Vulnerability, resilience and 'systemic interest': a connectivity approach

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Abstract

This paper analyzes the socio-economic dimension of vulnerability and resilience from the viewpoint of connectivity. While no consensus has yet emerged on the definitions of vulnerability and resilience or on their relationship, it has been recognized that both have an important normative dimension, in that whether a system is considered vulnerable or resilient depends on the interests of the stakeholders involved. The paper proposes a dimension of resilience and vulnerability that is likely to be shared across a significant spectrum of stakeholders. To do so, the paper analyses connectivity within social-ecological systems from a "Structural Political Economy" viewpoint. A key concept in this regard is "systemic interest", which is defined as the interest of stakeholders to keep viable the system of connections within which they act. Systemic interest has desirable properties to conceptualize the normative dimension of vulnerability and resilience and leads to problematize their link with connectivity. In fact, it raises the question of what features of connectivity can be expected to lead to systemic interest, and how this impinges on vulnerability and resilience in different contexts. On the one hand, one might expect that a more interconnected system is more vulnerable to shocks, which propagate more easily throughout the system. On the other hand, such system might have a stronger systemic interest, so that a shock would trigger stakeholders' reaction to counteract its effects and avoid systemic consequences. The paper points to the institutional conditions that might make either outcome more likely in any given context.

Keywords: Vulnerability; Resilience; Connectivity; Structural economic analysis; Structural Political Economy

1 Introduction

The concepts of vulnerability and resilience are often used to understand properties of social-ecological systems, i.e. systems that "[reflect] the idea that human action and social structures are integral to nature and hence any distinction between social and natural systems is arbitrary" (Adger 2006, p. 269; see also Reggiani, De Graaff and Nijkamp 2002; Turner et al. 2003).[1, 2] More specifically, vulnerability describes "states of susceptibility to harm, powerlessness, and marginality of both physical and social systems" (Adger 2006, p. 269; see also O'Brien et al. 2007). Resilience refers to "the magnitude of disturbance that can be tolerated before a socioecological system (SES) moves to a different region of state space controlled by a different set of processes" (Carpenter et al. 2001, p. 765) as well as "the capacity to self-organise and the capacity for adaptation to emerging circumstances" (Adger 2006, pp. 268-9; see also Holling 1973; Folke 2006). And while vulnerability and resilience are widely seen as related concepts that "have common elements of interest—the shocks and stresses experienced by the social-ecological system, the response of the system, and the capacity for adaptive action" (Adger 2006, p. 270), the connections between them are yet to be fully fleshed out (Modica and Reggiani 2015; see also Janssen and Ostrom 2006; Reggiani 2013; Caschili et al. 2015).

For the purposes of the present article, vulnerability and resilience can be treated jointly because they both have an important socio-political element. In fact, vulnerability "does not exist in isolation from the wider political economy of resource use. Vulnerability is driven by inadvertent or deliberate human action that reinforces self-interest and the distribution of power in addition to interacting with physical and ecological systems" (Adger 2006, p. 270). Analogously, resilience "relates to the response of a system to disturbance or change, whether that disturbance is sudden and shocking or more gradual. When a system is subjected to disturbance, these are the only possible outcomes: it withstands the disturbance, maintaining the specified features of interest, or not; if not, it either recovers the features of interest in an

[1] Examples of the systems studies from this perspective are transportation networks (Cantillo et al. 2018; Tamvakis and Xenidis 2012), urban systems (Osth et al. 2018) and electrical power systems (Holmgren 2007) among others.

[2] This broad definition of social-ecological systems includes spatial economic systems, for the latter address the spatial dimension of production and consumption (Nijkamp and Ratajczak 2013), which weave together social and natural elements. Moreover, the paper will use the concepts of "social-ecological system" and "socio-economic systems" interchangeably. In fact, while the strands of literature referred to in this paper tend to use one or the other of those concepts more frequently, both concepts refer to the intertwining of social (including economic) and natural aspects, and hence do not need to be kept distinct for the purposes of this paper.

acceptable time frame or not; if it does not maintain the specified features of interest and does not recover them, but ends up in a different condition following disturbance, then *the question is whether or not the change in the system is considered desirable, or even an improvement*" (Adger 2006, p. 270, emphasis added). In fact, the "policy implications of vulnerability and resilience are profound and contested. Policies and strategies, which reduce vulnerability and promote resilience change the status quo for many agencies and institutions and are frequently resisted" (Adger 2006, p. 278).

