rather than pooling all events over time and using a model that assumes that there are no universal effects cross time, we make use of a random effects model where time-constant effects such as business cycles, are assumed to affect the dependent variable. Using panel regression models to study over-time dynamics in local and regional labour markets from a regional economic resilience perspective has successfully been conducted before, by using wage statistics in the UK and employment statistics in the EU (Fingleton and Palombi 2013; Doran and Fingleton 2016). Apart from differences in research questions, this study differs from previous studies by the focus on the contribution of job accessibility for understanding regional economic resilience.

For both Sweden and the Netherlands we test four different models, wherein the first model use year-specific job accessibility, adding year-effects in model 2, introducing the engineering resilience (RCI) in Model 3 and finally introducing squared accessibility (Accessibility 2) in model 4 in order to test for non-linearity. All regressions are conducted using random effects.[4] In Table 1, the results from the regressions on Swedish municipalities are shown. The results indicate that accessibility significantly and positively correlate with ecological resilience (REI) in all of the three models. Adding year-effect strongly improves the explanatory power of the model but also shows that the global recession of 2007 stands out negatively (note that REI in this case shows the difference between 2006 and 2007). In model 3 the effects of introducing RCI is shown to be insignificantly positive and with limited effect on explanatory power. This suggests that engineering resilience (RCI) is a poor instrument for understanding short-term fluctuations on the local labour market. However, alternative specifications indicate that RCI is correlated with accessibility and regressions where RCI is introduced without accessibility render significant and positive coefficients and predicted REI-values that are similar to the models illustrated in the maps.[5] In model 4, squared accessibility (accessibility 2 in the table) is introduced in order to test for non-linearity in the accessibility regressor. The result shows that the accessibility coefficient is positive while the accessibility squared is negative. This indicates that accessibility is positively correlated with REI but in highly accessible regions correlations start becoming negative. Likely explanations for the latter is that competition and costs increase in the more dense areas.

[4] Using Hausman test to compare fixed effects regression to random effects regressions show that there is no significant difference in coefficients and random effects model are therefore used in all models and for both Sweden and The Netherlands.

[5] Alternative random effects (RE) regression with REI as dependent variable and RCI and Year as regressors renders: RCI-coefficient 0.7353 (0.2272)***, and an overall R^2 of 0.0608—Year have same direction and significance levels as in the full regression.

Table 1 Random effects regression using REI as dependent variable

	Model 1	Model 2	Model 3	Model 4
Variables	Coeff(SE)P > z	Coeff(SE)P > z	Coeff(SE)P > z	Coeff(SE)P > z
Accessibility	7.99E−06 (1.13E−06)***	7.93E−06 (1.13E−06)***	7.73E−06 (1.27E−06)***	1.85E−05 (2.71E−06)***
Accessibility 2				− 2.87E−11 (6.48E−12)***
RCI			0.0821 (0.2388)	− 0.1882 (0.2391)
Y2004		Reference	Reference	Reference
Y2005		1.7471 (0.2449)***	1.7472 (0.2449)***	1.7474 (0.245)***
Y2006		1.6196 (0.2449)***	1.6197 (0.2449)***	1.6183 (0.245)***
Y2007		− 0.4731 (0.2449)	− 0.4728 (0.2449)	− 0.475 (0.245)
Y2008		1.5621 (0.2449)***	1.5625 (0.2449)***	1.5613 (0.245)***
Y2009		1.776 (0.2449)***	1.7762 (0.2449)***	1.7785 (0.245)***
Y2010		2.0572 (0.2449)***	2.0576 (0.2449)***	2.059 (0.245)***
Y2011		1.3161 (0.245)***	1.3166 (0.245)***	1.3168 (0.245)***
Y2012		1.1446 (0.245)***	1.1452 (0.245)***	1.1462 (0.245)***
Y2013		1.1219 (0.245)***	1.1226 (0.245)***	1.1241 (0.245)***
Y2014		1.4329 (0.245)***	1.4336 (0.245)***	1.436 (0.245)***
Constant	− 0.9401 (0.0693)***	− 2.148 (0.1788)***	− 2.1434 (0.1793)***	− 2.3082 (0.1823)***
R^2 within	0.0001	0.0643	0.0643	0.0641
R^2 between	0.1504	0.1504	0.1506	0.2070
R^2 overall	0.0205	0.0762	0.0762	0.0838
$\sum u$	0.5588	0.6037	0.6068	0.5435
$\sum e$	3.0443	2.9487	2.9484	2.9476
ρ	0.0325	0.0402	0.0406	0.0328

