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13/2018

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SEEDS Working Paper 13/2018
November 2018
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VULNERABILITY, RESILIENCE AND EXPOSURE: METHODOLOGICAL ASPECTS AND AN EMPIRICAL APPLICATIONS TO SHOCKS

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The economic recession which followed the 2008 financial crisis has raised important issues concerning the asymmetry of the shocks – at both the regional and the community level, especially in the European Union Member States. The asymmetry of the shock might be due to the different levels of vulnerability and exposure. These differences can arise because of dissimilarities in the intrinsic characteristics of regions or communities (e.g. the pre-crisis economic characteristics of regions, ageing, household income, and so on). While a great deal of attention has been paid, in the scientific literature, to the concept of resilience (e.g. the capacity to bounce back or to resist a given shock) and vulnerability (e.g. the inherent characteristics that create the potential for harm), less attention has been devoted to the full set of measures of socio-economic exposure (e.g. the things affected by a shock), as well as both to the relationship between vulnerability, exposure and resilience and to the losses which ensue as a result of different external shocks and exposure.

The objective of this paper is the exploration of the above-mentioned links, since these interrelations might produce different outputs. To this purpose, we first review the existing literature on vulnerability, exposure and resilience, in order to understand the connections between these concepts, with reference not only to economic shocks but also to other catastrophic events, such as natural disasters, man-made disasters, and so on. We then provide evidence of the impact mechanism of the 2008 financial crisis at the regional and the age-cohort level for the German labour markets, by highlighting how a shock turns into different losses according to the vulnerability and exposure of the objects (the regions and the age cohorts) under analysis.

JEL Code: R11; R23; Q54; Q56;
Keywords: Resilience; Vulnerability, Exposure; Economic shock; German districts

1. Introduction

In recent years, a number of events have dramatically increased the perception of instability, insecurity and uncertainty across the world (Christopherson et al., 2010). To mention but a few of these events, we may refer to, economic crises (e.g. the great economic recession after the crisis of 2008); natural and man-made disasters (e.g. the Fukushima tsunami and the related impact on nuclear power in 2011); political instability (e.g. the Syrian conflict that has involved several parties in the fight against Daesh); and terrorist attacks (e.g. the terrorist attacks in Paris in 2015). The combination of all these crises has most likely played a significant role in generating a general sense of insecurity (Hudson 2010).

However, not all these crises have a uniform impact across regions. In fact, it is possible to recognise an asymmetry of shocks – at both the regional and the community level (Modica, 2014; Modica et al., 2017a). The asymmetry of a shock is relevant, since the shock might occur as a result of dissimilarities in the intrinsic characteristics of regions or communities (e.g. the pre-crisis economic characteristics of regions, ageing, household income, etc.) that are able to influence the capacity of areas to recover from or resist a shock. While a great deal of attention has been paid, in the scientific literature, to the concept of vulnerability (e.g. inherent characteristics that create the potential for harm; Modica and Zoboli, 2016) and resilience (e.g. the capacity to bounce back or to resist a given shock; Martin, 2012), less attention has been devoted to full measures of exposure (e.g. all the objects that are potentially affected by a shock, such as buildings and infrastructure when considering physical exposure, or population when considering socio-economic exposure), as well as to the relationships between vulnerability, resilience and exposure, in relation to different external shocks.

The objective of this paper is the exploration of the above-mentioned links, since these interrelations might produce different outputs. To this purpose, we first aim to review the existing literature on vulnerability and resilience in order to understand the connections between these concepts, with reference not only to economic shocks, but also to other catastrophic events, such as natural disasters, man-made disasters, and so on. Next, we focus on the concept of exposure, by concentrating on objects or areas exposed to a shock. We then provide evidence of the impact mechanism of the 2008 financial crisis at the regional and the age-cohort level for the German labour markets, by highlighting how a shock turns into different losses according to the vulnerability and exposure of the objects (i.e. the regions and age cohorts) under analysis.

Given the wide coverage of these concepts and the wide array of disciplines relevant to these issues, it is becoming common in the literature to focus vulnerability/resilience on the following elements: a) what?, b) when?, c) where?, and d) for whom? (Meerow and Newell, 2016; Modica and Reggiani, 2015). Using this framework, we may identify from the literature on vulnerability and resilience three main topics, for which it is possible to apply these concepts (‘what’), at least in the social sciences: economic shocks; natural and man-made disasters; and terrorist attacks. These events are all exogenous shocks that can be considered as the trigger of a response for a given object or area (‘for whom’) that defines an ex-ante and an ex-post period (‘when’). From an analysis of the literature, we distinguish four main classes of objects or entities: communities; firms; infrastructures; and

regions/areas. The 'where' question is mostly related to the location of shocks; indeed with regard to natural and man-made disasters, we may recognise different places such as urban or rural areas, whereas states, (sub)regions or municipalities are typically analysed in the presence of economic shocks.

The paper is organised as follows. In the next section we review the available literature in relation to the socio-economic vulnerability issue. Next, in Section 3 we review the resilience literature. Section 4 considers the exposure concept on the basis of the preceding two sections. In Section 5 we provide a case study for the German labour markets by analysing the vulnerability/resilience of the German cohorts, while also identifying the exposure of the cohorts. Section 6 concludes with some retrospective and prospective remarks.

2. Vulnerability

As indicated in the previous section, a wide range of different disciplines uses the term 'vulnerability', producing a multi–faceted meaning that differs according to the different objectives and points of view of the analysts. On the basis of the work by Sarewitz et al. (2003), a rough and general definition that encompasses several aspects of vulnerability is as follows: an inherent characteristic of individuals, communities, networks, infrastructure, and systems that is able to produce the potential (negative) effects, regardless of the risk of occurrence of any particular shock such as economic crises, natural and man-made disasters or, even terrorist attacks.

Given these premises, it is evident that a vulnerability approach may analyse this concept from several points of view. One way to review the literature on vulnerability is to focus on the variables that are commonly used to define and analyse vulnerability. Through a Scopus search concerning the key terms of 'vulnerability', 'economic vulnerability', and 'social vulnerability' as keywords since the year 2000, 389 articles were selected; however, among these, only 26 were in line with our analysis in terms of the specific type of shock under analysis (e.g. recession or natural and man-made disaster).

