An Analysis of Resilience in Complex Socioeconomic Systems

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Abstract

The notion of *resilience* originated in the ecology literature in the modern or post-World War II era. Even so, this term has now found widespread use in the social sciences in general and in regional science in particular. Although this expansion in the use of resilience is welcome, it is important to recognize that there is some ambiguity and confusion in the extant regional science literature about foundational issues and hence also about the nature of policy when resilience is a factor to contend with. Given this state of affairs, in this chapter, we provide a detailed discussion of three foundational and two policy related issues concerning the use of resilience in regional science. The three foundational issues are about definitions, whether resilience is a process, and whether resilience is always a good thing. The two policy issues concern multiple stable states and the connection between the twin notions of resilience and sustainability. The chapter concludes with some retrospective and prospective remarks.

Keywords: Complex System, Dynamic, Process, Resilience, Static, Sustainability

JEL Codes: Q57, R11, R58

1. Introduction

Following the etymology of the word, *resilience* derives from the Latin *resilire* which means to bounce back or to recover from a disturbance or shock of some kind. As pointed out by Levin (2015), in the 1950s, the American ecologist Robert MacArthur and the Australian theoretical physicist Robert May worked on different ways of ascertaining how an ecological system (ecosystem) might bounce back after it has been subject to one or more disturbances. These researchers also attempted to connect the stability of an ecosystem to the number of species in this ecosystem.

This early work notwithstanding, it is fair to say that in the modern or post-World War II era, the notion of resilience was formally introduced into the ecology literature in a prescient paper by Holling (1973). Since the publication of this paper, a vast literature on resilience has now emerged not only in ecology but also, more recently, in the social sciences in general and in regional science in particular.

Over the past few decades---and particularly in recent years---we have witnessed an avalanche of studies on the notion of resilience in a *social* context. This concept is often interpreted as the capacity of a socio-economic system to incorporate and cope with external shock related developments from a long-term perspective (see e.g., Cellini and Torrisi 2014, Boschma *et al.* 2014, Martin and Sunley 2015, Modica and Reggiani 2015, Nijkamp 2017, Rodin 2014, and Shaw and Maythorne 2013). Thus, the resilience concept in the social sciences focusses on the ability of a social system to withstand, to recover, and to transfer itself through adaptive behavior.[4]

[4] It is also possible to think of the resilience of a constituent component of a social system such as a business.

Similarly, there is a burgeoning literature on resilience in the broad regional science field. In this regard, three domains of study have now aroused great interest:

- The study of the *dynamics of regional development*; examples can, *inter alia*, be found in Aldrich and Meyer (2015) who study local resilience from a social capital perspective, or in Bene *et al.* (2014) who address poverty and regional development conditions against the background of a resilient economy. In this context, institutions appear to play a critical role in absorbing shocks (see e.g. Bristow and Healy 2014) and social capital acts as a mitigating factor (see Osth *et al.* 2018). An evolutionary-based interpretation of spatial resilience can be found in Reggiani *et al.* (2002).

- The study of *complex urban systems in stress situations*; examples of urban resilience studies can be found, *inter alia*, in Delgado-Ramos and Guibrunet (2017) who propose a system's architecture for urban resilience and sustainability based on a pyramid comprising ecological, economic, socio-cultural, and governance conditions (see also World Bank 2018), while Malik and Kontokosta (2018) design a resilience capacity index based on social infrastructure and community connectivity, physical infrastructure, economic strength, and environmental quality. There clearly is great diversity in the conceptualization and study of urban resilience. A rather comprehensive overview of interpretations and applications of urban resilience can be found in Elburz *et al.* (2019).

- The study of the recovery potential of spatial systems (regions or cities) *after a natural disaster or human-made catastrophe*; there is some literature on this issue. For instance, Modica *et al.* (2019) examine unanticipated regional development patterns in the context of spatial shocks, vulnerability, and resilience. A more comprehensive review of the system-wide impacts of disasters in spatial development from a resilience perspective can be found in Okuyama and Rose (2019) and Borsekova and Nijkamp 2019).

Unfortunately, some of the existing literature on resilience in regional science is not characterized by either conceptual transparency or terminological clarity on foundational issues. In the present study, we shall discuss three prominent aspects of resilience studies that have led to some ambiguity or confusion. These issues concern: the *definition* of the concept of resilience (Section 2); the characterisation of resilience as either a *process* or a *trait* of a system (Section 3), and whether resilience is always a *good* thing and hence worthy of promotion (Section 4). Next, our study addresses two policy-oriented questions, viz. the policy challenge of coping with *multiple stable states* of a system (Section 5), and the different meanings of *resilient* and *sustainable* systems (Section 6). Finally, in a concluding section (Section 7) we offer some retrospective and prospective remarks.[5]

2. Definitions

2.1. Two meanings of resilience

In the modern or post-World War II era, the notion of *resilience* was introduced and popularized in the ecology literature most notably by Holling (1973).[6] Even so, this concept now

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Our choice of topics in this chapter is, no doubt, subjective but this choice reflects what we believe to be the five most salient conceptual and policy issues involving the use of resilience in regional science. Space limitations prevent us from discussing other resilience related topics in regional science and this point should not be construed to mean that these other topics such as spatial considerations are insignificant. That said, we do discuss spatial matters briefly in footnote 11 and in sections 5.1, 5.2, and 7.