Model 1 shows the accessibility coefficient; Model 2 shows the effect of accessibility as well as year effects; Model 3 shows the effects of accessibility, years as well as REI; in Model 4, squared accessibility is introduced. Unit of analysis is Swedish Municipality, Balanced panel 3190 observations, 290 groups

***Represents significance on 99.9% level

**Represents 99% significance level

*Represents 95% significance level

Table 2 Random effects regression using REI as dependent variable, Model All (full model) is identical to model 4 in Table 1

	All	≥ 5000 jobs	≥ 10,000 jobs	≥20,000 jobs	≥ 40,000 jobs	≥60,000 jobs
Accessibility	+	+	+	+	(+)	(+)
Accessibility2	–	–	–	(−)	(−)	(−)
RCI	(−)	(−)	(−)	(−)	(+)	(+)
Year 2004	REF	REF	REF	REF	REF	REF
Year 2005	+	+	+	(+)	(−)	(−)
Year 2006	+	+	+	(+)	(−)	(−)
Year 2007	(−)	(−)	(−)	+	(+)	(+)
Year 2008	+	+	+	(+)	(−)	(−)
Year 2009	+	+	+	(+)	(−)	(−)
Year 2010	+	+	+	(+)	(−)	(−)
Year 2011	+	+	(+)	(+)	(+)	(−)
Year 2012	+	+	+	(+)	(−)	(−)
Year 2013	+	+	+	+	(−)	(−)
Year 2014	+	+	(+)	(+)	(−)	(−)
R^2 overall	0.0838	0.0734	0.0497	0.0539	0.0783	0.0667
Observations	3190	1891	1078	528	241	124
Groups	290	184	104	49	23	13

Models: ≥ 5000 jobs, ≥ 10,000 jobs, ≥ 20,000 jobs, ≥ 40,000 jobs and ≥ 60,000 jobs are full models with populations restricted to municipalities having at least as many jobs as indicated by the model title. + and − indicate significant positive and negative coefficients while (+) and (−) indicate insignificant positive and negative coefficients. Values in row: Groups, indicate the number of unique municipalities, and values in row: Observations indicate the total number of observations (years times groups) included in each model. REF means reference category

In addition to the models shown in Table 1, alternative populations are used to test the effects of restricting municipalities on the basis of the size of the local labour market as illustrated in Table 2. In order to show several different population selections in the table, the regression output is compressed to + and − for coefficients being significantly (95% confidence interval) positive and negative, and (+) and (−) for non-significant positive and negative coefficients.

Each model is listed in columns where the left column makes use of all municipalities all years (equal to model 4 in Table 1), while the subsequent models (columns) show the results from regressions that are restricting the population to municipalities holding at least 5000, 10,000, 20,000, 40,000 or 60,000 jobs at any time. It is worth noting that sign of the accessibility coefficients remains the same regardless of population while years and RCI effects tend to switch direction from selecting municipalities holding at least 40,000 jobs and lose most of the significance from 20,000 jobs. None of the population restricted regressions render an explanatory power that is equal to the full population. In Fig. 3, a mesh is used to indicate the municipalities selected for regression model ≥ 10,000 jobs. Though clearly not the best population from an explanatory power perspective, it is the most restrictive population that still renders significant coefficients and is as such chosen to visually represent the medium to larger labour market areas in Sweden.