The socio-economic dimension of resilience and vulnerability requires that we analyze the conflicting interests of stakeholders, and particularly the conditions under which it is possible to specify dimensions of vulnerability and resilience that are compatible with stakeholders' pursuit of their own interests. In particular, since any change in the system would favor some stakeholders over others, any policies that change the status quo would be contested by at least some stakeholders (Cardinale 2015).[3] In this sense, it is true that "what constitutes improvement or detriment is observer dependent" (Helfgott 2018, p. 853; see also Carpenter et al. 2001). However, this paper argues that the concept of "systemic interest" (Cardinale 2015, 2017, 2018b) can help identify a dimension of vulnerability and resilience that is likely to be shared across stakeholders. Systemic interest is the interest of stakeholders to preserve the viability of the socio-economic system within which they act. In fact, because of connectivity, changes that favor some stakeholders but might make the system unviable would end up jeopardizing the interests of those very stakeholders. Therefore, a view of vulnerability and resilience defined in terms of systemic interest is likely to be shared across stakeholders, because it is connected with the ability of the system to remain viable. It is important to note that this approach does not impose a unique direction of desirable change but a range within which change does not jeopardize viability. In other words, defining vulnerability and resilience on the basis of systemic interest provides not a univocally determined objective, but a constraint on the pursuit of particular interests on the part of stakeholders.

[3] The paper starts from analysing viability in the static sense that is associated with an economy whose technology is unchanged, and then goes on to discuss possible extensions to the viability of economies under conditions of structural change.

In the approach proposed in this paper, features of connectivity are fundamental for understanding what social-ecological systems are likely to afford a systemic interest.[4] In fact, connectivity determines whether a shock to a part of the system is more or less likely to affect systemic viability; it also has a crucial influence on whether a sufficiently wide spectrum of stakeholders have an interest in counteracting the effects of such a shock. In particular, the paper explores which features of connectivity are likely to generate an interest in maintaining the viability of the system by addressing shocks through policies (resilience) and in addressing exposure to shocks (vulnerability). It also discusses what institutional features are likely to favor or hinder such outcomes.

The paper is organized as follows. The next section introduces the "Structural Political Economy" approach to analyze how structural economic analysis can be revisited to define stakeholders through the analysis of connectivity in social-ecological systems. Section 3 suggests a route to identify conflicting interests and systemic interest. Section 4 presents the central contribution of the paper: exploring what features of connectivity are more likely to be associated with systemic interest, and how this impinges on resilience and vulnerability. A short section concludes.

2 Structural representations of socio-economic systems: from structural economic analysis to Structural Political Economy

In structural economic analysis, connectivity in the economy is typically understood from the viewpoint of division of labor. Whilst its roots can be traced back to Physiocracy and Classical Political Economy, modern structural analysis can be seen as starting from the work of Leontief (1941), von Neumann (1945), and Sraffa (1960). In particular, it explains key features of economic systems on the basis of interdependencies between parts of the system, and especially between industries (see Baranzini and Scazzieri 2012). The analysis of

[4] In political economy, the concept of system can be defined on the basis of different kinds of interconnectedness between parts of the system itself. In this paper, the definition of system based on productive interdependencies (introduced in Section 2) will be put in relation to the understanding of system based on networks. Following Calderelli and Vespignani (2007), we can adopt the general definitions of a network as "a graph whose nodes (vertices) identify the elements of the system. The set of connecting links (edges) represents the presence of a relation or interaction among these elements" (Calderelli and Vespignani 2007, p. 5) and connectivity as the property whereby "[when] a path exists between any couple of vertices […] in a graph, the graph is connected" (Calderelli and Vespignani 2007, p. 10). Among the manifold studies of networks and connectivity analysis, see for example the contributions in Friesz (2007).

connectivity in modern structural analysis has largely focused on the technical and material conditions under which production, income distribution and economic growth take place within economic systems. Structural economic analysis has very important connections with spatial economics, understood as the study of "the spatial pattern and interaction of systems of production, distribution or consumption (or more generally, human activities) in a spatial context" (Nijkamp and Ratajczak 2013, p. 9). A clear example of these connections is the use of concepts and techniques derived from structural economic analysis, such as input-output schemes, to address key issues in spatial economics, as pioneered by Isard's (1951) application of Leontief's approach to the spatial modelling of the economy.