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In this regard, it is worth quoting Alexander (2013, p. 2711) who says that there “is no doubt that the adoption of the scientific concept of resilience outside mechanics owes much to the theoretical work of Crawford Stanley Holling, the US-Canadian ecologist.”

has two meanings in ecology. That said, we believe that regional scientists who would like to study one or more aspects of resilience in the context of complex socioeconomic systems[7] need to be cognizant of the ways in which resilience has been used in the ecology literature. Why? There are three reasons. First, Alexander (2013, p. 2713) has pointed out that "resilience is being used as…a fashionable buzz-word." Echoing this sentiment, Walker (2020, p. 1) contends that resilience "is becoming a buzzword. Sometimes it is open to interpretation and sometimes it is simply wrong." So, unless regional scientists understand how resilience has been used previously in the ecology literature, there is the distinct danger that they will either use this concept inappropriately and/or give it a new meaning and thereby contribute to its use as a buzzword that delineates something that sounds good but has multiple meanings to multiple researchers. Second, with regard to the use of resilience in different disciplines, Alexander (2013, p. 2713) has rightly noted that "it is striking how the term is used in different disciplines without any reference to how it is employed in other fields, as if there were nothing to learn or transfer from one branch of science to another." Put differently, regional scientists who are unaware of the prior use of resilience in ecology may end up either "reinventing the wheel" or promoting a perspective that does not engender the cross-fertilization of knowledge across different disciplines. Finally, Alexander (2013, p. 2713) contends that "the use of resilience to describe homeostasis in systems is at variance with the 'resilience ideology' of people and communities that need to be protected – by means of dynamic changes." Homeostasis here refers to an equilibrium of some kind. Since regional scientists often focus on one or more equilibria of a socioeconomic system of interest, a lack of awareness about the prior

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The work of Levin *et al*. (1998), Garnsey and McGlade (2006), Terra and Passador (2018), and Helbing (2019) tells us that it makes sense to think of socioeconomic systems as complex systems. Therefore, even though we do not use the term "complex" every time we refer to socioeconomic systems that are typically of interest to regional scientists, it should be understood that in the remainder of this chapter, we have complex socioeconomic systems in mind.

use of resilience in ecology may give them the erroneous impression that the concept of resilience is essentially an equilibrium centered notion.

Let us now discuss the two meanings of resilience. First, we have *engineering* resilience or resilience of the first kind. Here, even though C.S. Holling (1996) came up with the term engineering resilience, resilience in this particular sense originates in the main from the work of Pimm (1984). Other researchers who have contributed significantly to the development of engineering resilience include O'Neill *et al.* (1986), and Tilman and Downing (1994).[8]

Second, we have *ecological* resilience or resilience of the second kind. This second sense in which the notion of resilience has been and is used in ecology is due to Holling (1973). It is important to understand that engineering resilience and ecological resilience are very *different* concepts and hence, in general, one does not expect there to be any identifiable relationship between these two dissimilar ideas.

To see exactly how these two notions of resilience are different from each other, let us consider standard definitions of these two concepts. In this regard, engineering resilience "concentrates on stability *near an equilibrium* steady state, where resistance to disturbance and speed of return to the equilibrium are used to measure the property…" (Holling, 1996, p. 33, emphasis added).[9] In contrast, ecological resilience "emphasizes conditions *far from any equilibrium* steady state, where instabilities can flip a system into another regime of behavior---that is, to another stability domain" (Holling, 1996, p. 33, emphasis added).[10] From these two definitions, it should be clear to the reader that, *inter alia*, engineering resilience is an "equilibrium-

8 Subject to the caveat noted in footnote 11 below, the reader may also want to peruse the work of Bruneau *et al.* (2003) to get a sense for how "engineers" think of "seismic resilience."

9 Also see Pimm (1984), O'Neill *et al.* (1986), and Tilman and Downing (1994).

10 Also see Holling (1973) and Holling *et al.* (1995).

centered" view of an ecosystem and that ecological resilience is a "far-from-equilibrium" view of an ecosystem.[11]

The work of Pimm (1991) and Perrings *et al.* (1995) informs us that both these notions of resilience are pertinent when analyzing the responses of ecosystems to shocks. In addition, the work of Perrings (1987, 1991) and that of Batabyal (1998, 1999a, 1999b, 2001) tell us that these two notions are also relevant when analyzing jointly determined ecological-economic systems such as fisheries, forests, and rangelands.[12] That said, the key question is this: Are these two notions of resilience useful as organizing concepts for *socioeconomic systems* which are the systems that regional scientists routinely work with? Here, the work of Levin *et al.* (1998), Batabyal (1998), Walker (1998), and others tells us that the answer to the above question is an unambiguous "yes."[13]

Once we agree with the "yes" answer in the preceding paragraph, the question arises as to which definition of resilience---engineering or ecological---to use when studying socioeconomic systems. Unfortunately, the extant literature in regional science does not provide a clear answer. For instance, on the one hand, Stanickova and Melecky (2017, p. 233, emphasis added) contend that for regional economic analysis, "the most natural conceptual meaning of economic resilience