In the Dutch case regressions were employed on both municipality and COROP levels. However, since the results were, in all essential, similar and COROPs are more equal

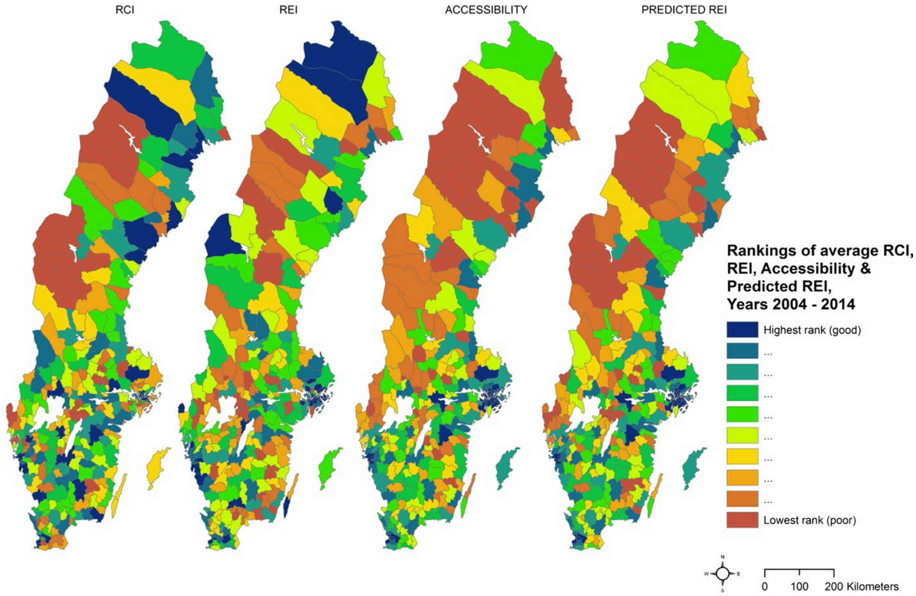

Fig. 3 Results on RCI and REI, accessibility and predicted REI in Sweden categorized into 10 quantiles from high ranks (blue) to low ranks (brown). (Color figure online)

to Swedish municipalities in size, only results from COROP-regressions are shown in Table 3. A notable difference between the Swedish and the Dutch case is that explanatory power and significance-levels are much lower compared to the Swedish regressions (this is the case also when using Dutch statistics on municipality-level). In model 1, accessibility is insignificantly and positively correlated with ecological resilience (REI). With the introduction of year-effects (model 2, model 3 and model 4), the accessibility coefficient changes direction, but remain statistically insignificant. Year-effects do not pick up the business cycle patterns detectable in Sweden, and the introduction of RCI (Model 3) does not render any significant coefficients. In contrast to the Swedish case, the introduction of square accessibility in Model 4 does not render any significant results and in addition, the relationships are opposite to relationships noted in the Swedish model 4. Having that said, by restricting the COROPs by the number of jobs, significant and to the Swedish case similar results are retrieved (see Table 4).

In the Dutch case, the COROPs are fewer in counts but more populous in terms of individuals and jobs compared to the Swedish municipalities. For this reason, the alternative Dutch populations are restricted and compared using very different counts. It should be noted however, that all cut-off values in the Swedish and the Dutch dataset have been tested in both datasets but the difference in size and population makes comparison from a cut-off value perspective meaningless. The results indicate, in difference from the Swedish case, that explanatory power increases as the population restrictions are enforced. Populations consisting of all COROPs to all COROPs with at least 100,000 jobs are performing poorly and render similar results. However, populations-restricted COROPs with more than 150,000 job have greater explanatory power and do (with the exception of the ≥ 300,000 jobs population) also render significant coefficients for accessibility, square accessibility and in one case RCI. The year-effects