In structural economic analysis, the socio-political stakeholders have typically been identified in terms of social groups defined on the basis of their type of income, e.g. as receiving wages or profit (see Baranzini and Mirante 2013 for a broader discussion of the definition of social groups that are compatible with different economic models). The "Structural Political Economy" (SPE) approach (Cardinale 2015, 2017, 2018b; Cardinale and Landesmann 2017; Cardinale and Scazzieri 2018) aims to provide a more general framework to analyze the socio-political dimension of economic systems, revealing manifold possibilities to identify relevant stakeholders. In fact, from an SPE perspective, models of division of labor can be seen as maps of constraints and opportunities for different stakeholders (Cardinale 2018b). For example, input-output representations of connectivity model the economy as a set of interdependent industries, whereby the output of each industry provides inputs to other industries. A key constraint, expressed by the Hawkins–Simon viability conditions (Hawkins and Simon 1949; see also Nikaido 2008), is that the economy must remain within proportions between industries that make it possible to reproduce the inputs used in production and generate a surplus. Opportunities can be seen as being associated with receiving a higher share of the system's surplus—but this depends on who the relevant stakeholders are. For example, for a social group defined on the basis of the type of income, this would amount to e.g. to a higher share of wages or profit. For an industry, the opportunity might be associated with a higher value added accruing to that industry, independently of how it is then distributed between categories of income (rent, profit, wage, etc.) across income earners within the industry (Cardinale 2018b).

We therefore need to delve deeper into the identification of relevant stakeholders within socio-economic systems. A useful starting point can be found in the idea that any socio-political aggregation that has an interest in common could, in principle, organize itself to promote policies that favor its interests. For this purpose, the concept of 'potential interest group' (Truman 1951) can be particularly useful. The idea is to identify what sociopolitical aggregations (based on division of labor) can be seen as potential stakeholders and what their interests may be, irrespective of whether they actually organize themselves to exert an influence on policy to pursue those interests. By providing a map of possible aggregations, connectivity in the economy opens up the possibility to identify different stakeholders, each of which corresponds to a socio-political aggregation that is relevant in the situation under study. In fact, each model can be seen as a different representation of division of labor, and each division of labor makes it possible to identify patterns of connectivity between different actors. Therefore, even a given division of labor does not determine group affiliations univocally. For example, it can be shown that a given system of productive interdependencies can be represented as a set of industries whose output is an input to other industries, or as a set of 'vertically integrated sectors' each of which produces a final commodity through an input of labour and primary commodities (Pasinetti 1973). From a socio-political viewpoint, this means that group affiliations (and therefore stakeholders) can be formed on the basis of industries, or social groups defined on the basis of the type of income, or vertically integrated sectors. Only in the analysis of specific contexts will it be possible to judge which criterion of socio-political aggregation, and hence which identification of relevant stakeholders, is more relevant. For example, analyses of economic development have often pointed to conflicts between industries (e.g. Furtado 1967; Hirschman 1968; Mamalakis 1969). Industries also seem to be crucial to understand party structure (Ferguson 1995; Ferguson et al. 2018) and transnational lobbying (Cohen 2007). In other contexts, however, vertically integrated sectors might be more relevant. For example, in the case of policies concerning the real exchange rate in the European Union, the relevant conflict might be between the vertically integrated sectors producing tradable or non-tradable goods (Cardinale and Landesmann 2017).

3 Vulnerability, Resilience and 'Systemic Interest': A Structural Political Economy Approach

Structural Political Economy provides the analytical tools to delve deeper into the normative dimension of vulnerability and resilience. Specifically, "[systems] can be considered resilient as long as the resulting change is judged to be at least as desirable as the original state or regime. The notion of desirability adds a clearly normative dimension to resilience" (Helfgott

2018, p. 853). In fact, resilience "is normative in that it relies on the definition of desirable versus undesirable system features. Judgement of what is desirable and what constitutes improvement or detriment is observer dependent. Changes that benefit one stakeholder may be detrimental to another. The questions of who gets to define what is desirable and how this will be negotiated raise interesting challenges to operationalizing resilience in practice, and directly point to practical and ethical considerations that the development sector has been wrestling with for decades", for example for what concerns "what constitutes development or improvement, for whom and by whom" (Helfgott 2018, p. 853; see also Carpenter et al. 2001). In a similar fashion, "where system boundaries are drawn, what is included in the analysis, which features of the system are allowed to change and which must be preserved, and what sorts of change constitute improvement, completely determines what is interpreted as resilience, adaptability, vulnerability or collapse, and so forth" (Helfgott 2018, p. 853-4). In short, "resilience is a property of a system that describes the nature of the response of the system to a particular disturbance, of a particular magnitude, from the perspective of a particular observer over a specified timescale" (Helfgott 2018, p. 854).