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The definition of engineering resilience that we are working with is *not* our own but provided by Holling (1996). The work of Bruneau *et al.* (2003, p. 737, figure 1) shows that the concept of "seismic resilience" used in the disaster management literature is also equilibrium centered and hence similar to the engineering resilience concept that we are discussing here. That said, it should be noted that the analytical framework for quantitatively assessing the seismic resilience of a community that Bruneau *et al.* (2003, pp. 741-742, emphasis added) present "focuses on the two desired ''ends'' of resilience—robustness and rapidity—and *assumes* that quantitative measures can be developed…" As such, it is unclear what a researcher is to do if the relevant quantitative measures cannot be developed. More generally, there are other context specific measures of resilience in the engineering literature that use techniques from operations research---such as the theory of Poisson processes and renewal theory---to construct measures of resilience. For a related application in the case of earthquake management, see Batabyal and Beladi (2001). For more on disaster resilience indicators in the United States, see Cutter (2016).

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Such systems are said to be jointly determined because their evolution over time---and possibly space---is determined by forces that are partly ecological and partly economic in nature.

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In this regard, it should be noted that the analysis of socioeconomic systems is made complex by the interacting roles of the trinity of institutions, markets, and prices. This trinity and the associated behavioral responses have no obvious counterpart in purely ecological systems.

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 shock." The implication here is that engineering resilience is the appropriate notion to focus on. In contrast, in their discussion of how regional social-ecological systems ought to be managed, Lebel *et al.* (2006, p. 3, emphasis added) note that "[t]he alternative to trying to maintain, or transform to, a system configuration that is very narrowly defined is to manage resilience. Resilience is a measure of the amount of change a system can undergo and still retain the same controls on structure and function or *remain in the same domain of attraction*…" These researchers are plainly talking about ecological resilience.

The fact that there is no one answer to the question of which definition of resilience to use when studying socioeconomic systems in regional science is not a problem. That said, researchers do need to comprehend the *criteria* that will help them decide whether their focus in any given instance ought to be on engineering or on ecological resilience. In this regard, we contend that there are four criteria to think about that *collectively* will help a researcher determine whether his or her focus ought to be on engineering or on ecological resilience. After this discussion we shall briefly comment on the idea of socio-economic resilience.

2.2. Choosing between engineering and ecological resilience

The first criterion relates to whether the socioeconomic system under study is largely *untouched* and hence essentially devoid of human influence or whether this system is a *managed* or regulated system. If the system being studied is largely untouched then the "near equilibrium" perspective associated with engineering resilience is pertinent. In contrast---and this is likely to represent the vast majority of socioeconomic systems that regional scientists are interested in---if the system under study is managed or regulated then it is a lot more likely that this system can exist in multiple stable states. In this case, the "far from equilibrium" viewpoint associated with ecological resilience is the notion to focus on.

The second criterion concerns whether the socioeconomic system under study has a *unique* equilibrium or has *multiple* equilibria. If this system has a unique equilibrium then, implicitly, there is an assumption of global stability and therefore engineering resilience is the appropriate notion to concentrate on. On the other hand, a managed or regulated socioeconomic system can be expected to exist in multiple stable states. Therefore, in this case we are interested in ascertaining the size of the stability domain associated with a particular stable equilibrium and, as such, ecological resilience is the apposite notion to pay attention to.[14]

Socioeconomic systems in general perform a variety of functions for humans. Therefore, following Holling (1996), the third criterion involves determining whether to study the *efficiency* with which these functions are being carried out or to analyze the *existence* of one or more of these functions.[15] If the objective of a research project is to determine the efficiency with which system functions are being performed then the researcher ought to focus on the engineering resilience notion. If, on the other hand, a researcher's objective is either to maintain the existence of a system's functions or to ascertain the survival of a particular function then this researcher's attention should be focused on the ecological resilience notion.

The fourth criterion concerns the nature of the question or questions that a researcher is seeking to analyze. If the objective is to examine a *specific* question concerning the functioning of a socioeconomic system then it makes more sense to concentrate on the notion of engineering

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See Perrings (1996) for additional details on this second criterion.

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It is important to comprehend that the definition of engineering resilience stated above in section 2.1 does *not* include the concept of efficiency. Also, saying that one is interested in studying the efficiency with which a function is performed in a socioeconomic system does *not* mean that one is endorsing the perspective that the pertinent definition of engineering resilience should also have the notion of efficiency in it.

resilience. On the other hand, if a researcher's intent is to shed light on *general* questions about a socioeconomic system then we contend that this researcher's attention ought to be focused on the ecological resilience concept.