Table 3 Random effects regression using REI as dependent variable

	Model 1	Model 2	Model 3	Model 4
Variables	Coeff(SE)P > z	Coeff(SE)P > z	Coeff(SE)P > z	Coeff(SE)P > z
Accessibility	1.43E−05 (1.31E−05)	− 1.42E−05 (0.0131)	− 1.48E−05 (1.37E−05)	− 6.4E−05 (5.38E−05)
Accessibiliy2				1.47E−10 (1.54E−10)
RCI			− 10120 (5.9638)	1.7717 (6.6435)
Y2007		Reference	Reference	Reference
Y2008		− 5.4243 (5.1365)	− 5.4243 (5.1365)	− 5.4221 (5.1371)
Y2009		− 0.097 (5.1366)	− 0.0983 (5.1366)	− 0.0784 (5.1372)
Y2010		0.0283 (5.1365)	0.028 (5.1365)	0.0364 (5.1371)
Y2011		0.1972 (5.1367)	0.1988 (5.1367)	0.2042 (5.1372)
Y2012		0.0676 (5.1366)	0.0671 (5.1366)	0.1167 (5.1374)
Y2013		− 0.0909 (5.1367)	− 0.0925 (5.1367)	− 0.0366 (5.1376)
Y2014		0.1214 (5.1366)	0.1202 (5.1366)	0.1624 (5.1374)
Constant	1.0241 (2.0356)	1.6693 (3.9654)	1.6067 (3.996)	4.3601 (4.9322)
R^2 within	0.0006	0.0071	0.0071	0.0073
R^2 between	0.0308	0.0308	0.0316	0.0537
R^2 overall	0.0038	0.0101	0.0102	0.0132
$\sum$u	1.2106	0.5908	1.4452	1.4647
$\sum$e	22.7942	22.9893	22.9593	23.0311
ρ	0.0028	0.0007	0.0039	0.0040

Model 1 shows the accessibility coefficient; Model 2 shows the effect of accessibility as well as year effects; Model 3 shows the effects of accessibility, years as well as REI; in Model 4, squared accessibility is introduced. Unit of analysis is the Dutch COROP (NUTS3), balanced panel 320 observations, 40 groups. (No significant coefficients were recorded)

are always insignificant and vary in direction between population restrictions. This suggests that accessibility is important for the magnitude and direction of ecological resilience (REI). However, a major difference is that of scale and job-density where the contrasting accessibility structures between the Netherlands and Sweden makes direct comparison difficult where accessibility seems to be more of a necessity for ecological resilience in Sweden and a matter of opportunity in the Netherlands. In Fig. 4, a mesh is used to illustrate the COROPs used in the ≥ 250,000 jobs population. The population is chosen since it renders strong explanatory power and significant accessibility coefficients.

The regression results suggest that Swedish municipalities are more sensitive to economic over-time fluctuations than The Netherlands, and also that the potential accessibility to jobs seems to be important for sustaining economic resilience in Sweden. The sheer size of Sweden, and its distances, is a major reason to why higher levels of job accessibility may be associated with economic resilience. In The Netherlands the *abundance of* potential job accessibility makes accessibility less of an indicator and the explanatory power is consequently also less important. However, the population restricted models reveal that accessibility may be of growing importance for sustaining economic resilience in major urban districts with agglomeration economies.

Table 4 Random effects regression using REI as dependent variable, Model All (full model) is identical to model 4 in Table 1

	All	≥ 50,000 jobs	≥ 100,000 jobs	≥ 150,000 jobs	≥ 250,000 jobs	≥ 300,000 jobs
Accessibility	(−)	(−)	(−)	+	+	(+)
Accessibility2	(+)	(+)	(+)	−	−	(−)
RCI	(+)	(+)	(−)	−	(+)	(−)
Year 2007	REF	REF	REF	REF	REF	REF
Year 2008	(−)	(−)	(−)	(+)	(+)	(+)
Year 2009	(−)	(−)	(−)	(+)	(−)	(−)
Year 2010	(+)	(+)	(−)	(−)	(−)	(+)
Year 2011	(+)	(+)	(+)	(−)	(−)	(−)
Year 2012	(+)	(+)	(−)	(−)	(−)	(−)
Year 2013	(−)	(+)	(−)	(−)	(−)	(−)
Year 2014	(+)	(−)	(−)	(−)	(+)	(−)
R^2 overall	0.0132	0.0153	0.0116	0.0517	0.0957	0.139
Observations	320	289	202	137	80	61
Groups	40	37	26	18	10	8

Models: ≥ 50,000 jobs, ≥ 100,000 jobs, ≥ 150,000 jobs, ≥ 250,000 jobs and ≥ 300,000 jobs are full models with populations restricted to COROPs having at least as many jobs as indicated by the model title. + and − indicate significant positive and negative coefficients while (+) and (−) indicate insignificant positive and negative coefficients. Values in row: Groups, indicate the number of unique COROPs, and values in row: Observations indicate the total number of observations (years times groups) included in each model. REF means reference category

