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Spatial Economic Resilience: Overview and Perspectives

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Abstract The concept of resilience has been receiving both theoretical and empirical attention in recent years, from different disciplinary fields, including spatial economics where resilience is becoming a 'popular' term. In particular, the concept of spatial economic resilience seems to assume slightly different interpretations. Starting from the basic definitions of resilience, which stem from ecology, this paper aims to highlight the similarities and the differences in the various analyses of resilience, in order to offer some insights into its use in the spatial economics literature.

Keywords Resilience · Ecological resilience · Engineering resilience · Spatial economics · Methodological review

1 Introduction

The concept of resilience has been adopted by all the economics fields and the social sciences generally. Resilience has become a 'popular' term and is associated mostly with certain threatening events that have critical and catastrophic phases (terrorism attacks on transport and digital systems, financial crises, epidemics, natural disasters such as earthquakes, tsunamis, fires, etc.). Resilience analysis refers to the speed at which a network returns to its equilibrium after a shock and to the perturbations/shocks that are absorbed, while vulnerability analysis generally refers to the propagation of shocks within a network (Reggiani 2013). Due to the non-specificity and flexibility of the term resilience, it has been interpreted and understood in different ways.

It is possible that the growing popularity of research on resilience, as suggested by Christopherson et al. (2010), might be due to the general sense of insecurity and uncertainty afflicting people across the world. However, this is not a sufficient justification since human beings have always faced crises (economic, environmental, war,

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etc.), but their combination with other factors, such as economic or environmental emergencies, most likely has played a relevant role (Hudson 2010). Also, these effects are exacerbated by their globalized setting. In brief, the uncertainty due to the interconnections between economic and environmental crises in the current complex (global) networks might be decisive for the increased attention being paid to resilience.

Both economic and environmental factors have been fundamental to the growing number of works that focus on socio-economic and spatial characteristics. According to Martin (2012), there are four main reasons why urban and regional analysts are focusing on the concept of resilience: a) the impact of natural and man-made disasters that have afflicted local communities; b) the influence of other disciplines, such as ecology, where the main interest is in how ecosystems respond to shocks; c) recognition that major disruptions can affect the whole economic landscape; and d) the effect at both local and regional levels of financial and economic crises and their consequences, due to the austerity policies pursued by many states.

Given these premises, the concept of resilience might be understood as a multifaceted notion that can be managed differently according to different objectives (Carlson et al. 2012). Readers interested in investigating the concept of resilience more deeply might be hindered by the range of definitions, classifications and uses of resilience.[1] We consider there is a need to reflect on the concept and its various interpretations and perspectives, in the spatial economics field.

According to Béné et al. (2012) and Cutter et al. (2008), resilience has two major characteristics: namely, a capacity to recover from shocks, and a degree of preparedness. To explore these aspects requires examining them from slightly different angles, which might lead to different policy conclusions based mainly on the differences between pre-event measures and post-event choices.

Given these premises, the present paper provides a review of the spatial economics literature in order to synthesize the knowledge from several different sources, including other reviews of resilience, and to propose a consistent methodological framework to highlight the similarities and differences in the concept of spatial economic resilience. Following a general treatment of resilience, we focus on the multifaceted nature of the concept of spatial economic resilience.

The paper is structured as follows: in Section 2 we discuss the various definitions of resilience and their interpretations in a spatial economic setting. Section 3 reviews a number of studies on the topic and emphasizes how the different indicators of spatial economic resilience depend on the aims, objectives, shocks and variables employed. It also explores the link between spatial economic resilience and vulnerability. Section 4 concludes the paper with some recommendations for future research, highlighting the need for more studies on the theoretical-analytical aspects of spatial economic resilience.

[1] For instance, the Project for Economic Resilience, Investment and Social Assistance in Indonesia (PERISAI) of the World Bank and the USAID programme, Resilience and Economic Growth in the Arid Lands-Accelerated Growth deal with economic resilience from slightly different perspectives, albeit they share the same main final goal, which is to improve economic resilience. The World Bank programme aims at a static version of resilience: namely, it is designed to strengthen the capacity of the Indonesian government to deal with the potential adverse impacts of international financial market volatility. The USAID program, instead, aims at an adaptive version of resilience since the goal of the project is to accelerate growth and move towards an improved market system

2 Definitions of Resilience: Historical and Inter-Subject Perspective

2.1 General Definitions of Resilience

In this section we review the main definitions of resilience, in order to provide the theoretical-methodological background to the subsequent discussion of economic resilience (Section 2.2) and spatial economic resilience (Section 2.3). The common basis of the several definitions of resilience is its etymology; also, as Batabyal (1998) notes, the concept of resilience shows resilient characteristics.

The word resilience comes from the Latin '*resilire*' which means to rebound or to leap back (Martin 2012; Reggiani 2013; Rose 2009). However, the first known use of the term 'resilience' in science was by Webster in the field of classical physics in 1824. Resilience initially was defined as the ability of a material to return to its initial condition in terms of size and shape after deformation due to a compressive shock.[2]

In 1973, Holling introduced the term 'resilience' into ecology, making the first differentiation of the term. In an ecological perspective, the word 'resilience' assumes a slightly different meaning: in this context, the focus of the attention shifts from the constancy of behavior to the persistency of the structure of the relationship (Holling 1973, p.1).

Moreover, the system under analysis is supposed to have different characteristics. In the initial (physical) interpretation of resilience, the system is characterized by equilibrium and an essentially static view that gives few opportunities to provide insight into the transient behavior of dynamic systems. In the ecological interpretation, the systems might have multiple local stable equilibria, or the system under study might be far from a state of equilibrium.

Ultimately, the adoption of the concept of resilience by two different disciplines (physics and ecology) led to the first differentiation in the definition of resilience. According to Perrings (1998), there are two ways to define the resilience of a system: according to the 'engineering view' and according to the 'ecological view'.

Engineering resilience is typically addressed in the physical sciences, and refers to the ability of a system which is approaching some stable equilibrium to return to that equilibrium after a shock, or a disturbance in general (Pimm 1984). This type of resilience is measured by the speed of the system's return to equilibrium.

The term 'ecological resilience' was first used by Holling (1973), and refers to the extent to which a shock can be absorbed by a local stable domain before it is induced into some other stable equilibrium (Holling 1973). Holling's alternative definition has two identifiable and important elements: a) the evolution of the system, and b) the relevance of the shock. It is clear that this definition, which is linked to the ability of the system to respond to an external shock by achieving different *equilibria*, represented a 'revolutionary' idea at that time when scientific research was mainly oriented to equilibrium and system optimization. Recall that chaos theory, related to uncertainty and intrinsic irregular dynamics in deterministic systems, did not emerge until a few years later, following the seminal work of May (1976).