A final remark related to the distinction between ecological and engineering resilience is in order here. In the more recent literature on resilience in the social sciences, a third idea, i.e., the notion of *socio-ecological* resilience has been discussed (see e.g. Sterk *et al.* 2017). This idea is based on the awareness that dynamic ecological systems and human-social constellations are often interdependent and hence there is a need for a joint scientific approach and investigation. The foundation stones for socio-ecological resilience were laid by Adger (2000, p. 347, emphasis added) who introduced this notion by referring to "*the ability of groups or of communities to cope with external stresses and disturbances as a result of social, political, and environmental change*". In this regard, Berkes *et al.* (2003, p. 13, emphasis added) have described socio-ecological resilience as "*the amount of change the system can undergo and still retain the same controls on function and structure…*" These authors have focussed in particular on the capacity for learning and self-organization in systems disturbed by a perturbation. As noted by Folke (2006), serious attempts to integrate the *social* dimension is presently taking place in resilience research that is reflected in the large numbers of disciplines that are involved in explorative studies and new discoveries of linked social–ecological systems. Recent advances here include an improved understanding of social processes such as social learning and social memory, social networks, adaptive capacity, and systems of adaptive governance that allow for the management of necessary ecosystem services.

The notion of socio-ecological resilience has also played a role in recent studies on spatial dynamics. For example, the social and cultural dimensions of a city in transition have been studied by Sanchez *et al.* (2018). An earlier study on linkages between social and ecological resilience concepts in spatial systems can be found in e.g. Reggiani *et al.* (2002), while the positioning of resilience in a planning context has been highlighted by Davoudi (2012).

2.3. Stability and conceptual confusion about resilience

The discussion thus far in this chapter ought to suggest to the reader that irrespective of whether we choose to focus on engineering or on ecological resilience, at a very fundamental level, the notion of resilience has everything to do with the notion of *stability*. In fact, this point has been made by the noted ecologist Stuart Pimm (1991, p. 13) who has pointed out that "theoretical and empirical ecologists [have] used the word *stability* to mean at least five different things…" and that resilience is one of these "five different things."

In this regard, it is worth reiterating Pimm's (1991, pp. 13-14) point that in addition to resilience, ecologists have used the word *stability* to refer to related notions known as *persistence*, *resistance*, and *variability*. For regional scientists, the point to understand is that words like *persistence* and *resistance* have well understood meanings in ecology. Therefore, when a regional scientist uses a word like *resistance* to describe something that is at variance with the way this word is used in ecology, (s)he unhelpfully creates confusion about the meaning of the underlying concept[16] in an environment in which regional scientists are already using the word *resilience* in different ways.

We now elaborate upon the above point by providing some examples from the extant literature in regional science. In this regard, the recent work of Rose (2015) is instructive. After distinguishing between *static* and *dynamic economic resilience*, Rose (2015, p. 247) provides

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This point is discussed in greater detail in section 3 below.

definitions of these two concepts. He interprets static economic resilience as "the efficient use of remaining resources at a given point in time." He then proceeds to define dynamic economic resilience as "the efficient use of resources over time for investment in repair and reconstruction."

Leaving aside the temporal element for the time being, the problem with the above two definitions of economic resilience is that they are very close to the definition of *economic efficiency*. In fact, if a system is using its resources efficiently then an economist would most likely say that such a system is Pareto efficient. In turn, this means that no one in the system can be made better off without making at least one person in the same system worse off.[17] Clearly, economists sometimes use the notion of efficiency in a narrower sense to refer to, for instance, *resource efficiency*. But even in this case, Rose's (2015) definitions of---static and dynamic---economic resilience would be very similar to the way in which economists typically think about resource efficiency.[18] Consequently, it may be problematic to define concepts (static and dynamic economic resilience) that are integrally related to a preexisting concept in ecology (resilience) with clear meanings (engineering and ecological) in a way that divorces the defined terms from any kind of stability consideration and, at the same time, risks conflation with other well understood concepts in economics (Pareto and resource efficiency).

Next, Rose (2015, p. 250) further partitions static economic resilience into two parts---a direct part and a total part. He argues that *direct* static economic resilience "refers to the level of the individual firm or industry (micro and meso levels) and corresponds to what economists refer to as "partial equilibrium" analysis…" In contrast, *total* static economic resilience "refers to the

17 See Bishop (1993), Hirshleifer *et al.* (2005, pp. 533-534), and Mas-Colell *et al.* (1995, pp. 312-313) for additional details on this point.

18 Go to https://www.resource-germany.com/topics/generel-remarks/what-is-resource-efficiency/ for additional details on this point. Accessed on 17 December 2020.

economy as a whole (macro-level) and would ideally incorporate what is referred to as "general equilibrium" effects…" However, it seems plausible that this direct versus total distinction is conceptually vacuous because there is no reason to believe that the general equilibrium effects that Rose (2015) refers to occur at *a point in time*. In other words, it may be problematic to use the word *static* to describe something (general equilibrium effects) that, almost surely, occurs *over time*.

Finally, Rose (2015, p. 248, emphasis added) claims that research on resilience is split into two camps and that approximately "half of the researchers view resilience as any *action* that can reduce losses from disaster…" He then says that the "other camp focuses on resilience as *actions* following the onset of a disaster." We note here that, consistent with our discussion in this section, resilience---either engineering or ecological---is a *property*[19] of a system be it ecological-economic or socioeconomic. In contrast to many policy documents (e.g. the UN Urban Agenda), resilience *per se* is *not* an action or even a set of actions.