This review shows that most studies analyse vulnerability in particular by means of composite indicators that include several aspects of the object of analysis. Vulnerability indicators are more or less complex, varying from only one variable to other more complex indicators which may include as many as 28 variables. In addition, all the adopted variables can be encoded to 10 'environments': economic (e.g. measures of wealth, inequality, employment and so on); institutional (e.g. corruption, institutional capacity, etc.); social (e.g. education, human health, etc.); business (e.g. business density, productivity, etc.); demographic (e.g. age structure, gender); natural (e.g. air pollution, quality of water, etc.); land (e.g. land use, urbanization); agricultural (e.g. presence of arable land, dependency on agriculture, etc.); material (e.g. infrastructures, buildings, etc.); and risk (e.g. exposure to hazard).

Table A, in Annex A, contains a review of the selected papers that analyse vulnerability by means of composite indicators. In Table A, the papers are ordered according to the number of variables included in the composite indicator, without considering duplicate variables from the papers in the above rows. The identification of the variables as described above (i.e. according to the 10 environments) is also included.

As a key finding we note here that most analyses refer to natural disasters (21 papers), while only a few papers focus on economic measures of vulnerability (5 papers), even though the economic and social environment are fundamental aspects evaluated in all studies concerned.

For an in-depth discussion on the composition of the variables included in the vulnerability analysis, we refer to Section 4 which provides a comparison with the aspects of resilience and exposure. We now proceed in the next section with a first look at the analysis of resilience.

3. Resilience

Given the broad extent of the disciplinary fields where the resilience concept can be applied, it is necessary to treat resilience according to its definition, context, and measurement. Resilience has been 'imported' in the social sciences from other disciplines such as engineering and ecology. For this reason, the interpretation and the definition of resilience changes according to the context of the analysis. For instance, when looking at resilience to economic shocks, Duval et al. (2007) define economic resilience as the ability to maintain the economic output close to the potential growth path in the aftermath of a shock. Rose (2007), on the other hand, defines resilience as the ability of a system to maintain its function after the shock or to hasten the speed of recovery (Rose and Krausmann, 2013). When the context of the analysis changes, for instance, to address natural and man-made disasters, even the interpretation of resilience is different: for instance, Rose and Liao (2008) focus on the inherent ability of firms and regions to adapt so as to reduce the potential losses of a shock. Similarly, Bruneau et al. (2003) focus on the reduction of the social disruption caused by a natural disaster on the social units concerned.

Interestingly, in the large number of definitions of resilience identified in our review, two major characteristics of resilience can be recognised: i) the capacity to recover from shocks; and ii) the degree of preparedness. These characteristics lead to three main definitions of resilience: i) the capacity to recover from a shock (known as 'engineering resilience'; Pimm, 1984); ii) the capacity to resist a shock (known as 'ecological resilience'; Holling, 1973); and iii) the ability to adapt after a shock (known as 'adaptive resilience'; Martin, 2012) or to develop new growth paths (Boschma, 2015). All the aspects mentioned above are clearly useful for a better comprehension of the works considered in the literature review.

After a Scopus search on the terms 'resilience', 'economic resilience' and 'community resilience', initially 311 papers were identified; however, only 31 papers were finally selected as being consistent with the aim of our study.

From our review, large differences in the analysis of economic resilience and resilience to natural disasters appear to emerge. Economic resilience is typically addressed by means of empirical analysis selecting one key factor (e.g. employment, GDP, etc.) as the dependent variable, while resilience to natural disasters is mainly expressed by means of composite indicators that include several aspects of the object of analysis.

Table B, in Annex A, contains a review of the papers which analyse resilience. Analogously to Table A, in Table B the papers are ordered according to the number of variables included in the

composite indicator without considering duplicate variables. The identification of the variables as described above (i.e. according to the 10 environments) is also included.

Our main finding is that most analyses of economic resilience refer to the resilience of regions to financial crises (21 papers), while only a few papers provide an economic evaluation of resilience to natural disasters (4 papers). In addition, in the light of natural disasters, 6 papers evaluate the social response of communities to extreme weather conditions. In the next section, we discuss the results from our review of the literature by considering the link between vulnerability, resilience and exposure. In particular, we summarise the results provided in Sections 2 and 3, by underlining that the main variables typically used in the vulnerability and resilience framework can be conceived as general measures of exposure.

4. The methodological connections between vulnerability, resilience and exposure

As highlighted in the previous sections, vulnerability is an inherent characteristic of individuals, community, networks, infrastructure, and systems that is able to produce potential (negative) effects, regardless of the risk of occurrence of any particular shock. Resilience, on the other hand, is the capacity to recover from a shock, or the capacity to resist a shock, or the ability to adapt after a shock and to develop new growth paths. Actually, the link between these two concepts is still debated (Cutter et al., 2008), but the two concepts share common characteristics, as denoted in Tables A1 and A2. Indeed, both these concepts focus mainly on the economic 'environment' and, in particular, on the macroeconomic characteristics of the object of analysis. Economic aspects are therefore important issues for both vulnerability and resilience. One possible explanation is that socio-economic conditions influence both the inherent characteristics of individuals, community, and network infrastructures (e.g. richer people live in dwellings which are better built in relation to the quality of materials used) and the capacity to recover from a shock.

But, when looking at vulnerability as a stand-alone concept, the literature focusses on other inherent characteristics that can influence the vulnerability of people or goods: for instance, the agricultural environment plays an important role in the vulnerability literature, because it is often related to the capacity of communities to deal with external shocks (especially natural disasters) in non-developed countries. For this reason, agricultural issues are covered by almost 50 per cent of the papers analysed in this review. Likewise, land use is an important aspect in the vulnerability analysis, because the anthropisation of territories often creates a great source of vulnerability, especially when analysing natural disasters. Finally, socio-economic aspects are also of a great importance in the analysis of vulnerability.

When looking at resilience as a stand-alone concept, the scientific attention is also paid to institutional and business environments; the first of these aspects refers to the capacity to develop mitigation plans and to respond to a given shock (natural disasters or economic crises); the latter aspect focusses on the capacity of business activities to be prepared for or to innovate after a shock.