[2] Merriam-Webster Dictionary and McDargh (2013) http://www.eileenmcdargh.com/blog/2013/11/tough-times-demand/

Table 1 summarizes the main characteristics of the two basic definitions of resilience provided above.

In 2012, Martin coined the term 'adaptive resilience'. According to Martin (2012), adaptive resilience is borrowed from complex adaptive systems theory, and refers to the ability of a system to implement reorganization (in terms of both pre-event and post-event forms) of the system's structure, so as to minimize the extent of the disturbance affecting the system, or to take advantage of the shock to achieve renewal of the system. In this context, it is worth nothing that a recent methodological framework dealing with static and dynamic resilience can be found in Rose and Krausmann (2013).

In the context of these considerations concerning the concept of adaptivity, it should be noted that Holling (1996, p. 32) described adaptivity in relation to policy and management in the presence of ecological resilience: "*Ecosystems are moving targets, with multiple potential futures that are uncertain and unpredictable. Therefore management has to be flexible, adaptive and experimental at scales compatible with the scales of critical ecosystems functions*". Also, Levin et al. (1998) argued that flexibility and adaptivity were necessary in a response system dealing with shocks. Carlson et al. (2012) reinforces the adaptivity concept by defining resilience as the capacity of an entity to absorb, adapt to, anticipate, recover from, resist, and respond to a shock.

Then adaptive resilience can be conceived as an insightful interpretation of ecological resilience which can be identified and explored using complex systems theory and related tools. On the other hand, engineering resilience seems more linked to conventional global stability theory.

In relation to modeling, the dynamic models belonging to the family of niche models (such as prey–predator models, competition and symbiosis models, etc.) can represent both kinds of resilience—engineering and ecological—since they can display both conservative and dissipative states, and consequently (un)stable although predictable features. Chaos models might represent only ecological resilience since instabilities can flip the system into another (unpredictable) regime behavior (Reggiani et al. 2002).

Starting from the basic definitions provided in Table 1, several recent studies of resilience are related to the socio-economic field and consider: a) only the engineering kind of resilience; b) only the ecological kind; or c) both kinds of resilience (Sections 2.2 and 2.3). In order to explain resilience in socio-economics, recall that Levin et al. (1998) state that socioeconomic systems are affected by human activities which could lead to qualitative shifts in structure and function involving loss of productivity. In this perspective, resilience might be seen as the capacity of a

Table 1 Basic definitions of resilience and their main characteristics

Type of resilience	Pre-condition	Focus	Kind of equilibrium	Relevance of	Interpretation of resilience
Engineering resilience (Pimm 1984)	Stability near equilibrium	Constancy of behaviour	Stable equilibrium	Strength of the shock	Measure of the speed of return to equilibrium
Ecological resilience (Holling 1973)	Far from equilibrium	Persistency of relationship	Multiple local *equilibria*	Behaviour of the system: size of the attractor/ stability domain	Measure of the elasticity of the system

socioeconomic system to experience disturbances while maintaining functional organization. Resilience then can be considered a measure of system integrity.

We review a series of definitions of both economic (Section 2.2) and spatial economic (Section 2.3) resilience, from various authors.

2.2 Towards Economic Resilience

In the 1980s and 1990s, economic resilience did not receive the level of scientific attention it is attracting today. Martin (2012) provides an interesting review of work on resilience from an economic viewpoint; in particular, Martin describes how resilience was regarded—in the broader economic literature—as a fuzzy concept (Markusen 1999). Swanstrom (2008) considers resilience as more than a metaphor but less than a theory: in other words, as a conceptual framework.

It should be noted that there are very few interpretations for economic resilience as a stand-alone concept. As highlighted earlier, economic resilience can be seen in terms of engineering resilience, of ecological resilience, or of both kinds of resilience (Table 2). The focus of economic resilience seems, on the one hand to be on analysis of the speed with which a system returns to its pre-shock condition (engineering resilience), and on the other hand on the capacity, of a system to reach new possible *equilibria* (ecological resilience).

It should be noted that, in order to investigate the capacity of a system to recover from a shock, several studies in the economic field adopt the notion of engineering resilience, essentially because it may be difficult to identify the new *equilibria* envisaged by ecological resilience. Nevertheless, from an economic viewpoint, ecological resilience—and its related interpretations—is undoubtedly interesting in the current era of globalization, where small shocks can induce new unpredictable dynamics in

Table 2 Some interpretations of economic resilience

Authors	Year	Definition	Kind of resilience
Briguglio et al.	2006	'the 'nurtured' ability of an economy to recover from or adjust to the effects of adverse shocks to which it may be inherently exposed' (p. 1)	Both kinds of resilience
Duval et al.	2007	'Economic resilience may be loosely defined as the ability to maintain output close to potential in the aftermath of shocks' (p. 2)	Engineering resilience
Hill et al.	2008	'the ability to recover successfully from shocks to its economy that either throw it off its growth path or have the potential to throw it off its growth path' (p.4)	Both kinds of resilience
Martin	2012	'the capacity of an […] economy to reconfigure, that is adapt, its structure (firms, industries, technologies and institutions) so as to maintain an acceptable growth path in output, employment and wealth over time' (p.10)	Both kinds of resilience
Rose	2007	'the ability of an entity or system to maintain function (e.g., continue producing) when shocked' (p. 384)	Both kinds of resilience
Rose and Krausmann	2013	'hastening the speed of recovery from a shock' (p. 2)	Engineering resilience

economic systems because of the high level of network connectivity among all their subsystems. Martin (2012, p. 7) explains that ecological resilience: "*assumes that systems are characterized by multiple stability domains, and that if a shock pushes a system beyond its 'elasticity threshold', the system may move to a different domain or state"*. Arthur (1990) paved to way to exploitation of the concept of ecological resilience in economics by showing the possibility of multiple states among competing technologies in economics, based on increasing returns to scale (see also Holling 1996). And in Samuelson's (1939) business cycle model, which is based on multiplier and accelerator concepts, we can perceive some elements of ecological resilience.

In sum, the equilibrium/stability notions in an economic setting reinforce application of the concept of engineering resilience in economics but the uncertainty and unpredictability of current economic phenomena call for an investigation of ecological resilience in economics.

A further point to consider is the spatial scale of analysis relevant to the identification of both engineering and ecological resilience. Martin (2012) develops the concept of 'adaptive resilience' combined with hysteresis, to capture the reactions of regional level economies to major shocks and recessions. Other authors have examined resilience on other spatial scales such as community, city, etc., which implies some methodological considerations.

In the next section we move a step forward and examine the role of resilience in the more specific field of spatial economics.