In conclusion, we reiterate that the literature on resilience in regional science has sometimes created conceptual confusion by defining and then working with this admittedly non-trivial concept in a way that does not add to our understanding of its true meaning. We now move on to discuss the second of our three foundational issues concerning the use of resilience in regional science. This issue involves shedding light on whether resilience is or is not a *process*.

3. Is Resilience a Process?

3.1. An aside

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Other appropriate synonyms here would be "attribute" or "trait."

Many researchers in the regional science profession postulate that resilience is a process. In this regard, the work of Martin and Sunley (2015, p. 13) is representative. According to these researchers, "resilience is a *process* that involves several elements…*vulnerability* …*shocks*…*resistance*…*robustness*…and *recoverability*."

Before we discuss this process issue, let us first get a separate matter out of the way. The above quotation from Martin and Sunley (2015) clearly suggests that resistance is a part of resilience or, put differently, that resilience is the broader concept. But we should recall from the discussion in section 2.3 that in the ecology literature, the word *resistance* has a specific meaning and that it is---following the work of Pimm (1991)---one kind of stability concept. Given this background, when Martin and Sunley (2015) suggest that resistance is a part of resilience, it should be noted that (i) this term has a specific meaning in ecology and that (ii) it is uncertain whether these researchers are using *resistance* in the same way as it is understood in ecology. As such, it is not clear whether it makes sense to think of one kind of stability concept (resistance) as being part of another stability concept (resilience).

3.2. Process

Returning to the process issue, there is considerable disagreement more generally in the social sciences about whether resilience is a process. For instance, the psychologist and social scientist Michael Ungar (2018, p. 3, emphasis added) notes that "studies of social-ecological systems tend to see resilience as the *capacity* of a system, closer to the description of a *trait* than a process…" He (2018, p. 3, emphasis added) then says that "[p]sychologists, social workers, and other mental health professionals, on the other hand, abandoned descriptions of resilience as a trait decades ago and now describe resilience most often as a *process*." Finally, he (2018, p. 3) contends that this "difference between the disciplines has become somewhat blurred as social-ecological systems researchers…have shown interest in the structure and processes associated with nested adaptive cycles across scales."

Although Ungar (2018) and other researchers such as Rutter (1987) and Masten (2014) argue that resilience is a process, our position is that resilience is a *property* of an ecological-economic or a socioeconomic system and *not* a process. Our argument to substantiate this position is in two parts. First, we go back to the ecology literature, where the term resilience originated, and pay careful attention to what prominent ecologists have said about this concept. Two examples follow in the next paragraph.

C.S. Holling, who introduced the notion of resilience into the ecology literature in 1973, says in a more recent contribution (1996, p. 32, emphasis added) that the resilience "of a system has been defined in two different ways in the ecological literature. These differences in definition reflect which of two *different aspects of stability* are emphasized." Simon Levin (2015, p. 1, emphasis added) says that ecological resilience is "the *ability of an ecosystem* to maintain its normal patterns of nutrient cycling and biomass production after being subjected to damage caused by an ecological disturbance." The clear inference we draw from these two quoted observations from ecology is that resilience is a *trait* of a system and not a process.

The second part of our argument is to point out the need to distinguish between a *trait* of a system and *observations* of this trait over time. Observations together or over a period of time clearly constitute a process but the observations themselves represent a trait and this trait can be viewed statically, i.e., at a point in time---in which case there is clearly no process---or dynamically, i.e., over time---in which case we do have a process. To appreciate the salience of the distinction we are making, consider the following two examples. The first (second) example refers to individuals (regions).

Obesity is clearly a trait of an individual and we can observe how obese an individual is at a point in time and hence there is *no* process issue to worry about. However, we can also observe how obese an individual is *over time* and this exercise would generate a series of *observations* that do constitute a process. The point to note is that the observations refer to the obesity trait and therefore it makes no sense to say that obesity is a process. The same line of reasoning would apply for other human traits such as the height of an individual.[20] Next, let us focus on physical regions, i.e., on regions that are described by shared physical characteristics. Clearly, physical regions are units of physical space that are similar in their natural traits. For example, the Great Plains are a physical region in North America. Within the larger continent, this section of land is defined by a distinct type of land that is different from the mountains and forested hills around it. So, the fact that the Great Plains possesses this distinct type of land is a *property* of this physical region. That said, we can clearly record, for instance, the state of this distinct type of land as a result of human activities over time and this recording would generate a time series of observations. But, one again, these observations refer to the distinct type of land *trait* and it does not make sense to say that this distinct type of land is a process. We believe that this two-part argument demonstrates the validity of our claim that resilience is a property of a system and not a process. We shall now discuss the third of our three foundational issues concerning the use of resilience in the broad field of regional science. This issue involves asking whether resilience is always a *good thing* that decision-makers ought to promote.

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We have thus far said nothing about uncertainty and hence have implicitly assumed that it makes sense to view an ecological-economic or a socioeconomic system as a deterministic system. However, if it makes more sense to view such systems as *stochastic* systems then a trait such as resilience ought to be viewed as a *random variable*. In this case, at a point in time, we would observe a *realization* of this random variable. In contrast, over time, we would have a *collection* of such realizations and this collection would constitute a *stochastic process*. Note though that even in this stochastic setting, resilience would still be a *trait* but this trait would now be probabilistic in nature. See Batabyal (1998) for a discussion of related issues.