Table 1 Review of vulnerability characteristics, by number of papers and their percentage of the total

Environment	Total	Sub-environment	No. of papers	% of the total
Agricultural	12/32	Extension of agriculture (e.g. arable land)	11	34.4
		Dependency on agriculture (e.g. food import dependency	5	15.6
		Rural population	2	6.3
Business	6/32	Financial exposure (e.g. debt/equity)	1	3.13
		Density of business	3	9.4
Demographic	16/32	Age	14	43.8
		Gender	3	9.4
		Population growth	2	6.3
Economic	28/32	Macroeconomic performance (e.g. GDP, saving)	18	56.3
		Debt (e.g. sovereign debt rating)	3	9.4
		Total revenue	2	6.3
		Transportation costs	1	3.1
		Poverty	13	40.6
		Household debt	3	9.4
		Inequality	7	21.9
		Unemployment	8	25
		Productivity	1	3.1
		Sectorial dependence	4	12.5
Institutional	13/32	Corruption	2	6.3
		Dependence on external resource (e.g. energy imports)	3	9.4
		Emergency plans (e.g. failure to communicate knowledge)	4	12.5
		Government effectiveness (e.g. governance index)	2	6.3
		Institutional capacity	6	18.8
		Political rights	5	15.6
Land	18/32	Land use (e.g. relative urban entropy)	3	9.4
		Population pressure (crowding)	13	40.6
		Urbanisation (e.g. formation of slums)	5	15.6
Material	8/32	Infrastructure characteristics (e.g. road density)	3	9.4
		Building characteristics (e.g. number of buildings)	8	25
Natural	10/32	Air pollution	2	6.3
		Ecosystem conversion (e.g. % land unmanaged)	4	12.5
		Ecosystem service value	1	3.13
		Environmental sustainability	2	6.3
		Erosion	2	6.3
		Soil pollution	2	6.3
		Water pollution	5	15.63
Risk	11/32	Insurance	1	3.13
		Population at risk	4	12.5
		Previous disaster effects (e.g. number of people affected)	6	18.8

Table 1 *(continued)*

Environment	Total	Sub-environment	No. of papers	% of the total
Social	17/32	Crime	2	6.3
		Disability	2	6.3
		Education (e.g. literacy rate)	14	43.8
		Family structure (e.g. % of single parents)	5	15.6
		Female condition (e.g. rate of female inactivity)	5	15.6
		Health conditions (e.g. child mortality)	12	37.5
		Ethnic minorities	4	12.5
		Social capital	3	9.4

Table 2 Review of resilience characteristics by number of papers and percentage of the total

Environment	Total	Sub-environment	No. of papers	% of the total
Agricultural	1/31	Rural characteristics	1	3.2
Business	10/31	Financial exposure (e.g. debt/equity)	1	3.2
		Density of business	6	19.4
		Credit market	2	6.5
		Corporate Taxation	1	3.2
		Redditivity (e.g. return on equity)	4	12.9
Demographic	6/31	Age	3	9.7
		Gender	4	12.9
		Population growth	2	6.5
Economic	31/31	Macroeconomic performance (e.g. GDP, savings, gross domestic fixed investments, consumption, growth, trade, inflation)	22	71.0
		Debt (e.g. sovereign debt rating)	7	22.6
		Poverty	9	29
		Housing (e.g. home ownership)	6	19.4
		Inequality	4	12.9
		Unemployment	16	51.6
		Productivity	7	22.6
		Sectorial dependence	5	16.1
Institutional	14/31	Emergency plans (e.g. failure to communicate knowledge)	3	9.7
		Government effectiveness (e.g. governance index)	6	19.4
		Institutional and financial capacity	8	25.8
		Political fragmentation	3	9.7
		Political rights	1	3.2
Land	3/31	Land use (e.g. relative urban entropy)	3	9.7
		Population pressure (crowding)	3	9.7
		Urbanisation (e.g. formation of slums)	2	6.5

Table 2 *(continued)*

Environment	Total	Sub-environment	No. of papers	% of the total
Material	7/31	Infrastructure characteristics (e.g. road density)	3	9.7
		Building characteristics (e.g. number of buildings)	4	12.9
Natural	7/31	Air pollution	1	3.2
		Ecosystem conversion (e.g. % land unmanaged)	4	12.9
		Ecosystem service value	1	3.2
		Environmental sustainability	1	3.2
		Erosion	1	3.2
		Soil pollution	2	6.5
		Water pollution	3	9.7
Risk	3/31	Insurance	2	6.5
		Previous disaster effects (e.g. number of people affected)	1	3.2
Social	13/31	Accessibility	4	12.9
		Crime	1	3.2
		Disability	2	6.5
		Education (e.g. literacy rate)	8	25.8
		Family structure (e.g. % of single parents)	1	3.2
		Female condition (e.g. rate of female inactivity)	2	6.5
		Health conditions (e.g. child mortality)	7	22.6
		Ethnic minorities	3	9.7
		Quality of life	1	3.2
		Social capital	8	25.8

Vulnerability and resilience appear to have some common characteristics, mainly regarding the socio-economic conditions of the objects of the analysis. However they also show important differences in some other characteristics (for example, Gallopín, 2006 states that a fundamental difference between vulnerability and resilience '*applies to the preservation of the behavior of the system as expressed by its state remaining within the considered domain of attraction, while vulnerability refers to transformations that may go beyond a single domain*', pp.299 – 300).

Given the similarities and differences in the vulnerability and resilience concepts, and given the multi–faceted aspects of these two concepts, it is important to define appropriately what the elements under observation are: namely, those covered by the concept of exposure. In any study regarding vulnerability and resilience, exposure can be defined as all the elements at risk from the shock under analysis; in particular, according to Cardona et al. (2012, p. 69), by exposed elements comprise: '*human beings, their livelihoods, and assets*'. The correct and preliminary definition of exposed variables may be important for two main reasons. First, this is needed for the proper definition of the research framework as well for developing the research questions. Second, many studies aim to analyse vulnerability and resilience for policy-relevant issues, for instance, to develop mitigation plans in reducing the vulnerability to hazards (Berry et al., 2006; Godschalk et al., 1998) or to draw resilient policy and adaptive strategy to face economic crises (MacKinnon and Derickson, 2013; Somers, 2009).

However, for a proper evaluation of these policies it is necessary to know the precise number of exposed entities (e.g. in some cases, the exposure might be too small to represent a real policy issue.)

For these purposes, given the difficulties of addressing all exposed variables that are considered in the literature, there is a short discussion of the exposure variables in the next paragraph, by assuming that the choice of a proxy – as the exposure variable – mostly depends on the sequence of effects which are expected to occur when a shock affects the object under analysis (Modica and Zoboli, 2016; Pelling, 2003).