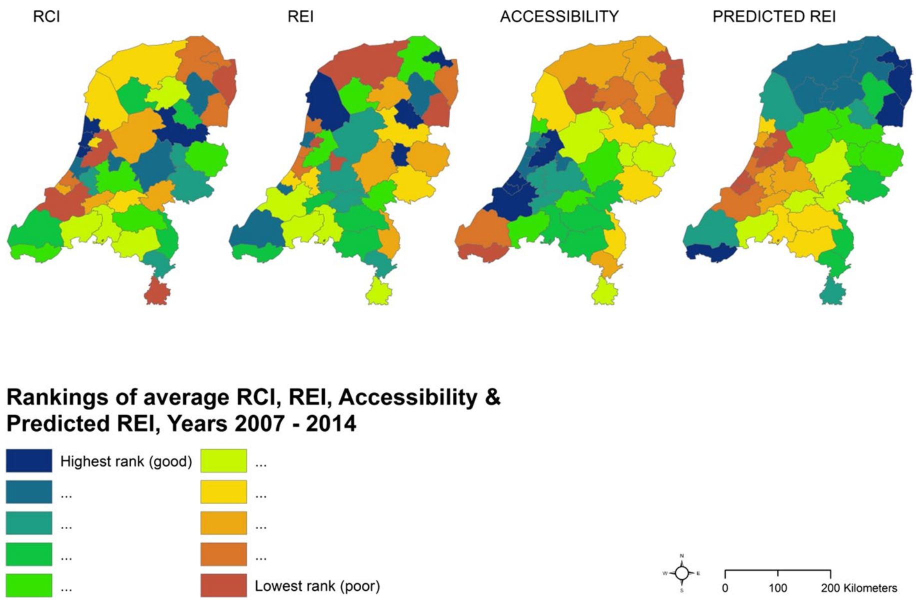

Fig. 4 Results on RCI and REI, accessibility and predicted REI in The Netherlands categorized into 10 quantiles from high ranks (blue) to low ranks (brown). (Color figure online)

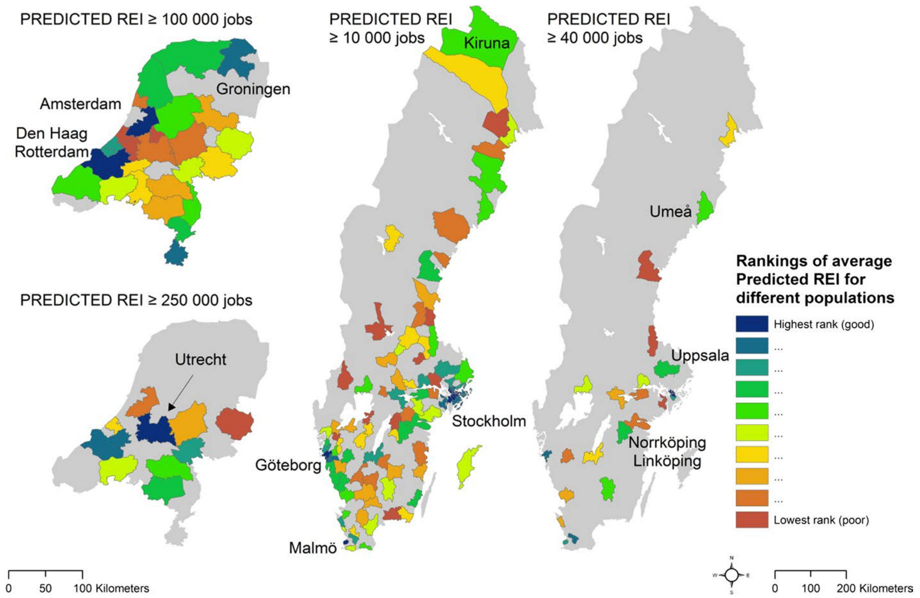

Fig. 5 Predicted REI-estimates from full model regressions where population is restricted to ≥ 100,000 jobs and ≥ 250,000 jobs in The Netherlands and to ≥ 10,000 jobs and ≥ 40,000 jobs in Sweden. City names are added to make identification of places easier

Maps

Mapping the results enable us to see the spatial organisation of the regressors and predictions. However, in order to map the data we have suppressed the temporal patterns by aggregating average values for each variable and municipality/COROP with the exception for the ecological resilience values (RCI) that are considered to be stable over time in the models. Both Figs. 3 and 4 are colour coded in 10 quantiles, ranking municipalities/COROPs according to their position in the statistics, where blue colours are representing high ranks (good) values, green colours intermediate positions and brown colours ranks in the lower positions (poor).