We therefore need to problematize what is desirable, and for whom. In fact, it is clear that different stakeholders are likely to differ in what they consider as an improvement. But does this mean that there can be no ground to identify dimensions of resilience and vulnerability that could be shared across stakeholders? SPE can provide a key concept to address the normative dimension of vulnerability and resilience: systemic interest. More broadly, it provides a framework to study the interplay of stakeholders' particular interests and systemic interest. For example, in the input-output representations of connectivity (specifically, those based on the Leontief open system), we can see relevant stakeholders as industries and identify their interest: receiving a higher share of value added (Cardinale 2018b). Conflict could therefore arise over quantities, that is, over the proportions between outputs of different industries across the economy. However, the Hawkins-Simon viability conditions impose that proportions between industries must remain within a certain range (Hawkins and Simon 1949). Alternatively, conflict might take place over prices. However, Steenge and van den Berg (2001) show that only a given range of prices is compatible with viability of the system. Therefore, in either case, the system of interdependencies leaves room for conflicts: if only one configuration of prices or quantities were admissible, conflict could not take place without making the system unviable. And yet, conflict must remain within limits that keep the system viable. Systemic interest can then be defined as the interest to keep the system viable, for otherwise the pursuit of policies that change proportions or prices in favor of some stakeholders might make the system unviable, thus jeopardizing those very stakeholders.

The implication for resilience is that shocks or policies that change quantities or prices must remain within a range that is compatible with the viability of the system. Such dimension of resilience is compatible with a variety of interests of stakeholders. More specifically, it is a constraint on the pursuit of such interests. In fact, systemic interest does not impose a specific policy, but identifies a range of viable proportions. As such, it is a constraint on possible outcomes, and is therefore compatible with a variety of policies (and outcomes). Furthermore, the dimension of resilience based on viability does not require a "normative" commitment to a view of collective interest that transcends particular interests; rather, this approach grounds stakeholders' interest in viability in the fact that the latter is *a necessary condition for the pursuit of particular interests*. Something analogous holds for vulnerability, i.e. the system's susceptibility to negative shocks: if vulnerability is likely to affect viability, stakeholders should in principle share a systemic interest in addressing it.

This approach to resilience and vulnerability, based on the interplay between particular and systemic interests, derives from the need for each stakeholder to consider the viability of the system as a whole. Hence, it depends on connectivity: without connectivity, there would be no reason for stakeholders to consider systemic viability. And while the foregoing argument has been developed with respect to input-output relationships between industries, which have traditionally been understood at the national level, its fundamental reasoning can be extended to different analytical problems. First, the approach can be used with reference to different spatial entities, to investigate the viability of any system of interdependencies, including regions, multi-region systems, national economies and supranational areas. Second, the approach can be generalized to other models of the production system. For example, this dimension of vulnerability and resilience can also be explored through models and databases that have been developed to generalize the basic Leontief approach. Such approaches have been extended to account for scarce resources (e.g. Quadrio Curzio 2009; Steenge 2015; see also Duchin 2015) and new databases such as the World Input-Output Database (WIOD) (Timmer et al. 2015) and Exiobase (Tukker et al. 2013; Wood et al. 2015) have been developed to address new features of production systems. Moreover, while the models considered above address flows of commodities across industries, another important component of systemic interest can be the formation of stocks (Quadrio Curzio 1967, 1975;

Cardinale 2015). Furthermore, viability can be understood not only in the static sense, as was done above, but also with respect to policies leading to structural change, such as the economic and political conditions that make stakeholders willing to support transitions whose outcome is uncertain (Cardinale 2015). Third, and more generally, the SPE approach can be extended to representations of connectivity that differ from the typical models of structural economic analysis. In fact, whilst the analysis above refers to input-output representations where the fundamental units are industries linked to one another through flows of goods and money, one could use any relational space, such as those expressed through a network. The idea would be to take the various possible aggregations suggested by the model being used (it could be input-output relations among industries, trade flows among countries, transport flows among cities, etc.) and evaluate whether it is plausible to consider such aggregations as potential stakeholders. In other words, through an SPE lens one would try to identify potential stakeholders and their interests, as well as conditions for viability of the system; one would then try to infer whether the relevant stakeholders could have an interest in keeping the system viable, and whether that interest could constitute a shared dimension of vulnerability and resilience. The possible extensions just discussed suggest that, while in the remainder of the paper the concepts of "economy" and "system" refer to a system of input-output interdependencies between industries within a country, the gist of the argument can be readily applied to any system of interdependencies under analysis. In particular, following Simon (1962), it will be suggested in the next section that the relevant systems and subsystems can be identified on the basis of the relative strength of interdependencies within and outside the system and subsystems under consideration.