As we have previously indicated, exposure is characterised by three main aspects that are all related to human beings: namely, their human life, their livelihoods, and their assets; in addition, according to different types of analysis, differences in the exposure variables used can be observed. For example, the density of the built environment (asset) is used as the exposure variable in the case of flood risk assessment (e.g. Jongman et al., 2012; Koks et al., 2014, 2015: Sterlacchini et al., 2016); Gross Domestic Product (livelihoods), population density (human life), and the value of real estate assets are used in earthquake loss assessment (Field et al., 2005; Meroni et al., 2016). In this study, we focus on the population by age – as the exposure variable – to assess the vulnerability and the resilience of the labour markets to the great recession in Germany.

As a last step, it may be necessary to mention briefly the potential losses of a shock. It turns out that, in the case of economic crises, potential losses are estimated by looking at macroeconomic variables that are able to synthesise the exposed value of the entire economic system (e.g. GDP, employment, GVA, etc.). When considering natural disasters, the analysis is much more complex, since, in this case, there is an extensive literature which focusses on what might be defined as losses due to extreme events (for more details see Marin and Modica, 2016 and ECLAC, 2003). In this regard, direct and indirect losses can be recognised. Direct losses refer to direct damages to people (injuries and fatalities) and objects (e.g. goods, buildings, infrastructures: see ECLAC, 2003) or even damage arising from the interruption of economic activities (see Rose and Lim, 2002; Rose et al., 2007). The category of indirect losses is, instead, broader, because it includes all the losses that are caused by the disasters through a sequence of actions or reactions that are not directly related to the extreme event but that started because of the shock; for instance, foregone production due to interruption of activities because of a disaster might affect the whole supply chain of the production activities including that of customers and suppliers (e.g. Van der Veen and Logtmeijer, 2005).

This first part of the present paper has aimed to highlight the complexity and the multi–faceted aspects involved in the analysis of vulnerability and resilience by addressing the additional and relevant aspect of exposure. Next, in Section 5, we present a case study which underlines the vulnerability and resilience in the German labour markets to the great recession that started in 2008, with a particular focus on the role of ageing, as a way of defining the impact of crises on the employment of several age cohorts. For the variable of exposure we therefore look at the age structure of the population of the German labour market districts.

5. Vulnerability, resilience and exposure in the German labour market

In this section we analyse the impact of the great recession on the German labour markets. In particular, the aim of this study is to determine how different age cohorts (i.e. the exposure variables) have been affected by the shock. The existing literature provides evidence of the great vulnerability of young people to financial crises (e.g. Verick, 2009; O'Higgins, 2012; Cho and Newhouse, 2013).

We explore these issues by means of a vulnerability and resilience framework. In particular, we aim to identify how different cohorts react to a labour market shock or, in general, to a period of recession (e.g. resilience), and what are the most vulnerable cohorts. To this purpose, the objective of this section is twofold: first, we assess the vulnerability of German labour market cohorts to external shocks by means of unit root tests; second, we control for a response of the German labour market in space and in demography (namely, we control for regional differences and ageing characteristics). While examining the vulnerability and resilience aspects, we also focus on the exposure variables which are all elements at risk. In this setting, we define the exposure as the number of people of a given cohort at district level. The German Institute for Employment Research (IAB) provided the data set used in this study. It contains the number of employees and population for all German districts and cities from 2000 to 2011. Data are also available for cohorts of 5 years (i.e. 20-24, 25-29, and so on).

For assessing the vulnerability of an economic system, a dedicated operational method firmly based on the proportionate growth process literature, often referred to as Gibrat's law, has been adopted (for a review see Fazio, 2015; Modica and Reggiani, 2017; Modica et al., 2017a).[1] Gibrat' s law implies that the growth rate of employment follows a non-stationary growth process, implying that any shock will last forever, because the series will never bounce back towards its mean (Gibrat, 1931; Lalanne and Zumpe 2015). If this happens, the system will experience a reduction in the ability to resist or to return to the conditions existing before the shock, in this way increasing the vulnerability of the system. Empirically, to control for this eventuality, the presence of a unit root in the growth process needs to be tested. Following Ioannides and Overman (2003), we use the Nadaraya-Watson (NW) method (Nadaraya, 1964; Watson, 1964). If the series is non-stationary, we expect that the non-parametric estimation of conditional mean and variance should be constant and equal to 0 (for the mean) and 1 (for the variance). This is due to the typical normalisation that is carried out in this framework.

Figure 1 shows that Gibrat's law is verified for cohorts 20-24 and 25-29, indicating a higher vulnerability for those ageing cohorts. Clearly, we should interpret this result as a national result, meaning that in Germany in the period 2000–2011, the cohorts that are more vulnerable to financial crises are those between 20 and 29 years old.

As a second step of our analysis, we change this national perspective, and focus on the regional differences of both exposure and resilience in the light of the vulnerability/resilience issues. For this purpose, we first define the degree of exposure of the German districts in order to determine which

[1] This part of the analysis refers to Modica et al. (2017b). In the present paper, we briefly summarise the main empirical strategy and the results useful for defining the vulnerability of the age cohorts. We refer to Modica et al. (2017b) for a complete discussion.

districts are the most exposed to eventual financial crises; and then we control for regional differences in the resilience of the districts.

Concerning the first issue, we take the district population as the exposure variable. In this context, Figure 2 provides: (a) the total population by German districts in the year immediately before the crises (i.e. 2007); and (b) the population aged 20-29, to be compared with (a). It should be noted that the Western and Wouth-western districts are those with a higher presence of young people aged 20-29 (it should also be noted that no changes exist when looking at the population in relative terms).

In this first part of the analysis, two important results appear to emerge: a) the cohorts that are most vulnerable are those between 20–29; and b) the most exposed districts are located in the Western and South-western part of Germany. The second step of the analysis aims to identify the spatial resilience, i.e. control for the capacity of the German districts to face financial shocks, and compare the resilience results with the vulnerability and exposure findings.