4. Is Resilience Always a Good Thing?

4.1. A salient related question

If resilience is a (preferably quantitative) characteristic of a dynamic system under stress, we may ask the question whether more resilience should be seen as a desirable feature of such a system. To answer this question, let us begin by returning to the wide-ranging paper by Martin and Sunley (2015). These researchers (2015, p. 1, emphasis added) point out that resilience "is now invoked in diverse contexts, both as a perceived (and *typically positive*) attribute of an object, entity or system and, more normatively, as a desired feature that should somehow be *promoted* or *fostered*."[21] Agreeing with this perspective, Stone-Jovicich *et al.* (2018, p. 1, emphasis added) point out that "[g]rowing attention is…being focused on social-ecological resilience. Indeed, it is increasingly being adopted as a *centerpiece* of policy making, planning processes, and management strategies…"

These and other researchers such as Brown *et al.* (2017) have all maintained that resilience, in general, is a *good* thing. In the context of this discussion, when we say *good* we mean something of which more is preferred to less. Therefore, as far as policy is concerned, the suggestion here is that decision-makers need to do what they can to enhance the resilience of an ecological-economic or a socioeconomic system. Such claims are often found in recent policy documents of the United Nations (UN), the Organization for Economic Cooperation and Development (OECD), and the European Union (EU) (see e.g. OECD 2014). This viewpoint notwithstanding, our position is that resilience is *not* always a good thing and that in order to ascertain whether resilience in a given setting is a good thing, one must first answer the question "*Resilience of What*?"

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Note that even though elsewhere in their paper, Martin and Sunley (2015) say that resilience is a process, this specific reference to resilience as an *attribute* of an object, entity, or system would appear to bolster our basic contention in section 3 that resilience is a trait and *not* a process.

4.2. The argument

To demonstrate the validity of our position, we begin with some comments on the probabilistic analysis of Batabyal *et al.* (2003) that focuses on lake ecological-economic systems. These researchers point out that many lake ecological-economic systems exist in one of three possible states---a stable eutrophic state that is *bad* from the standpoint of humans, a stable oligotrophic state that is *good* from the standpoint of humans, and a third unstable state that marks the boundary between the eutrophic and the oligotrophic states. The lake may move from the oligotrophic to the eutrophic state as a result of natural and/or human induced factors but this move is typically stochastic. In this setting, actions taken by a decision-maker can, in principle, move the lake from the eutrophic to the oligotrophic state, but the success of these actions is, once again, stochastic and not deterministic. The key point to grasp now is that the lake under study can be resilient in either the eutrophic or in the oligotrophic state. Since the eutrophic (oligotrophic) state is bad (good) from the standpoint of humans, the goal of policy clearly ought to be to lower (raise) the resilience of the eutrophic (oligotrophic) state. Put differently, when the answer to the "Resilience of What" question posed at the end of section 4.1 is "the eutrophic state," resilience in this state is *not* a good thing and hence policy should seek to reduce the resilience of the lake ecological-economic system in this *bad* state.

The same argument applies in the context of regional development. In regional science, there is now a substantial literature on what are commonly known as lagging and leading regions.[22] In this two-part classification, lagging regions are typically not dynamic,[23] they are frequently rural

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See Batabyal (2018), Batabyal *et al.* (2019), Batabyal and Nijkamp (2014a, 2014b, 2019), and the references cited in these papers for additional details about this literature.

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By "dynamic" we mean vibrant or full of life.

or peripheral or remote, they are technologically backward, and they exhibit sluggish economic growth rates. In contrast, leading regions are more often than not dynamic, they are frequently urban and centrally located, they are technologically advanced, and they display relatively rapid rates of economic growth. Lagging or remote regions are often resilient and, as the work of Wolman *et al.* (2017) and Anoni *et al.* (2019) shows, resistant to change, sometimes even when a significant amount of resources have been devoted to changing their lagging status. Looking at this issue through the lens of the question "*Resilience of What*" demonstrates convincingly that the resilience of lagging regions is clearly *not* a desirable state of affairs.

We conclude this section be highlighting two key points made in a thought-provoking study by a team of ecologists and economists. Levin *et al.* (1998, p. 226, emphasis added) first point out that *"[n]ot all resilient phenomena are desirable*. For example, discriminatory class systems have proved resilient. Similarly, racism has proved stubbornly resistant to policies aimed at wrecking its foundations." Therefore, we need to comprehend that "[r]esilience…makes no distinctions, preserving ecologically or socially *undesirable* situations as well as desirable ones" (Levin *et al.* 1998, p. 225, emphasis added). With this discussion of the three foundational issues out of the way, we now proceed to discuss the two policy related issues. These two issues concern multiple stable states (Section 5) and the connections between the twin notions of resilience and sustainability (Section 6).

5. Multiple Stable States

5.1. Predictability and policy fixity

The work of Holling *et al.* (1995), Holling (1996), and Schroder *et al.* (2005) informs us that ecological-economic systems can exist in *multiple* stable states. Similarly, the work of Arthur (1989, 1990) and Perrings and Brock (2009) points out that socioeconomic systems---the systems that regional scientists typically study---can also exist in *multiple* stable states. To the best of our knowledge, this fundamental point and its implications for the design and implementation of "resilience sensitive" policy are insufficiently recognized by regional scientists.