2.3 Towards Spatial Economic Resilience

The term 'spatial economics' focuses on a merger between space and economics. In this context, Nijkamp and Ratajczak (2013) discuss a broad framework of this new branch of economics, viz. spatial economics, which embraces fields/areas such as regional economics, urban economics, spatial science, and so on, by emphasizing that this scientific orientation is concerned with "*the spatial pattern and interaction of systems of production, distribution or consumption (or more generally, human activities) in a spatial context, including the management, planning and forecasting of spatial development"* (Nijkamp and Ratajczak 2013, p. 9).

Starting from this basic analysis and definition of the spatial economy,[3] in this section we illustrate and discuss a classification of works dealing with resilience in the spatial economic field, with the ultimate aim of capturing similarities and differences among these interpretations from a more synthetic and 'universal' perspective of spatial economic resilience.

First, an investigation of work on spatial economic resilience leads to the important definitional dilemma related to how the authors treat time and space (Christopherson et al. 2010). According to Christopherson et al. (2010), we can identify two distinct frameworks. In the first approach, the region—hence space—is considered merely as an action container, and time is recognized as a moment: pre-shock, shock, and post-shock. In the second approach, region/space is the result of human actions (social interactions), and thus is constantly subject to a constant process of transition, and time is considered a flow. Equilibrium approaches could be described using the concept of

[3] For a review of spatial science see also Ducruet and Beauguitte (2013).

engineering resilience, and evolutionary approaches could refer to ecological (adaptive) resilience.

As a result of these methodological differences, spatial economic resilience has been differently defined depending on the approach adopted, the focus of the analysis, the scale-level of the analysis, the characteristics of the object under analysis, and the object itself. Table 3 presents the various definitions of spatial economic resilience which in turn, have led to a variety of different socio-spatial economic indicators.

We reviewed 16 papers[4] that offer slightly different definitions but which can be classified according to the previously mentioned two main categories of engineering and ecological resilience. It is clear that, in spatial economic resilience studies, there seem not to be a preferred category or definition. Among the 16 studies analyzed, six adopt an ecological perspective of resilience, six interpret it as engineering resilience, and four refer to both ecological and engineering resilience.

Although some of the definitions of resilience in Table 3 may overlap with and be included in one of the general definitions of resilience presented in Table 1, the merging of definitions, aims, tools, and contexts of analysis leads to a multifaceted concept of spatial economic resilience. This is discussed in the next section.

3 The Multifaceted Nature of Spatial Economic Resilience

3.1 Resilience Analysis Considered as the Joint Influence of Shocks, Objects, Aims, and Frameworks

Table 3 shows that definitions of spatial economic resilience can assume different shades of meaning depending on aspects such as: type of shock, analytical contexts, aims and framework used, level of analysis, and so on.

In this section we report the results for our resilience classifications in the spatial economics literature. We reviewed (36) papers and articles,[5] extracting from each the main characteristics, tools used, and interpretation of resilience, with the aim of providing a (possibly) complete overview to suggest new research questions and directions. The papers and working papers were selected—again using Google Scholar and the Scopus database. We restricted our search to papers containing the words resilience', 'regional resilience', 'spatial resilience' 'economic resilience', or 'community resilience' in their titles, abstracts or key words: '. The classification is presented in Table 4.

In relation to *shocks*, Table 4 shows that the concept of spatial economic resilience was used to explore the capacity of a region/area to recover from two main shocks: a) disasters (typically man-made or resulting from extreme weather conditions, e.g. Rose and Krausmann 2013), and b) recessionary (e.g. Martin 2012).

The *analytical context* changes according to the different spatial economic objectives which range from regional accountability (Cellini and Torrisi 2014; Fingleton et al. 2012; Martin 2012), job market analysis (Di Caro 2013), business analysis (Rose

[4] This selection of papers and working papers was obtained using the Google Scholar search engine and the Scopus database. Duplications or cross citations of the definitions are not considered.

[5] We did not consider single authored books, edited volumes, or Special Issues on resilience.

Table 3 Different interpretations for spatial economic resilience

Author(s)	Year	Main field	Definition	Kind of resilience
Adger	2000	Community	'The ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change' (p. 347)	Ecological resilience
Ashby et al.	2008	Local places	'The extent to which local places and local government are capable of riding the global economic punches, working within environmental limits, dealing with external changes, bouncing back quickly, and having high levels of social inclusion'	Both kinds of resilience
Bristow	2010	Places	'Resilience emphasises the importance of healthy, dynamic local businesses—businesses which are 'competitive' and successful—and yet it does so in a manner which sees virtuous interrelationships between competition, environment and distribution' (p.156)	Ecological resilience
Bruneau et al.	2003	Community	'The ability of social units […]to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways that minimize social disruption and mitigate the effects of future earthquakes' (p. 735)	Engineering resilience
Coles and Buckle	2004	Community	'The total of the individual elements that thorough capacities, skills, and knowledge are able to participate fully in recovery from disasters and to cope with wider social, economic and political communities' (p. 6)	Engineering resilience
Davies	2011	Region	'The capacity of a regional economy to withstand change or to retain its core functions despite external upheaval', (p.370)	Both kinds of resilience
Foster	2007	Region	'The ability of a region to anticipate, prepare for, respond to and recover from a disturbance' (p.14)	Both kinds of resilience
Hill et al.	2011	Region	'[Regional resilience] is the ability of a regional economy to maintain or return to a pre-existing state (typically assumed to be an equilibrium state) in the presence of some type of exogenous (i.e., externally generated) shock' (p. 1)	Engineering resilience
Martin	2012	Region	'The capacity of a regional economy to reconfigure, that is adapt, its structure (firms, industries, technologies and institutions) so as to maintain an acceptable growth path in output, employment and wealth over time' (p.10)	Ecological (adaptive) resilience
Paton and Johnston	2001	Community	'The capability to "bounce back" and to use physical and economic resources effectively to aid recovery following exposure to hazard activity' (p. 158)	Engineering resilience

Table 3 (continued)

Author(s)	Year	Main field	Definition	Kind of resilience
Pendall et al.	2010	City	'Resilient city would be one that resumed its previous [economic/population/built form] growth trajectory after a lag' (p. 73)	Engineering resilience
Pendall et al.	2012	Region	'A resilient region, is one whose governance decisions identify and anticipate stresses, avoid those that can be avoided, and mitigate those that cannot, thereby protecting individuals and households from many harms and helping them recover from others' (p. 272)	Both kinds of resilience
Pfefferbaum et al.	2005	Community	'The ability of community members to take meaningful, deliberate, collective action to remedy the effect of a problem, including the ability to interpret the environment, intervene, and move on' (p. 349)	Ecological resilience
Rose and Liao	2005	Firm and region	'Inherent ability and adaptive response that enables firms and regions to avoid maximum potential losses' (p.76)	Engineering resilience
Swanstrom	2008	Region	'A resilient region would be one in which markets and local political structures continually adapt to changing environmental conditions and only when these processes fail, often due to misguided intervention by higher level authorities which stifle their ability to innovate, is the system forced to alter the big structures' (p. 10)	Ecological resilience
Wolfe	2010	Region	'How a particular economy gets locked into a specific pattern of growth through a cumulative series of decisions over time. This perspective is also concerned with how new paths are launched and regions alter their trajectory of development' (p.140)	Ecological resilience

and Liao 2005; Rose and Krausmann 2013), and living standards and quality of life (Pendall et al. 2012).