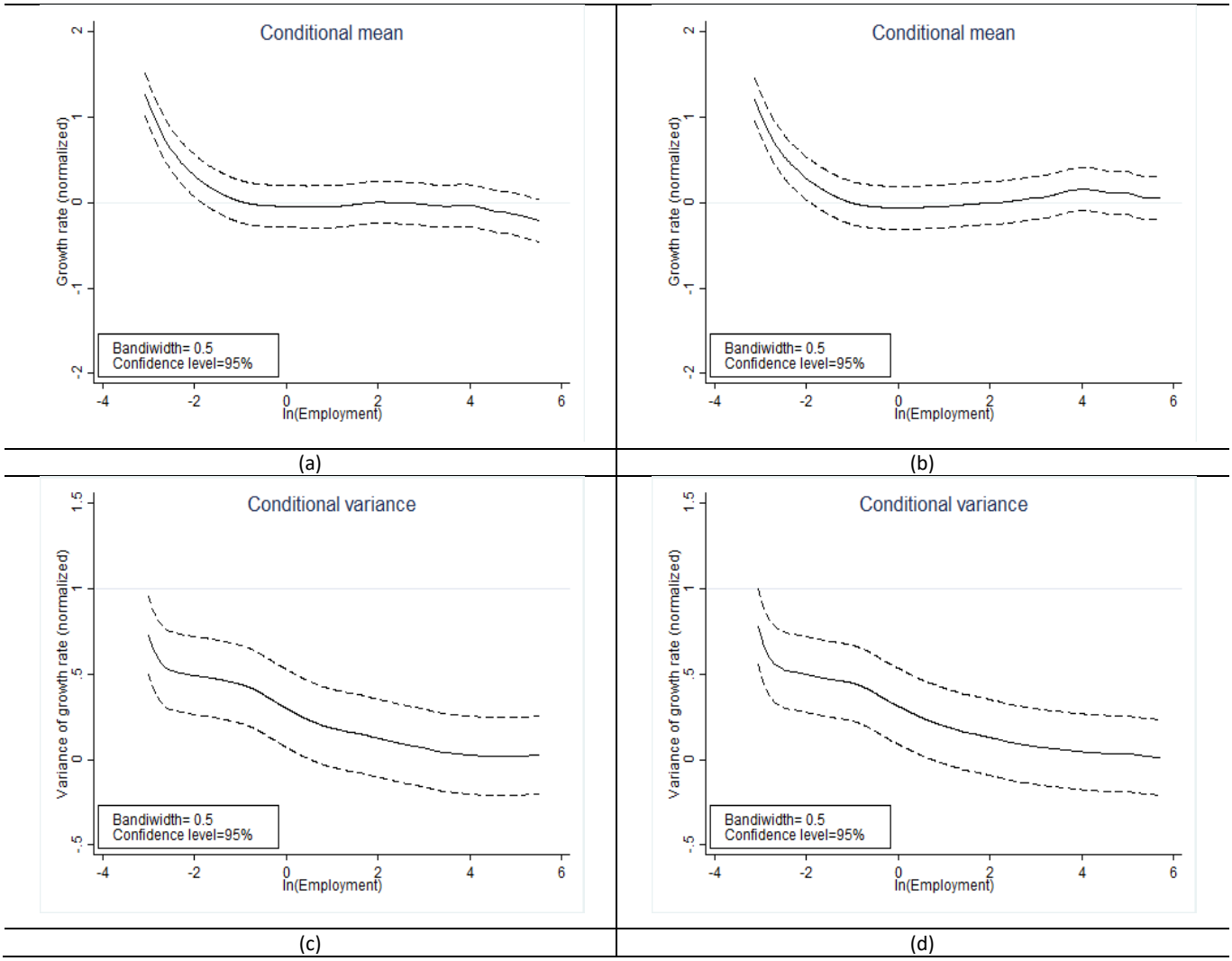


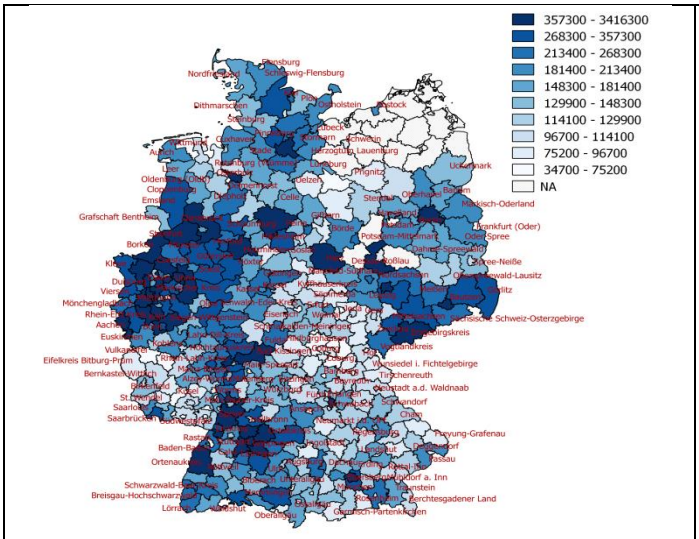
Figure 1 Conditional mean (upper panels) and conditional variance (lower panels) in the 20-24 cohort (a) (c) and the 25-29 cohort (b) (d). Source: Modica et al. (2017b)

To control for the spatial resilience of the German districts, the resilience index developed by Lagravinese (2015), on the basis of Martin (2012), has been adopted here, with reference to the year 2007, and over 4 post-crisis years till 2011:

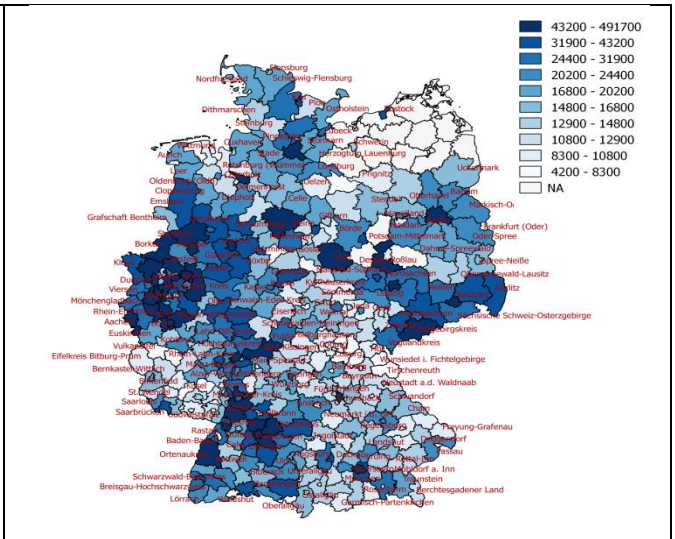
$$Resilience_d^{2011-2007} = \frac{\left(\frac{E_d^{2011} - E_d^{2007}}{E_d^{2007}}\right) - \left(\frac{E_n^{2011} - E_n^{2007}}{E_n^{2007}}\right)}{\left|\frac{E_n^{2011} - E_n^{2007}}{E_n^{2007}}\right|}, \qquad (1)$$

where E_d is the employment in district d, and E_n denotes the overall national employment. According to equation (1), a district can be: a) resilient, if the index is greater than zero; b) non-resilient, if the index is lower than zero; and c) neutral, if the index is equal to zero. It should be noted that the resilience index (1) defines a spatial measure of resilience, meaning that it represents the districts that perform better than the others. Then (1) is a sort of local measure of resilience. This characteristic should be kept in mind when considering both vulnerability and resilience measures.