The four Swedish maps display relatively large similarities where especially the northwestern parts of Sweden are brown (lower ranks) and areas in proximity to the major urban areas are blue (higher ranks). Mining cities, tourist resorts as well as a few industrial cities constitute most of the municipalities that deviates from the general pattern in the more remote areas of Sweden. The predicted REI values are generated by taking the over-time average of the full-model regression (Model 4 in Table 1) for each municipality.

The Dutch maps in Fig. 4 are less similar compared to the Swedish maps. In the most population dense areas, concentrated to the western and central parts of the country, accessibility is high, but engineering resilience (RCI) is relatively low. Ecological resilience (REI) and predicted REI are relatively dissimilar which may be interpreted as a result of the poor model fit, using all COROPS.

The maps look different if the predicted REI values from the population restricted regressions are illustrated. In Fig. 5, two Dutch and two Swedish predictions are shown. In the Dutch case, the ≥ 250,000 jobs model has a considerably greater explanatory power compared to the full model and the coefficients for accessibility are both significant. In the ≥ 100,000 jobs model the accessibility coefficients are near significant. Both of the models display estimates that are more similar to the spatial distribution of accessibility compared to the full and non-restricted model. It is interesting to note that in the ≥ 250,000 jobs model, the positive coefficient for accessibility and negative coefficient for accessibility square moves the best rank to Utrecht which is a COROP with high levels of job accessibility but with lower levels of job accessibility compared to Amsterdam and The Haag/Rotterdam. The population-restricted Swedish models render decreasing levels of explanatory power compared to the full model. In the ≥ 10,000 jobs model, results are similar to the full model predictions but in the ≥ 40,000 jobs model, the highest ranks are becoming more concentrated to the major urban areas while the more remote municipalities are getting poor ranks.

The mapped results confirm the patterns indicated in the regressions; that the explanatory power is better in Sweden but that the population restricted models are doing a better job in The Netherlands. These results underline, in different ways, the importance of accessibility in the two countries. In Sweden, job accessibility is more of a necessity for sustaining an economically resilient local labour market. In The Netherlands, accessibility is a ubiquitous good that become significantly important only in economies of scale. It is likely, that job specialization and agglomeration specific parameters are of importance in the core employment areas in The Netherlands.

Conclusions

In this study, two very different proxies for regional economic resilience have been employed with the underlying aim to determine if measures of resilience and accessibility play out well together and to increase our knowledge about how a resilient regional economic labour market functions, also when tested in two countries with two different levels of density and two different principles for municipality classifications. One of the resilience measures (RCI) makes use of a wide range of parameters from a wide range of socioeconomic geographical fields. This means that the composite RCI encompasses many different factors and makes the measure relatively robust both over time and measuring for local economic functions. The other measure (REI) has the advantage of being easy to construct, using a single measure direct targeting local changes in employment over time. The latter measure (REI) appears to give a good statistical performance. In order to understand how potential job accessibility affects regional economic resilience we constructed panels for The Netherlands and Sweden that consisted of changes in REI, variations in job accessibility and RCI values for all municipalities in Sweden and for all COROPS in The Netherlands before, under and after the 2007–2008 economic crisis.