The *aims* of the analysis are multifaceted; however, it is possible to identify various domains. According to Christopherson et al. (2010) and Dawley et al. (2010), resilience might be analyzed to measure the economic success of a region/area in terms of: i) adjustment, ii) adaptation, iii) convergence, or iv) equilibrium; or according to Martin's (2012) categories: i) renewal, ii) reorientation, iii) recovery, or iv) resistance. These aspects account respectively for: a) the degree of regeneration along a regional growth path, b) the degree of adaptation in response to shock of the object under study; c) capacity in terms of speed and degree of recovery from shocks, and d) the extent of sensitivity to the shock.

Framework refers to the treatment of time and space which has important impacts on the way the economic process that characterizes resilience is understood. The typical

Table 4 Main characteristics of the spatial economics resilience literature

Authors, year	Shock	Context	Aim	Framework	Tool	Measure for resilience	Case study
Adger 2000	Institutional shock	Livelihood system	Adjustment	Static	Qualitative analysis	Inequality of income Property rights	Mangrove conversion in Vietnam
Ashby et al. 2008	2008–2010 downturn	Economic development	Adaptability	Static	Methodological framework	Environment Infrastructure Socio-economic	6 urban areas around the world
Briguglio et al. 2009	–	Output	Recovery	Static	Indices	Good governance Macroeconomic stability Market efficiency Social development	86 different countries
Bristow 2010	Economic downturns	Regional Development	Adaptability recovery	Static	Cultural political economy approach	Measures of competiveness	Methodological approach
Bruneau et al 2003	Earthquake	Economic development	Resistance	Static	Performance measures index on the quality of infrastructures	Socio-economic Technical Organizational	Methodological approach
Cardona et al. 2008	Earthquake	Output	Recovery	Static	Disaster deficit index	Financial resources Loss	The Americas in 2000
Cellini and Torrisi 2014	Economic downturns	Output	Resistance	Static	SURE Seemingly Unrelated Regression Equations, RCM Random Coefficient Method, MA Metropolitan Area, VECM Vector Error Correction Model, MSA Metropolitan Statistical Area, CGEM Computable General Equilibrium Model	Regional heterogeneity of estimated parameters	Italian regions in 1890–2009
Chan et al. 2014	Flood	Economic development	Adaptability	Static	Indices	Built environment Institutional	Tan-sui river basin in Taiwan

Table 4 (continued)

Authors, year	Shock	Context	Aim	Framework	Tool	Measure for resilience	Case study
						Natural environment	
						Socio-economic	
						Technology	
Chapple and Lester 2010	–	Employment	Adjustment adaptability	Dynamic	Performance indices discriminant function analysis	Demographic Socio-economic	US MA in 2000
Coles and Buckle 2004	Disasters	Recovery activities	Recovery	Static	Qualitative analysis	Operational Planning Policy	Lewes district, UK in 2000
Cutter et al. 2008	Disasters	Recovery activities	Recovery	Static	Composite indicator	Community Ecological Infrastructure Institutional Socio-economic	Southeastern United States
Davies 2011	2008–2010 downturn	Employment	Adaptability	Static	Regression analysis	Regional strength and weakness	Europe in 2008–2010
			Adjustment Recovery Resistance	Dynamic	Semi-structured interviews	Sectorial structure	
Dhawan and Jeske 2006	Energy price shocks	Output	Resistance	Static Dynamic	Counter-factual analysis	Counter-factual growth rate	USA 1970-2005
Di Caro 2013	Economic downturns	Employment	Resistance	Static	SURE VECM	Regional heterogeneity of estimated parameters	Italian regions in 1970–2010
Duval et al. 2007	Common unobserved shocks	Employment	Recovery	Static	Pooled regression analysis (i.e. dynamic	Labour and product market regulations	20 OECD Countries in 1982–2003

Table 4 (continued)

Authors, year	Shock	Context	Aim	Framework	Tool	Measure for resilience	Case study
		Output	Resistance	Dynamic	(non-linear) panel regression)	Policy and institutional	
Estoque and Murayama 2014	External pressures	Socio-economic development	Recovery	Static	Indices	Ecological integrity Governance integrity Social integrity	The Philippines in 2010
Fingleton et al. 2012	Employment shocks	Employment	Adjustment Resistance	Static Dynamic	SURE VECM	Regional heterogeneity of estimated parameters	British regions in 1970–2010
Foster 2007	Prolonged economic decline	Livelihood system	Resistance	Static	Indices	Socio-economic	Buffalo-Niagara Falls MA 1970-2000
Graziano 2013	Socio-economic shocks	Socio-economic development	Recovery	Static	Indices	Economic Enterprise Household Infrastructure Innovation Local economy	Italian local systems in 2007–2011
Hassink 2010	–	–	Adaptability	Dynamic	Methodological framework	Firms variety Regional innovation policy Sunk costs	Methodological approach
Hill et al. 2011	Economic downturn Industry shock	Employment Output	Adjustment Recovery Resistance	Dynamic	Hazard models Logistic regression	Socio-economic	MSA, USA 1970–2007
Jordan et al. 2011	Disasters	Output	Recovery	Static	Qualitative comparative analysis	Disaster impact Infrastructure Institutional	Hurricane Katrina Indian Ocean Tsunami

Table 4 (continued)