To substantiate this claim, we begin with the simpler case. If a given socioeconomic system can exist in only a single stable state and hence has a unique equilibrium, then we believe that it makes sense for a decision-maker to focus on the engineering resilience of this system. Why? This is because when shocked, such a system will tend to return to its unique equilibrium. Now, of the two definitions of resilience that we have been working with in this chapter, the one that emphasizes the speed of return to the stable state after a shock---or a near equilibrium response of the system---is engineering resilience (Holling 1996). Hence, the usefulness of engineering resilience or resilience of the first kind for such systems. A significant distinguishing feature of such "single stable state" socioeconomic systems is that their behavior over both time and space is *predictable*, at least relative to truly multiple stable state systems. Therefore, *fixed* policies that are both relatively straightforward to design and to implement make more sense for such systems.

5.2. Unpredictability and policy variability

Moving on to the more complex and also more realistic case, we contend that most and probably all socioeconomic systems that regional scientists analyze are multiple stable state systems. As such, their behavior over time and space is, most likely, rather unpredictable. As a result, in this case, the focus of a decision-maker has to be on the size of the stability domain associated with a particular stable state. In other words, this decision-maker needs to focus on the ecological resilience of the system being studied. From the standpoint of the design and implementation of policy, we need "a response system that is flexible and adaptive" (Levin *et al.* 1998, p. 224). In this regard, our reading of the literature supports the contention of Sellberg *et al.*

(2018, p. 906) who point out that "studies of resilience practice are still rare. Few studies have analyzed the applications of resilience thinking in real-world settings and assessed what it has actually managed to achieve."[24] Hence our claim in the first paragraph of section 5.1.

The validity of the above claim notwithstanding, we recognize that compared to fixed policies, flexible and adaptable policies are *more costly* to design and implement. Therefore, in any given instance, a decision-maker will need to engage in a benefit-cost exercise in which the "hard to quantify" benefit from the pursuit of such flexible policies is compared in a meaningful way with the "easy to quantify" cost of these same policies.

One final point deserves some mention. Today, war and civil unrest in a nation like Syria and President Trump's trade war with China represent a breakdown of the balance of peace and security and therefore are emblematic of "qualitative shifts in which initially small disturbances may become magnified through non-linear feedbacks" (Levin *et al.* 1998, p. 225). When confronted with such qualitative shifts, flexible and adaptive policies of the sort that we are advocating need to concentrate on more than just the present consequences of specific actions. In particular, decision-makers need to think about the possibility that the *impacts* of a series of small actions---each action harmless by itself---will accumulate so as to *destabilize* socioeconomic systems. In such settings, decision-makers confront yet another problem and that is the problem of interdependent chain reactions. Even for flexible and adaptive policies, we can generally predict the *immediate* effects of particular actions. However, it is much harder to predict the effects of a *sequence* of actions without comprehending the *dynamics* of the systems that are being impacted by the pertinent actions. That said, we now move on to discuss in section 6 below, the second of

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When we say we "support the contention" we mean that there are very few applications of resilience thinking that quantitatively account for the size of the stability domain associated with a specific stable state of a given socioeconomic system.

two policy issues and this concerns the relationship between the twin concepts of resilience and sustainability.

6. Resilience versus Sustainability

6.1. A key difference

The two notions of resilience and sustainability have increasingly become buzzwords and there is now some confusion in the literature about the relationship, if any, between these two concepts. As noted by Marchese *et al.* (2018), some commentators believe that these two notions are the same whereas others believe that they are different.[25] Regional scientists need to be clear on the point that these two notions are *not* the same. To see this, recall two points from our discussion in sections 2 and 3 of this chapter. First, the term resilience has two meanings and these two meanings are *not* the same. Second, resilience is a *trait*---and not a process---of an ecological-economic or a socioeconomic system and therefore it can, in principle, be studied either at a point in time (statically) or over time (dynamically).

The notion of sustainability now has many definitions but it is important to point out that the idea of sustainability was introduced into the social sciences literature most noticeably in the form of the closely related notion of *sustainable development*. In particular, the so called Brundtland Commission, supported by the United Nations, pointed out in its prominent report---see Brundtland (1987, chap. 2, para. 1)---that "sustainable development is development that satisfies the needs of the present without compromising the needs of the future." Now, although other meanings are possible, one of the commonest meanings of the word *sustain* is "to cause or

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Go to https://www.barillacfn.com/en/magazine/food-and-sustainability/sustainability-and-resilience-refer-to-two-different-concepts/ for additional details on this point. Accessed on 17 December 2020.

allow something to continue for a period of time."[26] So, sustainable development is inherently a *dynamic* phenomenon or a *process*. From this line of reasoning, we contend that the more general but still related notion of sustainability[27] also has a distinct intertemporal dimension to it.