The results are given in Figures 2c – 2d. Figure 2c provides results for the resilience, at district level, of total employment. It should be noted that the most exposed districts in terms of population are those that show a lower degree of spatial resilience (see the Western and South-western districts).



(a)



(b)

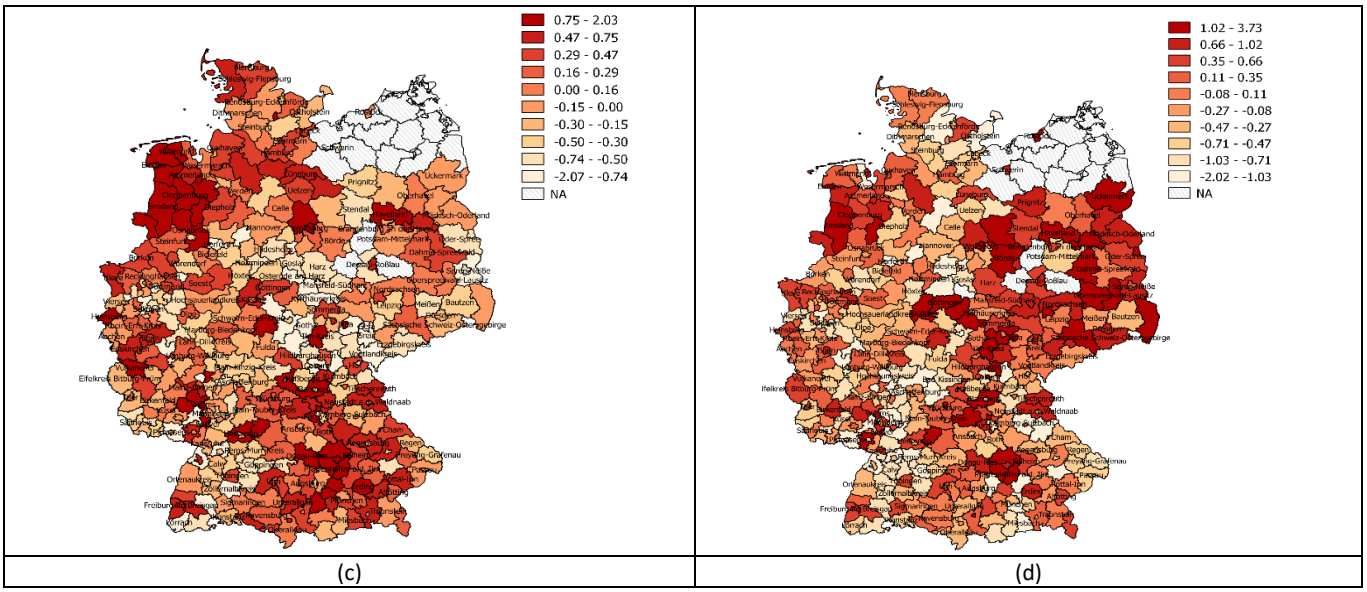


Figure 2 Total population (a) and population aged 20-29 (b) of the German districts in 2007, and resilience at the district level for total employment (c), and employment cohorts 20-29 (d). Source: elaboration of IAB data.

This evidence is made stronger by analysing the resilience of German districts for the employment of the cohort 20-29 (Fig. 2d); we can observe – in the Western and South-western districts – a low capacity to recover from financial shocks in the most exposed districts and for the most vulnerable cohorts. At the same time, the Eastern districts show a higher resilience, but only in areas where the population is lower (less exposed, e.g. Eastern and South-eastern districts). This evidence might be explained by internal migration or differences in schooling (for instance the unemployed might decide to study more); however, these considerations are beyond the scope of this study, and deserve further empirical analysis in the future.

6. Conclusions

The aim of this paper was twofold: a) an in-depth investigation of the concepts of resilience, vulnerability and exposure, on the basis of the scientific literature; and b) an empirical application, with reference to these three concepts. Consequently, in the first part of this paper, a review of the major papers dealing with two relevant concepts, resilience and vulnerability, was given, providing evidence of the close link between these two concepts. Furthermore, attention was paid to another concept, i.e. exposure, which has been less analysed in the literature on economic and natural disasters. In this framework, a series of articles which adopt different measures of exposure in different contexts were analysed as well.

We considered a particular case study, i.e. the impact mechanism of the 2008 financial crises on the German labour markets, by measuring vulnerability and resilience at the district and the age-cohort level, and by highlighting how a shock turns into different losses, according to the vulnerability and exposure of the objects (districts and age cohorts). In particular, by means of Gibrat' s law, we were able to show that, at the national level, the population cohort 20-29 appeared to be the most vulnerable,

in the presence of the 2008 financial crisis. In addition, by means of resilience indicators based on employment characteristics, we identified the geographic of locations, i.e. the Western and South-western districts, which are the most vulnerable for this particular cohort (20-29).

Summing up, our joint analysis (Gibrat's law and resilience) seems to provide novel insights into the relationship 'vulnerability, resilience and exposure' in a geographical context. It would be interesting to apply this joint approach to further case studies, in order to verify whether and how the cohort 20-29 is vulnerable in other EU countries and spatial areas.