Authors, year	Shock	Context	Aim	Framework	Tool	Measure for resilience	Case study
						Recovery strategy	
						Socio-economic	
Martin 2012	Economic downturns	Employment, output	Adaptability	Static	Ratio of decline	Economic index	British regions in 1970–2010
			Adjustment	Dynamic	Sensitivity indices		
			Recovery		Growth trends		
			Resistance		Structural composition of employment change		
Ormerod 2010	Coal-Industry specific shocks	Employment in coal field areas	Recovery	Static	Regression analysis	Percentage change in employment growth	UK Local authority areas 1983–2002
Osth et al. 2014	–	Output	Recovery	Static	Measure of accessibility	Accessibility	Sweden municipalities in 1990–2010
					Resilience capacity index	Community-connectivity	
						Economic	
						Socio-demographic.	
Paton and Johnston 2001	Volcanic eruptions	Community risk perception	Recovery	Static	Pearson product–moment correlations	Community practices	New Zealand in 1995–1996
					Regression analysis	Personal characteristics	
Pendall et al. 2010	–	–	Adaptability	Static	Review	Socio-economic	Methodological approach
			Adjustment	Dynamic			
			Resistance				
Reggiani et al. 2002	–	Employment	Resistance	Dynamic	Lyapunov exponents	Economic	Regional labour market in West-Germany 1987–1997
	General shocks	Output	Recovery	Static	Indices	Biophysical environment	Goulburn-Broken

Table 4 (continued)

Authors, year	Shock	Context	Aim	Framework	Tool	Measure for resilience	Case study
Resilience Alliance (Walker et al.) 2009*						Socio-economic	Catchment, Australia
Rose 2007 Rose 2009 Rose and Krausmann 2013	–	Business recovery	Recovery	Static	Mathematical index	Deviation of direct output reduction from likely maximum potential reduction	Methodological approach
Rose and Liao 2005	Earthquake	Individual business Regional market	Resistance	Static	CGEM Simulation	Production responses	Portland
Simmie and Martin 2010	Economic downturn	Employment	Adaptability	Static Dynamic	Growth trends Structural composition of employment change	Economic	Cambridge and Swansea, UK 1970–2008
Swanstrom 2008	–	–	Adaptability, recovery	Static Dynamic	Methodological considerations	–	Methodological approach
University at Buffalo Regional Institute 2011	–	Output	Recovery	Static	Resilience capacity index	Community-connectivity Economic Socio-demographic	US Metropolitan Area
Wolfe 2010	Technological bubble Economic downturn	Firms growth rate	Adaption Recovery	Dynamic	Qualitative analysis	Civic capital Socio-economic	Ottawa and Waterloo, Canada in 2001–2002 and 2008–2009

SURE Seemingly Unrelated Regression Equations, *RCM* Random Coefficient Method, MA Metropolitan Area, *VECM* Vector Error Correction Model, *MSA* Metropolitan Statistical Area, *CGEM* Computable General Equilibrium Model

* Note that Resilience Alliance manages different projects on resilience worldwide; see, among others, Walker et al. (2009)

framework is static. Thus, time can be measured in moments of pre-shock, shock, and post-shock events, within the confines (container) of the region/area. Alternatively, time can be seen as a constant process of transition in which space can be thought of as the result of a continuous flow of actions.

Concerning the *case-studies*, there are numerous applications in the USA and UK contexts, at both regional and community spatial level.

Also relevant is the choice of '*indicators*' of spatial economic resilience and related '*measurements*'. For instance, resilience analysis of disasters typically is conducted based on indices, while studies of recessionary shocks are based mainly on econometric models and particularly time-series analysis. In this context, it should be noted that the literature devotes a great deal of attention to defining the most appropriate indicators of resilience, and how to aggregate composite indicators. This issue is explored next in sub-section 3.2.

3.2 Indicators for Spatial Economic Resiliency

We need a short discussion on indicators. Numerous groups have developed methodologies which provide synthetic indices for spatial economic resilience. Table 5 expands on the studies included in Table 4, and presents some of the variables used to study spatial economic resilience. Notice that the number of variables used to build an indicator of resilience varies from 1 in Martin (2012), to 29 in Cutter et al. (2008). This is indicative of the variability and sensitivity of the indicators with reference to the selection of what is important/matters for resilience.

Despite this wide range in the number of variables considered in the various indicators of resilience, the variables fall into six main categories. First, all the indices in Table 5 take account of the *socio-economic characteristics* and *financial resources* of individuals (e.g. personal income, pension per capita, income equality, poverty, and so on), as well as the entire spatial economic system (e.g. business environment, economic diversification, business density, credit market, fiscal deficit, GDP, and so on).

Another important aspect, considered in most of the papers in Table 5, is the *institutional capacity* of the spatial economic system, especially in terms of resource distribution capability, continuity of operational plans, political system, public facilities, and so on.

Infrastructure is an important aspect of resilience since the societal functions in a spatial economic system are all highly dependent on the infrastructure networks—which are able to improve the system's economic efficiency (Percoco 2004). The relevance of accessibility vs. spatial economic resilience has been discussed recently, with reference to the commuting patterns in Swedish municipalities (Osth et al. 2014).

Good c*ommunity capacity* might be seen as a strength allowing a given area to cooperate and cope with a disturbance. For this reason, variables such as civic infrastructure, local understanding of risk, and so on, are often considered in a resilience index.[6]

Innovation and technology and *natural environment* are strictly related and can be considered jointly as the capability to prevent or to reduce the impact of a disaster, especially natural disasters (e.g., river basin management plans are based on knowledge of the physical characteristics of river basins).

[6] Concerning the role of the spatial interaction in social networks see, among others Illenberger et al. (2013).

Table 5 Resilience indicators by number and description of its components

Authors, year	Sub-division	No. of vars.	Variables	Weighting
Briguglio et al. 2009	Financial resources Institutional Socio-economic	13	Banking industries Control on interest rates Credit market External debt Impartiality of courts Intellectual property rights Judicial independence Military interference Political system Education Fiscal deficit Inflation and unemployment Health	Equal weight
Cardona et al. 2008	Financial resources Loss	8	Aids and donations External credit Insurance and reinsurance payments Internal credit Margin for budgetary reallocations New taxes Reserve funds for disasters GDP	Equal weight
Chan et al. 2014	Infrastructure Institutional Natural environment Socio-economic Innovation and technology	13	Public facilities Spatial structure of land use Disaster prevention plans Resource distribution capability River basin management organizations Environmentally sensitive area Slope area conservation Water resource conservation Government's financial capability Individual capability Vulnerable population Accuracy of weather forecasts Rescue capability	
Cutter et al. 2008	Community Infrastructure Institutional Natural environment Socio-economic	29	Absence of psychopathologies Counseling services Health and wellness Local understanding of risk Quality of life Commercial and manufacturing establishment Lifelines and critical infrastructure Residential housing stock and age Transportation network Continuity of operations plans Emergency response plans Emergency services	

Table 5 (continued)