6.2. Competing objectives?

As noted by Saunders and Becker (2015), the point that resilience and sustainability are dissimilar concepts is now understood by a fair number of researchers. Interestingly, this understanding appears to have led some writers such as Zolli and Healy (2012) to think of resilience and sustainability as competing objectives for decision-makers. For instance, Zolli (2012, p. 1, emphasis added) says that "because the world is so increasingly out of balance, the *sustainability* regime is being quietly *challenged*, not from without, but from within. Among a growing number of scientists…a new dialogue is emerging around a new idea, *resilience*…" He then contends (2012, p.1, emphasis added) that "[w]here sustainability aims to put the world back into balance, resilience looks for ways to manage in an imbalanced world."

Given this "competing objectives" perspective, it is worth pointing out that in the ecological economics literature, the relevance of resilience for sustainable economic development has been recognized at least since the research of Common and Perrings (1992). Consistent with our discussion above, this research informs us that whereas resilience is a system attribute, sustainable development is about designing and implementing policies that maintain the trajectories (time-paths) of key aspects of the system under consideration. As such, the main point to grasp is that if a policy attenuates the resilience of a socioeconomic system, then it does *not*

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[26] Go to https://dictionary.cambridge.org/us/dictionary/english/sustain for more details on this point. Accessed on 17 December 2020.

[27] We say "more general" because it is, in principle, possible to think of sustaining things that have nothing to do with economic development *per se*.

make sense to attempt to sustain the (undesirable) resulting time-path of key system attributes with diminished resilience. Therefore, Perrings (2006, p. 418, emphasis added) is certainly right when he points out that a "development strategy is *not sustainable* if it is *not resilient*: i.e. if it involves a significant risk that the economy can be flipped from a desirable state (path) into an undesirable state (path), and if that change is either irreversible or only slowly reversible."

We close this section by pointing the reader to three noteworthy findings that emanate collectively from the various papers published in a special issue of the journal *Environment and Development Economics* in 2006 and that regional scientists ought be cognizant of when analyzing socioeconomic systems and particularly when exploring the nexuses between resilience and sustainable development. First, for socioeconomic systems, markets may be *missing* for traits of the system that may influence its resilience and thus its sustainability. In such situations, prices can lead decision-makers to take actions that push the system closer to unseen *thresholds*. Second, sustainable management of a socioeconomic system depends on comprehending the dynamics of the system. In turn, this influences the choice a decision-maker makes between actions that involve *adapting* to future changes and actions that *mitigate* these same changes.[28] Finally, using the lens of modern finance, sustainable development requires that the value of the *asset base* available to a population not decline over time. In this regard, a resilience perspective implies that the *composition* of this asset base is very significant. This concludes our discussion of five outstanding issues concerning the use of resilience in regional science.

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Following Perrings (2006), adaptation involves actions by a decision-maker that modify either the benefits or the costs of change *without* modifying the likelihood of that change. In contrast, mitigation involves actions by a decision-maker that *influence* the known probabilities of future outcomes.

7. Conclusions

In this chapter, we provided a thorough discussion of three foundational and two policy related issues involving the use of the concept of resilience in regional science. The three foundational issues were about definitions, whether resilience was a process, and whether resilience was always a good thing. The two policy issues related to multiple stable states and to the relationship between the twin notions of resilience and sustainability. The study of resilience in the context of socioeconomic systems is an active area of research. Therefore, we hope that researchers in regional science pay heed to the issues we have raised here. This will, we believe, assist regional scientists in constructing and analyzing models that are marked by the trinity of conceptual clarity, analytical rigor, and policy relevance.

Finally, the five issues discussed in this chapter are by no means the only challenging research issues in current spatial resilience research. Several other questions will, most likely, have to be addressed as well in contemporaneous resilience research in regional science. In this regard, it is worth emphasizing that key gaps in the extant literature are:

- The translation of resilience---as a trait of socioeconomic systems---into a measurable indicator that is *representative of the evolutionary dynamics and adaptivity of a system* that is out of balance after a perturbation. The popularity of employment indicators---delineated in the work of Martin (2012)---is no guarantee that this indicator is always the best possible metric to characterize the nature of a recovery process.
- Spatial processes in a complex force field are usually *multidimensional* in nature and may incorporate different system variables. Hence, there is certainly much scope for multivariate analysis of different resilience indicators in a complex system.

- The identification of a proper resilience indicator calls also for a thorough examination of the very nature of the indicator used in terms of its *input* or *output* character. For example, depending on the nature of the underlying model architecture of a dynamic system, a resilience indicator like employment can be either an input or an output (or performance) indicator. This reveals an inherent weakness of much contemporary resilience research: without a well specified model of the system under study, it may be difficult to interpret the outcomes of a dynamic system in terms of its resilience. This holds particularly for spatial-economic systems, which often exhibit interdependent linkages among variables in adjacent regions. In such instances, spatial autocorrelation methods and spatial econometric tools may well be needed to conduct useful analysis. Finally, when data limitations preclude econometric analysis, simulation models such as computable general equilibrium models may be useful.

It goes without saying that spatial resilience research is fraught with many difficulties that are both conceptual-methodological (architectural composition) and operational statistical-econometric (specification) in nature. Therefore, the conduct of meaningful research in this area will be a major challenge for regional scientists in the years to come.

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