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ANNEX A

Table A Papers analysed for the vulnerability review

Paper, Year	Kind of assessment	Subdivision	Nr. of variables	Variables	Method
Brooks et al., 2005	Vulnerability to climate change	- Risk	1	- Number of people affected	-
Reggiani et al., 2016	Economic vulnerability	- Economic	1	- Employment	Indicator
Flatø et al., 2017	Vulnerability to climate change	- Economic	1	- Household income	Indicator
Wei et al., 2004	Vulnerability to natural disasters in China	- Economic - Land - Risk	4	- GDP - Population density - Total cost of the damage	Data Envelopment Analysis (DEA)
UNDP, 2015	Social vulnerability to climate change	- Demographic - Economic - Social	4	- Expected years of schooling - GNI per capita - Life expectancy at birth - Mean years of schooling	Indicator
Briguglio, 1995	Vulnerability for small islands to climate change	- Economic - Risk - Natural - Demographic	6	- Ratio of imports and exports to GDP - Transport and freight costs - Index of disaster proneness - Environmental fragility - Dependence on foreign finance sources - Demographic changes	Indicator
Estoque and Murayama, 2014	Social-Ecological status	- Land - Risk	6	- Land use - National protected areas - Relative (urban) entropy - Ecosystem service values	Indicator
Haddad, 2005	Vulnerability to climate change	- Natural - Economic - Institutional - Social	7	- Gini coefficient - Low/middle income nation - % shared water basin - Political rights - PPP adjusted GDP - Sovereign debt rating - Water stressed countries	Indicator
Mustafa, 1998	Vulnerability to flood hazard	- Agricultural - Land - Economic - Social	8	- Landholdings - % of non-agricultural sources of income - Number of cattle heads - Market/community means of recovery (e.g. sales of livestock/loans from family)	Indicator

Tab. A *(continued)*

Paper, Year	Kind of assessment	Subdivision	Nr. of variables	Variables	Method
Zou and Wei, 2009	Vulnerability to coastal hazards in Southest Asia	- Economic - Demographic	8	- External debt - GDP Annual change - Gross domestic saving - Ratio of agriculture - Ratio of consumption - Total revenue - Trade balance	Factor analysis over 41 variables
Ding et al., 2017	Economic Vulnerability to climate change on marine fisheries	- Agriculture - Economic - Business - Institutional - Risk	8	- Gross indicator of climate change - Food security dependence - Employment dependency to marine resources - Economic dependency to marine sectors	Indicator
Vincent, 2004	Vulnerability to climate change in Africa	- Demographic - Economic - Institutional - Social	9	- Corruption - % of dependent population - Health expenditure - % HIV/AIDS - Poverty - Rural population - Urban population growth	Indicator
Graziano, 2013	Vulnerability of the economic dimension in Italy	- Business - Economic	9	- Bad loans to enterprise - Bad loans to households - Debt/equity - Production specialisation - Labour costs/value added - Net interest expenses - Protests/population - Rate of female inactivity	Factor analysis over 52 variables
Yohe and Tol, 2002	Vulnerability to natural disasters	- Business - Economic - Institutional - Risk - Social	10	- Income per capita - Land area	Indicator
Chakraborty et al., 2005	Social vulnerability for evacuation assistance (Usa)	- Economic - Material - Social	10	- Number of housing units - Number of mobile homes - group quarters - % of persons with disability - households with no vehicles	Indicator

Tab. A *(continued)*

Paper, Year	Kind of assessment	Subdivision	Nr. of variables	Variables	Method
Cutter et al., 2003	Social vulnerability to environmental hazards	- Business - Demographic - Economic - Material	11	- % of minority per race - % employed in extractive industries; services and transportation - Median age - Commercial density	Factor analysis over 42 variables
Brooks et al., 2005	Vulnerability to natural disasters	- Economic - Institutional - Social	11	- Average calorie intake - Government effectiveness - Literacy - Maternal mortality - No access to clean water - Voice and accountability	Correlation analysis over 46 possible vulnerability variables
Lonergan et al., 2000	Vulnerability to climate change	- Economic - Institutional - Natural - Social	12	- Access to safe water - Child mortality - Energy imports - Expenditure in defense - Fertility rate - Food import dependency - Water Resources per capita	Indicator
Manuel-Navarrette et al., 2007	Vulnerability to hydrometeorogical disasters in Central America and the Carribean	- Agricultural - Demography - Economic - Land - Risk - Social organisation	13	- Ecosystem conversion - Erosion - Expansion of agriculture - Failure to communicate knowledge - Presence of slums - Migration rural/urban - Population growth	Methodological framework
Yusuf and Francisco, 2010	Vulnerability to climate change in Southest Asia	- Agricultural - Economic - Risk - Material - Social	13	- Electricity coverage - Extent of irrigation - Multiple hazard risk map - Fixed phones line - Road density	Indicator
Graziano, 2013	Vulnerability of communities dimension in Italy	- Demographic - Institutional - Social	13	- Accidents at work - Crime damages per capita - Death rate from several diseases - Traffic accidents per capita	Factor analysis over 57 variables

Tab. A *(continued)*

Paper, Year	Kind of assessment	Subdivision	Nr. of variables	Variables	Method
Colburn et al., 2016	Social vulnerability in fishing dependent communities to climate change	- Demographic - Land - Economics - Business	13	- Poverty - Crime index - % females separated - % self employed - % of people receiving social security - No. Of fishing permits - Dealers with landing - Pounds of landing	Indicator
Flanangan et al., 2011	Social vulnerability to disaster in New Orleans	- Economic - Social	15	- Crowding - % multi-unit structure - % persons who speak English less than well - % of single parents with children under 18	Indicator
Akter and Mallick, 2013	Economic vulnerability to cyclones in Bangladesh	- Demographic - Material - Risk - Institutional - Economic	15	- Religion - Proximity to the cyclone shelter - Distance from the coast - Assistance after the cyclone - Credit - Propensity to save - Elite acquaintance	Indicator
Islam et al., 2014	Vulnerability to disasters in Bangladesh	- Agricultural - Economic - Natural - Risk - Social	15	- % of agricultural labor - Distance from river or paved road - Distance from administrative office - % of sanitary latrines - loan/income per household - Unemployment	Multi - hazard Index
Inter American Development Bank (IDB), 2011	Community resilience to natural disaster for Belize	- Agricultural - Economic - Natural - Risk - Social	16	- Capital stock - Imports and exports - Investment - Arable land and permanent crops - Inflation - Dependency on agriculture - Soil degradation	Indicator