To summarize, the foregoing analysis suggests two fundamental points about resilience and vulnerability. First, even if their definition may vary across stakeholders—in that they concern the vulnerability, maintenance or improvement of different aspects depending on the stakeholder under consideration—systemic interest might provide a minimum ground to be accepted by significant coalitions of stakeholders, because it concerns the viability of the system as a whole. Second, this definition of vulnerability and resilience does not dictate a specific interest (or policy), but is a constraint on the pursuit of stakeholders' particular interests, which is compatible with a variety of proportions and hence with a variety of interests (and policies).

4 Connectivity, resilience, and systemic interest: a socio-political analysis

Systemic interest has emerged from the foregoing analysis as a property deriving from connectivity. What systems are likely to display systemic interest, depending on their features of connectivity? And what are the implications for resilience and vulnerability?

Before proceeding, it is useful to note that, as was discussed in a previous section, resilience and vulnerability are different concepts. Whilst interpretations differ and there is yet no agreement in the literature on the relationship between the two concepts (see Modica and Reggiani 2015 for a discussion), following Briguglio et al. (2009) we can take vulnerability to be a condition of exposure to exogenous shocks, whereas resilience concerns the ability to recover or improve desirable aspects, which in turn often requires actions of private actors or policy-makers. However, systemic interest relates to both concepts, as it can be seen as the interest in keeping the system viable by addressing shocks through policies (resilience) and/or in addressing the condition of exposure to shocks (vulnerability). Therefore, for the sake of conciseness, this section concentrates on resilience, but the reasoning can be readily extended to the identification of systemic interest and policy decisions that concern vulnerability.

The seminal work of Herbert Simon on connectivity within hierarchical systems is a very useful starting point. Simon defines hierarchies as "systems composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem" (Simon 1962, p. 468). In Simon's analysis, this definition refers to "all complex systems analyzable into successive sets of subsystems" (Simon 1962, p. 468), including "systems in which there is no relation of subordination among subsystems" (Simon 1962, p. 468).

Simon goes on to distinguish between "the interactions *among* subsystems, on the one hand, and the interactions *within* subsystems— i.e., among the parts of those subsystems—on the other. The interactions at the different levels may be, and often will be, of different orders of magnitude" (Simon 1962, p. 473-4). On this basis, Simon distinguishes between decomposable systems, in which links between subsystems are negligible, and nearly decomposable systems, in which links *within* subsystems are strong, whereas links *between* subsystems are weak but not negligible, so that they can be ignored in the short run but not in the long run (see also Simon and Ando 1961; Fisher and Ando 1962; Ando and Fisher 1963;

Landesmann and Scazzieri 2009). By extension, we can also consider non-decomposable systems, where links between subsystems are strong and cannot be ignored even in the short run.

Simon finds that "near decomposability is generally very prominent" (Simon 1962, p. 475) in social systems, including economic systems. In fact, "[in] economic dynamics, the main variables are the prices and quantities of commodities. It is empirically true that the price of any given commodity and the rate at which it is exchanged depend to a significant extent only on the prices and quantities of a few other commodities, together with a few other aggregate magnitudes, like the average price level or some over-all measure of economic activity. The large linkage coefficients are associated, in general, with the main flows of raw materials and semifinished products within and between industries. An input-output matrix of the economy, giving the magnitudes of these flows, reveals the nearly decomposable structure of the system—with one qualification. There is a consumption subsystem of the economy that is linked strongly to variables in most of the other subsystems. Hence, we have to modify our notions of decomposability slightly to accommodate the special role of the consumption subsystem in our analysis of the dynamic behavior of the economy" (Simon 1962, p. 475).

It is interesting to complement Simon's distinction with considerations about network topology. For example, one could take two types of connectivity analyzed by Barabási and Oltvai (2004): random networks, in which "most nodes have approximately the same number of links [and] nodes that significantly deviate from the average are extremely rare" (Barabási and Oltvai 2004, p. 105), and scale-free networks, in which "[the] probability that a node is highly connected is statistically more significant than in a random graph, the network's properties often being determined by a relatively small number of highly connected nodes that are known as hubs" (Barabási and Oltvai 2004, p. 105). This is important for the analysis of resilience and vulnerability, because while scale-free networks are much more resistant than random networks to failure of randomly chosen nodes, they are more vulnerable if failure concerns hubs (Barabási and Oltvai 2004, p. 110; see also Reggiani 2013 for an application to transport networks).[5]

[5] For a general discussion of spatial networks see also Tsiotas and Polyzos (2018). For further applications of network approaches to other spatial problems, see for example Marshall et al. (2018) and Neal (2018).