Authors, year	Sub-division	No. of vars.	Variables	Weighting
			Hazard mitigation plans Hazard reduction program Interoperable communications Zoning and building standards Biodiversity Erosion rates % Impervious surface No. coastal defense structure Wetlands acreage and loss Community values/cohesion Demographics Employment Faith based organizations Municipal revenues Value of property Wealth generation Social networks	
Estoque and Murayama 2014	Institutional Natural environment Socio-economic	5	Good governance index Ecosystem service value index Human to ecosystem service value ratio index[a] Human development index Poverty incidence among families	Equal weight
Foster 2007	Socio-economic	4	% Employment change % Population change Per capita income Poverty	Equal weight
Graziano 2013	Infrastructure Innovation and technology Socio-economic	19	Broadband services Electrical network Energy networks Rail infrastructure Application of designs Application of models European application of designs European application of models Patents Bank deposits Business density Housing Liquidity ratio Loans to firms Non food consumption/total consumption Pensions per capita Population growth rate Return on equity Value added per capita	Factor analysis
Martin 2012	Socio-economic	1	Employment	–
Resilience Alliance 2009	Infrastructure Natural environment Socio-economic	10	Water table depth Water table equilibrium Biodiversity measure River condition	Equal weight

Table 5 (continued)

Authors, year	Sub-division	No. of vars.	Variables	Weighting
			Riverine ecosystem condition Soil acidity Water infrastructure Balance among values held Farm income Presence of high multiplier economic sectors	
University at Buffalo Regional Institute 2011	Community Socio-economic	12	Civic infrastructure Home ownership Without disability Business environment Economic diversification Educational attainment Health insured Income equality Metropolitan stability Regional affordability Out of poverty Voter participation	Equal weight

[a] Both ESVI and H-ESVI come from Estoque and Murayama (2014)

It should be noted that these six 'macro-indicators' are related not only to resilience but also to the vulnerability of a system. However, in the papers reviewed, there was little discussion of vulnerability. The concept of vulnerability has been analysed and measured in relation to transport networks due to the important role of physical connectivity in this field but has been rather overlooked in spatial economics.[7] In the next section, we briefly examine the concepts of spatial economic resilience vs. vulnerability.

3.3 Spatial Economic Resilience and Vulnerability

Spatial economic resilience leads to the exploration of a related framework, that is, the concept of vulnerability: "*Resilience is the responsiveness of the system, i.e. its elasticity or capacity to rebound after a shock, indicated by the degree of flexibility, persistence of key functions, or ability to transform. Vulnerability is more about the susceptibility of the system or any of its constituents to harmful external pressures*" (Seeliger and Turok 2013, p. 2119).

Vulnerability refers to the degree to which a system is susceptible to harm. However, it should be noted that vulnerability is not dependent on the probability of the occurrence of a shock (Smit et al. 1999). In general, vulnerability is not seen as the opposite state to resilience, as highlighted by Seeliger and Turok (2013).

We discussed earlier that vulnerability is an issue that is generally not treated in spatial economics where its impact is small compared to the impact on physical transport, which has strong links with vulnerability. For example, in road systems,

[7] Note that vulnerability and resilience play key roles in the sensitivity of a system to natural disasters, and in development studies.

the rupture of a link immediately triggers change in the performance of the whole road network and alternative transport modes (for a study of vulnerability in public transport, see Cats and Jenelius 2014; for a review of resilience and vulnerability in transport, see Reggiani et al. 2014).

In relation to spatial economic vulnerability, several authors consider vulnerability to be a pre-event characteristic, and resilience the outcome of a post-disaster response (Adger 2000; Cutter et al. 2008; Foster 2007; Pendall et al. 2012; Rose 2007). Thus, resilience is often seen as a way to reduce vulnerability and a more resilient system as a system with less vulnerable sub-systems (Pendall et al. 2012).

Connectivity—which is strictly related to vulnerability—is mostly ignored in the contributions we examined. Connectivity is more difficult to detect and measure in spatial economics because it is 'hidden' within the socio-spatial-economic interactions between regions/areas/cities where the links are less obvious than in a transport network. Connectivity certainly plays a fundamental role in the topological configuration of spatial economic networks (e.g. hub and spoke networks, random networks, etc.) and associated network accessibility (Reggiani 2013). However, only a few works examine these aspects and much more research is needed in this area.

The relationship between vulnerability and resilience needs to be tackled in depth. Cutter et al. (2008) believe that this topic is poorly articulated and might change with the object of study. For instance, in studies on the impact of global environmental change, resilience is embedded in vulnerability (Gallopin 2006) but research on hazards, vulnerability and resilience are treated as separate concepts with some interconnections (Cutter et al. 2008). As shown above, work on spatial economics includes very little consideration about the relationship between vulnerability and resilience.

Among these few contributions, we outline the methodological approach identified by Briguglio et al. (2009). In Briguglio et al. (2009), economic vulnerability is considered an inherent condition that affects the exposure of a country/region to exogenous shocks, while economic resilience is related more to the set of actions implemented by private economic actors and policy makers to help the country/region to recover from and/or to adapt to a negative shock or to benefit to the greatest extent from a positive shock.

Overall, it seems that, like resilience, vulnerability depends on factors such as nature of the system, and type of shock, which vary for different spatial and socio-economic contexts. Brooks et al. (2005) offer the example of developmental factors including poverty, health status, economic inequality, and types of governance as constituting vulnerability. However, these factors, as shown in the previous sections and Table 5, are also included in various resilience indicators. Thus, the link and difference between resilience and vulnerability appears to be ambiguous and is not well defined in the spatial economic literature. Investigation of this relationship in tandem with an examination of how shocks propagate would be a fruitful direction for future research.

Figure 1 depicts the methodological framework underlying the above mentioned issues. It shows the inter-connections between spatial-economic systems, vulnerability, and resilience, through their evolutionary dynamics and exposure to shocks. The shock plays a central role. When a shock hits the spatial economic system, either in its entirety or one of its parts, it causes an economic loss or gain that is more or less pronounced according to the vulnerability and resilience characteristics of the system.

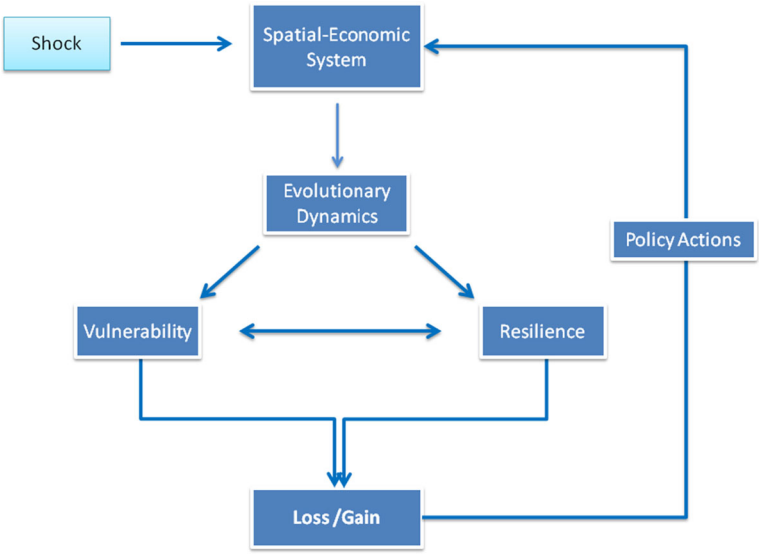

Fig. 1 A methodological framework linking resilience and vulnerability

This loss/gain will change the original structure of the spatial economic system and result in a new *equilibrium*. The new *equilibrium* will be the motivation for the introduction of 'adaptive' strategies by policy makers (e.g., policy measures aimed at mitigating an economic loss, etc.). A good 'preventative' action would be policy to enhance resilience (or to reduce vulnerability). However, this action would also affect the spatial-economic system.