Tab. A *(continued)*

Paper, Year	Kind of assessment	Subdivision	Nr. of variables	Variables	Method
Martins et al., 2012	Vulnerability to seismic risk in Vila Franca, Azores, Portugal	- Demography - Economic - Material - Risk	16	- Buildings (%) - Building constructions/year - Building characteristics - Family structure - Gender	Multicriteria analysis
Brenkert and Malone, 2005	Vulnerability to climate change in India	- Agricultural - Economic - Institutional - Land - Material - Natural - Risk	17	- Cereal production/crop area - Fertilizer use/crop land area - % Land unmanaged - Population at flood risk - Renewable supply - SO_2 / state area - Water use	Indicator
Polsky et al., 2007	Generic community water system vulnerability to drought	- Agricultural - Institutional - Material - Natural	18	- Conservation program of technology - Emergency plan - Frequency and intensity of drought - Rainfall correlation - Safe yield	Framework
Ibarraràn et al., 2010	Vulnerability to climate change in Mexico	- Agricultural - Economic - Material - Natural - Social	19	- Precipitation - Air pollution/state area	Indicator
Cardona, 2005	Vulnerability to disasters in the Americas	- Exposure and susceptibility - Lack of resilience - Socio-economic fragility	24	- Debt servicing - Environmental sustainability index - Governance index (Kaufmann) - Hospital beds per 1000 people - Insurance of infrastructure and housing - Television sets per 1000 people	Indicator
Cutter and Finch, 2008	Vulnerability to disasters in the USA	- Business - Demography - Economic - Social	28	- Earnings in all industries - New residential housing unit permits - Social security beneficiaries	PCA

ANNEX B

Table B Papers analysed for the resilience review

Paper, Year	Kind of assessment	Subdivision	Nr. of variables	Variables	Method
Several authors*	Regional economic resilience	- Economic	1	- Employment - GVA - Real per capita GDP - Regional productivity	Econometric analysis
Boschma, 2015	Evolutionary economic resilience	- Business - Economic - Institutional	3	- Institutional adaptability - Knowledge Networks - Techno-industrial variety	Theoretical framework
Foster, 2007	Regional economic resilience	-Demographic -Economic	4	- % Population change - Poverty measure	Methodological framework
Estoque and Murayama, 2014	Socio-ecological resilience	- Institutional - Natural - Social	5	- Ecosystem service index - Good governance index - Human Development Index	Indicator
Cardona et al., 2008	Community resilience to natural disaster	- Business - Institutional - Risk	8	- Aids and donations - External and internal credit - Insurance - Deficit - New taxes - Reserve funds for disasters	Indicator
Inter American Development Bank (IDB), 2011	Community resilience to natural disaster for Belize	- Institutional - Natural - Social	8	- Gender Development Index - Social expenditure - Television set per capita - Hospital beds per capita - Environmental sustainability index	Indicator
Walker et al., 2009	Regional economic resilience	- Agricultural - Economic - Natural - Social	10	- Biodiversity measure - Farm income - High multiplier economic - Riverine ecosystem - Sectors balance among values - Soil acidity - Water infrastructure	Indicator
Hallegatte, 2014	Economic resilience to natural disasters	- Business - Economic - Institutional - Social	10	- Economic diversification - Income inequality - Interest rate - Reconstruction duration in years - Ripple effects - Social protection - Value of a statistical life	Indicator

* Note: Capello et al., 2015; Cellini and Torrisi, 2014; Crescenzi et al., 2016; Cuadrado-Rouraa and Maroto, 2016; Di Caro, 2015; Doran and Fingleton , 2015; Eraydin, 2016; Fingleton et al., 2012; Fratesi and Rodríguez-Pose, 2016; Giannakis and Bruggeman, 2015; Lagravinese, 2015; Palaskas et al., 2015; Xiao et al., 2016

Tab. B *(continued)*

Paper, Year	Kind of assessment	Subdivision	Nr. of variables	Variables	Method
Martin and Sunley, 2015)	Economic resilience	- Business - Economic - Institutional	10	- Business confidence - Economic dynamism - Export - External relations - Openness	Theoretical framework
Foster, (2007)	Regional economic resilience	- Business - Demographic - Economic - Social	12	- Civic infrastructure - Home ownership - Metropolitan stability - Voter participation - Regional affordability - Educational attainment - Without disability	Indicator
Graziano, 2013	Community resilience in Italy	- Social	12	- Foundations, gyms, arts or sports organizations, libraries, nurseries per capita - Lifelong learning - Newspapers sold per capita - Rate of medical staff	Factor analysis over 57 variables
Briguglio et al., 2009	Regional economic resilience	- Business - Economic - Institutional - Social	13	- Impartiality of courts - Intellectual property rights - Judicial independence - Military interference - Political system - Banking industries	Indicator
Chan et al., 2014	Resilience to natural disasters in Taiwan	- Economic - Institutional - Land - Material - Natural - Social	13	- Accuracy of weather forecasts - Disaster prevention plans - Environmentally sensitive area - Individual capability - Public facilities - Rescue capability - Slope area conservation - Spatial land use - Vulnerable population	Analytic Network Process (ANP)
Östh et al., 2015, 2017	Regional economic resilience in Sweden and the Netherlands	- Demographic - Economic - Land - Social	13	- Accessibility - local deviation from the national industrial mix - Rank in the business climate - Working population not receiving a sickness benefit	Indicator

Tab. B *(continued)*

Paper, Year	Kind of assessment	Subdivision	Nr. of variables	Variables	Method
Sherrieb et al., 2010	Community resilience in Mississipi counties	- Business - Economic - Land - Social	19	- Corporate tax revenues - % Creative class occupations - Net business gain/loss rate - Property crime rate - Religious adherents - % Two-parent families - Urban influence	Indicator
Graziano, 2013	Regional economic resilience	- Business - Economic - Material - Social	19	- Application of designs - Application of models - Broadband services - Electrical network - Energy networks - Non-food consumption/total - Liquidity ratio - Pensions per capita - Patents business density - Return on equity	Factor analysis over 52 variables
Mayunga, 2007	Community resilience: Capital based approach	- Demographic - Economic - Institutional - Land - Material - Social	24	- Accessibility to transports - Air quality - Business/industry - Dependency ratio - Household characteristics - Housing quality - Informal sociability - Number of housing units - Population density - Public meetings	Indicator
Cutter et al., 2008	Community resilience to natural disaster	- Economic - Institutional - Land - Material - Natural - Risk	29	- Wetland, forests and national and local parks - Counselling services - Local understanding of risk - Quality of life - Erosion rates - % Impervious surface - Municipal revenues - Emergency response plans - Zoning and building standards	Indicator

Tab. B *(continued)*

Paper, Year	Kind of assessment	Subdivision	Nr. of variables	Variables	Method
Cutter et al., 2010	Community resilience to natural disaster	- Business - Demographic - Economic - Institutional - Material - Risk - Social	36	- Number of mobile houses - Number of physicians - Public school density - % Population in storm-ready communities - Population participating in Community Rating System for Flood risk - % Population with a telephone - % Population with a vehicle - Large to small business ratio - % Vacant rental units	Indicator