Considering that Simon's classification highlights the strength (weight) of links, whereas the Barabási and Oltvai approach focuses on the number of links, and hence on the distinction between nodes that are hubs and nodes that are not, we can combine the two classifications, obtaining the four types in Table 1.[6]

Table 1: Decomposability and network topology

	Scale-free network (Barabási and Oltvai 2004)	Random network (Barabási and Oltvai 2004)
Near-decomposable system (Simon 1962)	Weak links between hubs, strong links between each hub and the nodes to which it is connected.	Strong links between nodes within a subsystem, weak links between nodes belonging to different subsystems; no hubs.
Non-decomposable system (Simon 1962)	Strong links between hubs, as well as between each hub and the nodes to which it is connected.	Strong links between nodes within and between subsystems; no hubs.

What does the typology above suggest for what concerns the first question posed at the beginning of the section, i.e. the link between connectivity and systemic interest? We can conjecture that non-decomposable systems, such as the subsystems characterized by Simon as having strong internal connectivity, will be likely to display systemic interest because a shock or policy that makes an industry unviable can directly affect other industries through interdependencies. However, this result also depends on network topology. In fact, if the non-decomposable system under consideration is a scale-free network, so that it has strong links between hubs, systemic interest will concern keeping the hubs functional, even if a considerable part of other nodes (which are not hubs) is affected. If it is a random network, so that weights are strong both within and between subsystems, systemic interest has to do with making sure that a sufficient proportion of nodes are kept active, without a clear priority for certain links over others.

[6] The typology developed in what follows does not consider decomposable systems, which are unlikely to characterize socio-ecological systems.

In near-decomposable systems, instead, the crisis of a given subsystem will be unlikely to lead to effects across the overall system. However, this statement needs to be qualified in the light of network topology. If the near-decomposable system under consideration is a random network, we can conjecture that the crisis of a small number of nodes that are weakly connected to other nodes (because the system is near-decomposable) is unlikely to compromise systemic viability. However, if the network is scale-free, i.e. there are weak links between hubs but strong links between each hub and the other nodes connected to it, it is possible that the crisis of some hubs, though weakly connected to other hubs, could make the whole network unviable. However, this cannot be determined ex ante, given that, as Barabási and Oltvai (2004) show, the network's robustness depends on both the number and strength of links.

For example, in order to analyze systemic interest in the Eurozone through Simon's criterion, I suggested that we can assess whether an economy (be it regional, national, etc.) is near-decomposable or non-decomposable by comparing the relative strength of productive interdependencies within and outside that economy (Cardinale 2017). If interdependencies within the economy under investigations are relatively stronger, we can take the system to be non-decomposable, which in turn suggests that features of connectivity require that conflicts between stakeholders are constrained by consideration of systemic viability. If interdependencies outside the economy are stronger, we can expect that important stakeholders will be relatively less concerned with viability of the economy, because the pursuit of their particular interests is not directly affected by viability. Hence, whilst perhaps geographically situated within the economy under investigation, their interdependencies lie elsewhere, so that their interest in systemic viability might concern a different system. (Of course, geographical proximity might entail further dimensions of connectivity that the analysis of input-output interdependencies might not fully capture; and this is a reason why stakeholders' representation of the interdependencies to which they are subjected is crucial for determining systemic interest and understanding resilience, as I argue below). This analysis of viability in the Eurozone could be extended, following the typology synthesized in Table 1, by considering whether the system under consideration has the features of a random or scale-free network. This could have important consequences in terms of understanding whether systemic interest requires the preservation of viability of all national economies in the Eurozone or only of some economies, which may appear to be more important than others in terms of number and/or weight of their links. The consequences of this difference would obviously be momentous from a political and institutional viewpoint.

The analysis of socio-economic systems outlined above can arguably provide a way to address a perceived risk of holistic approaches, i.e. that the “fundamental interdependence and interrelatedness of all things” (Helfgott 2018, p. 855) can make it difficult to draw boundaries and identify subsystems that are analytically manageable. In fact, this paper suggests a heuristic to draw boundaries between different subsystems of socio-economic systems, based on analysis of what interdependencies are likely to be stronger in some parts of the system than in others and how different network structures can lead to prioritize certain nodes over others, at least within time horizons compatible with the analysis at hand.