Thus, vulnerability and resilience might be regarded as concepts that play a key role in modifications to the spatial economic system's structure. The current literature provides much discussion of the various options for enhancing resilience—mainly increasing the redundancy of systems, and double technology and increased inputs are considered valid instruments in this respect (Reggiani 2013). However, the related costs might be prohibitive, and more research is needed that takes account of these aspects.

4 Conclusion

The aim of this conceptual overview is stimulate discussion about what spatial economic resilience is, and how it has been analysed so far. It seems that two basic concepts of resilience—ecological resilience and engineering resilience—are considered in the literature and constitute a common framework that allows slightly different interpretations. We suggest that spatial economic resilience is a multifaceted concept, linked to the notions of stability (engineering resilience) but also to the idea of adaptivity which is based on evolutionary theories (ecological resilience).

The contributions examined suggest that the analysis and measurement of spatial economic resilience is related to specific shocks, specific contexts, aims, and the framework and spatial level adopted. Thus the methodologies and tools used to explore

resilience should vary according to the variables adopted to define indicators of spatial economic resilience.

Starting from these considerations, we would add that there are only a few studies that investigate resilience in depth from the theoretical viewpoint. Most studies investigate resilience empirically, using a variety of indicators and methods, and different spatial levels.

In addition, much more attention should be paid to the analysis of vulnerability vs. resilience—an area where currently there is a theoretical/methodological gap. Further research should focus on developing a more consistent analytical framework of spatial economic resilience—and vulnerability—to achieve a clear understanding and representation of the evolutionary (spatial economic) process under study, and its possible policy implications.

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References

Adger NW (2000) Social and ecological resilience: are they related? Prog Hum Geogr 24(3):347–364

Arthur B (1990) Positive feedbacks in the economy. Sci Am 262:92–99

Ashby J, Cox D, McInroy N, Southworth D (2008) Delivering economic success: an international perspective on local government as stewards of local economic resilience. CLES Bull 2010

Batabyal AA (1998) The concept of resilience: retrospect and prospect. Environ Dev Econ 3:235–239

Béné C, Godfrey Wood R, Newsham A, Davies M (2012) Resilience: new utopia or new tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. IDS Working Paper N. 405

Briguglio L, Cordina G, Bugeja S, Farrugia N (2006) Conceptualizing and measuring economic resilience. Mimeo, Department of Economics, University of Malta

Briguglio L, Cordina G, Farrugia N, Vella S (2009) Economic vulnerability and resilience: concepts and measurements. Oxf Dev Stud 37(3):229–247

Bristow G (2010) Resilient regions: re-'place'ing regional competitiveness. Camb J Reg Econ Soc 3:153–167

Brooks N, Adger WN, Kelly PM (2005) The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Glob Environ Chang 15(2):151–163

Bruneau M, Chang S, Eguchi R, Lee G, O'Rourke T, Reinhorn A, Shinozuka M, Tierney K, Wallace WA, vonWinterfeldti D (2003) A framework to quantitatively assess and enhance the seismic resilience of communities. Earthquake Spectra 19:733–752

University at Buffalo Regional Institute, State University of New York (2011) Resilience capacity index retrieved at http://brr.berkeley.edu/economic-resilience

Cardona OD, Ordaz MG, Carreño ML, Marulanda MC, Barbat AH (2008) Fiscal impact of future earthquakes and country's economic resilience evaluation using the disaster deficit index. Paper presented at the 14th World Conference on earthquake engineering, Beijing, China

Carlson L, Bassett G, Buehring W, Collins M, Folga S, Haffenden B, Petit F, Phillips J, Verner D, Whitfiled R (2012) Resilience: theory and applications, Argonne National Laboratory, U.S. Department of Energy, Oak Ridge, USA. Retrieved from: http://www.dis.anl.gov/pubs/72218.pdf

Cats O, Jenelius E (2014) Dynamic vulnerability analysis of public transport networks: mitigation effects of real-time information. Netw Spat Econ (forthcoming)

Cellini R, Torrisi G (2014) Regional resilience in Italy: a very long-run analysis. Reg Stud 1–19