Regression results indicated that accessibility is an important factor for regional economic resilience in Sweden. This makes sense considering that Sweden is a sparsely populated country and where many municipalities would not be able to offer alternatives in case a major employer left the labour market. The Dutch panel rendered a very different result indicating that accessibility was of little importance for regional economic resilience. Also this makes sense under the assumption that high job accessibility in most locations makes it easier to find a replacement job or to hire replacement labour. However, by restricting the panel to include only larger labour market areas in Sweden and the Netherlands, different results emerged especially for The Netherlands. In the Dutch panel, accessibility significantly contributed to explain variation in REI when labour markets where large. This may suggest that there are agglomeration effects where factors such as knowledge spillovers affects regional economic resilience on spatial levels beyond what is observable on the regular labour market levels.

In either case, accessibility seem to be important for sustaining a regional economic resilience. Due to the formation of Swedish municipalities on the basis of the Central Place Theory (Christaller 1933), most municipalities in Sweden are spatially very large and with a substantial amount of the total commuting takes place within the borders of the municipalities (leave aside the metropolitan municipalities). Earlier studies have indicated that municipalities with both poor accessibility and poor resilience levels lose population at a greater pace than other types of municipalities (Eriksson and Hane-Weijman 2015; Östh et al. 2015). This suggests that Swedish municipalities are dependent on either being located in proximity to alternative and resilient labour markets or to be a community where important resilience-building factors including, health, education, industrial mix etc. plays an important role in shaping the local economy. The results also indicate that greater levels of proximity means that local communities are less dependent on engineering resilience but instead more responsive to ecological resilience. In both The Netherlands and in Sweden job accessibility is important for sustaining a resilient labour market. The equity of availability to accessibility is, in transport planning and for communication with policy makers in transport planning of great importance (Lucas et al. 2016). The study has indicated that accessibility is an important factor for understanding how resilience is played out in different places and countries.

Authors' contribution JÖ: Empirical analyses, manuscript writing and editing; AR: Literature search, manuscript writing and editing; PN: Content planning, manuscript writing and editing.

Appendix

See Tables 5, 6 and 7.

Table 5 List of variables used for the estimation of the RCI economic capacity component, where the left column names the variables and functions according to the original RCI definition and where middle and right columns indicate the degree of measurement similarities between the original definition and the definitions used in Sweden and in The Netherlands

RCI A) Economic activity	Sweden	Netherlands
A1) Income Equality is measured as the inverse Gini coefficient in each municipality	Identical to original	Similar Measures share of individuals not categorized as rich and poor
A2) Economic Diversification. the vulnerability is expressed as the local deviation from the national industrial mix	Identical to original	Identical to original
A3) Affordability. measured as the share of the regional population spending less than 35 percent of their income on housing	Similar Relationship between home-ownership and income	Similar Relationship between home-ownership and income
A4) Business Environment	Similar Ranking of municipalities	Similar Creation of new firms as share of all firms

Table 6 List of variables used for the estimation of the RCI Socio-Demographic Capacity, where the left column names the variables and functions according to the original RCI definition and where middle and right columns indicate the degree of measurement similarities between the original definition and the definitions used in Sweden and in The Netherlands

RCI B) Socio-Demographic Capacity	Sweden	Netherlands
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	Identical to original	Similar Measured as share of individuals in employable ages with higher education
B2) The Without Disability. Indicator measures the share of the civilian non-institutionalized population who report no disabilities	Similar, combination of age and health	Similar, combination of age and health
B3) The Out of Poverty. The indicator measures the municipality share of the population having a greater annual income than what is defined as the poverty line	Similar—share of individuals not being in relative poverty	Similar—share of individuals not listed as poor
B4) Health-Insured	Not identical, sick-leave statistics	Not identical, self-valued health

Table 7 List of variables used for the estimation of the RCI Community Connectivity Capacity, where the left column names the variables and functions according to the original RCI definition and where middle and right columns indicate the degree of measurement similarities between the original definition and the definitions used in Sweden and in The Netherlands

RCI C) Community Connectivity Capacity	Sweden	Netherlands
C1) Civic Infrastructure is a measure of the density of civic organization employees	Similar (different from The Netherlands). Counts jobs rather than organisations	Similar (different from Sweden). Measures religious attendance and membership in religious organisations
C2) Metropolitan Stability is measured as permanent residency over a time period	Identical to original	Identical to original
C3) Home ownership is measured as share of population owning their property of residency	Identical to original	Identical to original
C4) Voter participation	Identical to original	Identical to original

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