We can now address the second question: what are the implications for resilience? This has become a highly topical issue in the light of the ever-increasing interconnectedness of socio-ecological systems across the world (see, for example, Young et al. 2006). If we do not account for changes in policy stances induced by system interest, we would consider a near-decomposable system more resilient than a non-decomposable one: the rationale is that shocks to some parts of the system would not necessarily affect the others in the short run, because of weak links between subsystems. However, as discussed above, this result also depends on network topology: if the near-decomposable system is scale-free, a shock affecting a hub which is weakly connected to other hubs could have systemic effects—but this depends on the strength of connections. With systemic interest, the opposite is likely to be the case: systemic interest (and changes in policy stances that would preserve it) would be more likely in a non-decomposable system because a shock would *trigger a political reaction*. If we consider network topology, we can further refine this result: in a scale-free network, systemic interest is more likely to concern preservation the hubs, whereas in a random network it is likely to be more concerned with the various nodes without a clear criterion of priority of some over others. In turn, this poses the problem of understanding whether stakeholders are aware of which nodes can be considered as hubs, and therefore whether there is a systemic interest in preserving them.

For example, it can be conjectured that, in a monetary union, sectors producing tradable goods in ‘advanced’ economies and sectors producing non-tradable goods in a ‘catching up’ economies will in principle oppose policies that pursue real exchange rate appreciation in the ‘advanced’ economies, respectively because of considerations of competitiveness and because of concerns for domestic demand and cost of inputs (Cardinale and Landesmann 2017). However, once external imbalances threaten the viability of the monetary union, it is possible that the aforementioned sectors change their stance, for example because real appreciation in ‘advanced’ economies might favor an expansion in ‘catching up’ economies whose effect on imports from ‘advanced’ economies is stronger than the price effect, or because it could allow the tradable sector of ‘catching up’ economies to recover. In this connection, it might be interesting to analyse the network structure of tradable and non-tradable sectors across the Eurozone, with particular attention to the presence of hubs and the strength of connections between sectors within and across ‘advanced’ and ‘catching up’ countries.

The foregoing analysis of systemic interest is in line with Young et al.’s (2006, p. 312) idea that, unlike biophysical systems, the resilience of socio-ecological systems also depends on the fact that they are characterized by “foresight and reflexivity” of the actors that operate within them, and that this “can lead either to initiatives aimed at avoiding or mitigating the dangers of globalization or to positive feedback processes that intensify the impacts of globalization”. However, this paper’s approach suggests that, in order to assess whether reflexivity will express itself in the awareness of systemic interest, we need to problematize whether the system under investigation has institutional arrangements that make it possible for changes in policy stances to manifest themselves. Therefore, from the viewpoint of this paper, the existence of such arrangements is a key factor in determining whether resilience is more likely to characterize non-decomposable or near-decomposable systems. If such institutional arrangements are not sufficiently effective, we can expect non-decomposable systems to be less resilient. In cases in which such institutional arrangements are sufficiently effective, we can expect that a non-decomposable system will be more resilient because of systemic interest. Table 2 summarises the relationship between connectivity, systemic interest and resilience put forward in this paper.

Table 2 Connectivity, systemic interest and resilience

	Scale-free network (Barabási and Oltvai 2004)		Random network (Barabási and Oltvai 2004)	
	Systemic interest	Resilience	Systemic interest	Resilience

Near-decomposable system (Simon 1962)	Shocks affecting some hubs, even if these are weakly connected to other hubs, could make the whole network unviable. Therefore, systemic interest is likely to concern preservation the hubs.	Whether resilience requires systemic interest depends on which nodes are affected by shocks: if hubs are not affected, systemic effects are unlikely. If hubs are affected, even if these are weakly connected to other hubs, shocks could have systemic effects.	Shocks to a small proportion of nodes that are weakly connected to other nodes are unlikely to compromise systemic viability. Therefore, systemic interest has to do with preserving a sufficient proportion of nodes, without a clear criterion of priority of some over others.	Resilience does not necessarily require systemic interest: shocks to some parts of the system would not necessarily affect the others, at least in the short run.
Non-decomposable system (Simon 1962)	Systemic interest concerns keeping the hubs functional.	The system can be resilient if its institutional features make it possible for stakeholders to act upon the systemic interest in preserving the hubs.	Systemic interest has to do with ensuring that a sufficient proportion of nodes are kept active, without a clear priority for certain links over others.	The system can be resilient if its institutional features make it possible for stakeholders to act upon the systemic interest in preserving a sufficient proportion of nodes.