Chan SL, Wey WM, Chang PH (2014) Establishing disaster resilience indicators for Tan-sui river basin in Taiwan. Soc Indic Res 115(1):387–418
Chapple K, Lester TW (2010) The Resilient regional labour market? The US case. Camb J Reg Econ Soc 3(1): 85–104
Christopherson S, Michie J, Tyler P (2010) Regional resilience: theoretical and empirical perspectives. Camb J Reg Econ Soc 3:3–10
Coles E, Buckle P (2004) Developing community resilience as a foundation for effective disaster recovery. Aust J Emerg Manag 19:6–15
Cutter SL, Barnes L, Berry M, Burton C, Evans E, Tate E, Webb J (2008) A place-based model for understanding community resilience to natural disasters. Glob Environ Chang 18:598–606
Davies S (2011) Regional resilience in the 2008–2010 downturn: comparative evidence from European countries. Camb J Reg Econ Soc 4:369–382
Dawley S, Pike A, Tomaney J (2010) Towards the resilient region? Local Econ 25:650–667
Dhawan R, Jeske K (2006) Energy price shocks and the macroeconomy: the role of consumer durables. Working Paper No. 2006–9 Federal Reserve Bank of Atlanta
Di Caro P (2013) Recessions, recoveries and regional resilience: evidence on Italy. University of Catania Working Paper
Ducruet C, Beauguitte L (2013) Spatial science and network science: review and outcomes of a complex relationship. Netw Spat Econ (forthcoming)
Duval R, Elmeskov J, Vogel L (2007) Structural policies and economic resilience to shocks. OECD Economics Department Working Papers No. 567
Estoque RC, Murayama Y (2014) Social–ecological status index: a preliminary study of its structural composition and application. Ecol Indic 43:183–194
Fingleton B, Garretsen H, Martin R (2012) Recessionary shocks and regional employment: evidence on the resilience of UK regions. J Reg Sci 52(1):109–113
Foster KA (2007) Case study approach to understanding regional resilience. Working paper 2008–07. Institute of Urban and Regional Development, University of California, Berkeley
Gallopin GC (2006) Linkages between vulnerability, resilience, and adaptive capacity. Glob Environ Chang 16:293–303
Graziano P (2013) Vulnerability and resilience of the economic, social and environmental dimensions of Italian provinces. Regional studies association, European conference
Hassink R (2010) Regional resilience: a promising concept to explain differences in regional economic adaptability? Camb J Reg Econ Soc 3:45–58
Hill EW, Wial H, Wolman H (2008) Exploring regional economic resilience. Working paper 2008–04. Institute of Urban and Regional Development, University of California, Berkeley
Hill EW, StClair T, Wial H, Wolman H, Atkins P, Blumenthal P, Ficenec S, Friedhoff A (2011) Economic shocks and regional economic resilience. Working paper 2011–03. Institute of Government Studies, University of California, Berkeley
Holling CS (1973) Resilience and stability of ecological systems. Annu Rev Ecol Syst 4:1–23
Holling CS (1996) Engineering resilience versus ecological resilience. In Schultze P (Ed) National Research Council. Eng Ecol Constraints. The National Academies Press, Washington, DC (USA), pp 31–43. Retrieved from: http://www.environmentalmanager.org/wp-content/uploads/2008/03/holling-eng-vs-eco-resilience.pdf
Hudson R (2010) Resilient regions in an uncertain world: wishful thinking or a practical reality? Camb J Reg Econ Soc 3:11–25
Illenberger J, Nagel K, Flotterod G (2013) The role of spatial interaction in social networks. Netw Spat Econ 13:255–282
Jordan E, Javernick-Will A, Amadei B (2011) Pathways to communicate recovery and resiliency. In: Toole TM (ed) Proceedings of the engineering project organizations conference. Colorado, USA
Levin SA, Barrett S, Aniyar S, Baumol W, Bliss C, Bolin B, Dasgupta P, Ehrlich PR, Folke C, Gren IM, Holling CS, Jansson AM, Jansson BO, Martin D, Maäler KG, Perrings C, Sheshinsky E (1998) Resilience in natural and socioeconomic systems. Environ Dev Econ 3:222–235
Markusen A (1999) Fuzzy concepts, scanty evidence, policy distance: the case for rigour and policy relevance in critical regional studies. Reg Stud 37:701–717
Martin RL (2012) Regional economic resilience, hysteresis and recessionary shocks. J Econ Geogr 12:1–32
May RM (1976) Simple mathematical models with very complicated dynamics. Nature 271:459–467
McDargh E (2013) Tough times demand resilient leaders. The Resiliency Group retrieved at http://www.eileenmcdargh.com/blog/2013/11/tough-times-demand

Merriam-Webster Dictionary Online. An encyclopaedia Britannica Company retrieved at http://www.merriam-webster.com
Nijkamp P, Ratajczak W (2013) The spatial economy—a holistic perspective. Research Memorandum 37-Faculty of Economics and Business Administration, VU Amsterdam, The Netherlands. Retrieved from: http://dare.ubvu.vu.nl/bitstream/handle/1871/50705/2013-37.pdf?sequence=1
Ormerod P (2010) Resilience after local economic shocks. Appl Econ Lett 17(5):503–507
Osth, J, Reggiani A, Galiazzo G (2014) Spatial economic resilience and accessibility: a joint perspective. Comput Environ Urban Syst (forthcoming)
Paton D, Johnston D (2001) Disasters and communities: vulnerability, resilience, and preparedness. Disaster Prev Manag 10:270–277
Pendall R, Foster KA, Cowell M (2010) Resilience and regions: building understanding of the metaphor. Camb J Reg Econ Soc 3:71–84
Pendall R, Theodos B, Franks K (2012) Vulnerable people, precarious housing, and regional resilience: an exploratory analysis. Hous Policy Debate 22(2):271–296
Percoco M (2004) Infrastructure and economic efficiency in Italian regions. Netw Spat Econ 4:361–378
Perrings C (1998) Resilience in the dynamics of economy-environment systems. Environ Resour Econ 11(3–4):503–520
Pfefferbaum B, Reissman D, Pfefferbaum R, Klomp R, Gurwitch R (2005) Building resilience to mass trauma events. In: Doll L, Bonzo S, Mercy J, Sleet D (eds) Handbook on injury and violence prevention interventions. Kluwer Academic Publishers, New York
Pimm SL (1984) The complexity and stability of ecosystems. Nature 307:321–326
Reggiani A (2013) Network resilience for transport security: some methodological considerations. Transp Policy 28:63–68
Reggiani A, De Graaff T, Nijkamp P (2002) Resilience: an evolutionary approach to spatial economic systems. Netw Spat Econ 2:211–229
Reggiani A, Nijkamp P, Lanzi D (2014) Transport resilience and vulnerability: the role of connectivity. Mimeo
Rose AZ (2007) Economic resilience to natural and man-made disasters: multidisciplinary origins and contextual dimensions. Environ Hazards 7:383–398
Rose AZ (2009) Economic resilience to disasters. Published articles & papers. Paper 75
Rose AZ, Krausmann E (2013) An economic framework for the development of a resilience index for business recovery. Int J Disaster Risk Reduction
Rose AZ, Liao SY (2005) Modelling regional economic resilience to disasters: a computable general equilibrium models of water service disruptions. J Reg Sci 45:75–112
Samuelson PA (1939) A synthesis of the principle of acceleration and multiplier. J Polit Econ 47(6):786–797
Seeliger L, Turok I (2013) Towards sustainable cities: extending resilience with insights from vulnerability and transition theory. Sustainability 5:2108–2128
Simmie J, Martin RL (2010) The economic resilience of regions: towards an evolutionary approach. Camb J Reg Econ Soc 3:27–43
Smit B, Burton I, Klein RJT, Street R (1999) The science of adaptation: a framework for assessment. Mitig Adapt Strateg Glob Chang 4:199–213
Swanstrom T (2008) Regional resilience: a critical examination of the ecological framework. Working paper 2008–07. Institute of Government Studies, University of California, Berkeley
Walker BH, Abel N, Anderies JM, Ryan P (2009) Resilience, adaptability, and transformability in the Goulburn-Broken catchment, Australia. Ecol Soc 14(1):12
Wolfe D (2010) The strategic management of core cities: path dependency and economic adjustment in resilient regions. Camb J Reg Econ Soc 3:139–152