The foregoing analysis suggests that the resilience of a given socio-ecological system depends on its features of connectivity as well as institutional arrangements that make it possible to act upon systemic interest and preserve resilience in highly interconnected systems. Another crucial element is stakeholders' definition of particular and systemic interests, which in turn depends on their representation of the system (i.e., their awareness of connectivity). In fact, stakeholders' representations of connectivity are crucial for determining which aggregations, out of those that are possible within a given space of connectivity, actually 'become stakeholders', and what particular and systemic interests are seen as such among those that a given system affords (Cardinale 2018a, b, c).

To conclude, the SPE approach makes it possible to identify a systemic interest of stakeholders in a shared dimension of resilience: preserving the viability of the system in which they operate. The first step is to analyze whether a given system's pattern of connectivity makes systemic interest possible. The further step is to determine what particular and systemic interests are likely to prevail in a specific case. To do so, we need to look at how stakeholders represent the system—given that each pattern of connectivity affords a variety of representations and hence a variety of understandings of particular and systemic interests. In this light, studies of resilience and connectivity can be crucial for fostering stakeholders' awareness of possibilities for systemic interest, and hence of shared dimensions of resilience.

5 Conclusion

This paper has addressed the socio-political dimension of vulnerability and resilience from the viewpoint of connectivity. In particular, it has addressed the normative character of the two concepts, i.e. their dependence upon the interests of different stakeholders. The key contribution of the paper lies in the use of the concept of systemic interest (Cardinale 2015; 2017; 2018b) to characterize a dimension of vulnerability and resilience that is (or should be) shared across stakeholders, exploring how this depends on features of network connectivity. Systemic interest was described as the interest of stakeholders to keep the system viable. In fact, because of connectivity through material flows, a shock or policy that pushes proportions between industries or prices outside a certain range would make the system unviable, jeopardizing the interests of all stakeholders. On the view proposed in this paper, therefore, resilience (and reduction of vulnerability) should be conceptualized not as an objective in itself, but rather as a constraint on the pursuit of particular interests.

The approach developed in this paper can be extended in several directions. One is to consider how connectivity structures change over time, both endogenously as a result of technological change, and exogenously as a result of shocks and/or policies. An important issue in this case has to do with how to define viability in a dynamic context. For example, a change in technology will result in the creation of new nodes (e.g., new industries) as well as changes in the intensity of use of different inputs by different industries, which weaken some existing links while strengthening others. Crucially, changes in technology also influence which resources are relatively scarce, and hence the rents associated with them (Quadrio Curzio 1967; Quadrio Curzio and Pellizzari 2018). Because the direction of technological change is uncertain, so is the dynamic of rents for different stakeholders. Therefore, stakeholders forming their stances on policies to address vulnerability or to improve resilience will face fundamental uncertainty as to how such policies will affect them dynamically (Cardinale 2015). In this analytical context, the relevant conflict might be, for example, between owners of different scarce resources (Quadrio Curzio and Pellizzari 2018), or between 'owners of life-cycle capital' and 'owners of inter-generational capital' (Baranzini 1991). Therefore, while the gist of the analysis of the paper, which was developed for the 'static' case of given technology, holds for dynamic analysis as well, future research will need to devise definitions of systemic interest that are suitable for tackling dynamic problems.

A further interesting direction might be to apply the key insights of this paper to analyses of connectivity in other fields. In fact, while possible extensions within economic analysis have been discussed in Section 3, one might also consider exploring the fundamental idea of the paper—that systemic interest provides a dimension of resilience and vulnerability that has the potential to be widely shared across stakeholders—in the context of work that relies on network analysis in other disciplines. For example, Barabási's research on connectivity in network analysis has been used across many disciplines (see Barabási 2007 for a brief review). Accordingly, the SPE approach developed in this paper can be used to investigate the socio-political dimension of different types of connectivity in a variety of applications that concern socio-economic systems, in which actors' awareness of their interconnectedness is likely to be an important factor in the formation of their stance towards policies addressing resilience and vulnerability. Analogously, the connection between analysis of weak and strong links on the one hand, and of vulnerability, resilience and systemic interest on the other hand, can generate new insights for studies inspired, for example, by Granovetter's

(1983) distinction between strong and weak ties, or by Burt's (1992) analysis of 'structural holes' whereby nodes occupying specific network positions (especially that of ‘broker’) are associated with more opportunities than other nodes, even if they have the same number of links.

This paper’s approach to vulnerability and resilience raises the question of what features of network connectivity are likely to be associated with systemic interest. It has been shown that this depends not only on connectivity in itself but also on awareness of connectivity on the part of key stakeholders. Enhancing and shaping such awareness can therefore constitute a key contribution of research into the socio-political dimensions of connectivity.

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