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Insights into systemic resilience from innovation research

perspectives

policy brief

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Insights into systemic resilience from innovation research

Authors

Florian Roth, Philine Warnke, Pia Niessen and Jakob Edler

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Background

In the wake of the COVID-19 pandemic, the concept of resilience has become an increasingly important guiding principle. Voices from politics, business and society are calling for strategies which help to better weather crises or ideally prevent them from occurring in the first place.

In order to increase the resilience of infrastructures (for example in healthcare), supply chains, organizations or entire societies, the corresponding systems need to become more robust, redundancies created and emergency plans prepared for the widest possible range of disruptive scenarios. The overriding goal of these measures is usually to enable the management of crises and disruptions and to ensure rapid restoration of a functioning system after major shocks.

This policy brief assumes that such measures are only the first steps toward a comprehensive resilience strategy. More is required for successful crisis management and above all long-term crisis prevention in a highly complex and uncertain world. More importantly, we must not see resilience merely as a kind of systemic bounce back under stress, as is understood for example in the engineering sciences, in order to restore the functionality of the relevant technical systems. This is because individual companies as well as entire industries or societies are all complex adaptive socio-technical systems. In other words, they have the capacity to learn from experience and to change system properties in response to disturbances and crises, even fundamentally if necessary (bounce forward, Hynes et al. 2020).

Accordingly, it is imperative that resilience strategies foster the capacity to adapt and transform systems (Roth et al. 2021). However, there have been few practical recommendations of how to strengthen adaptive and transformative resilience to date.

Innovation research provides valuable tools to fill this gap. For some time now, innovation research has been addressing the questions of how complex socio-technical systems evolve under changing environmental conditions and which instruments and steering mechanisms are suitable to strengthen innovation and transformation capacities and actively control transformation processes. However, so far, the findings from innovation research, especially with regard to modern innovation policy, have hardly been used to develop resilience strategies. In this policy brief, we use several case studies to illustrate how approaches from innovation research and policy can be harnessed to strengthen key dimensions of systemic resilience.

» To date there have been few practical recommendations for strengthening adaptive and transformative resilience

Foresight

Transformative tools

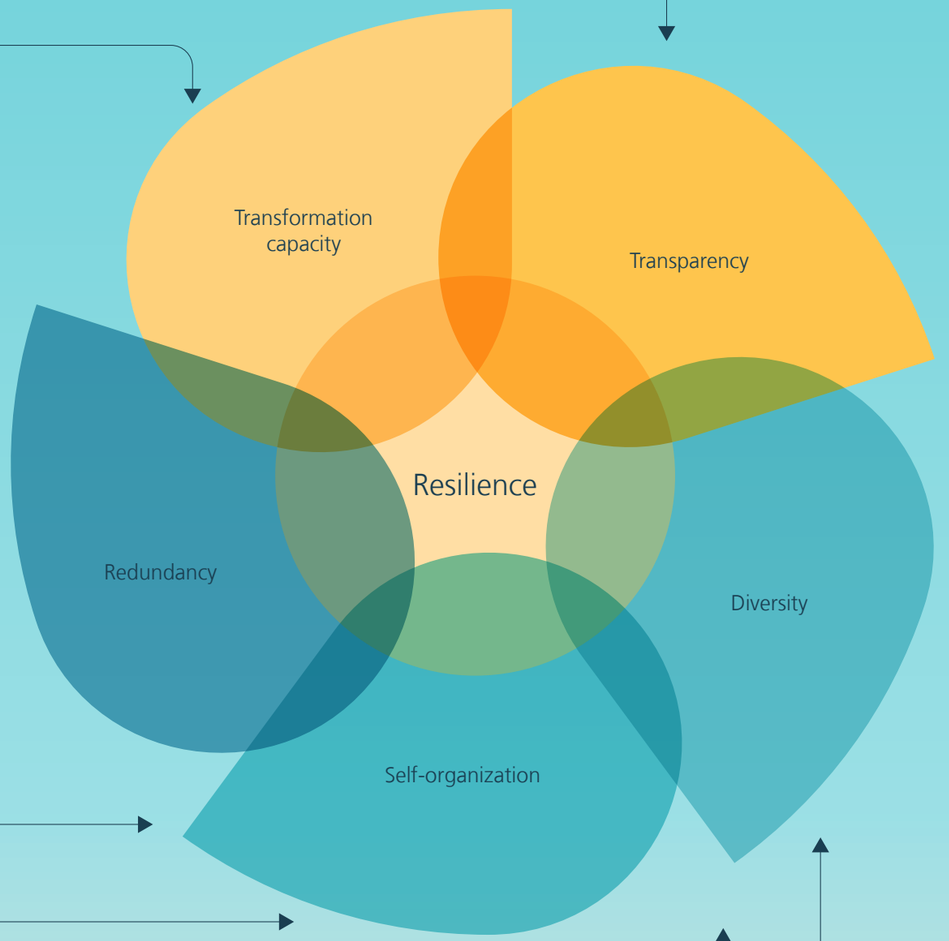
Initial research

Stakeholder integration

Systemic tools

Diversity-enhancing tools

Local innovation systems



The basic principles of resilience

The definition of resilience has evolved across disciplines as well as over time. In general terms, resilience is understood as the ability to withstand shocks and disruptions, dependent on the type of system being considered.

The psychological resilience of an individual is based on different criteria than those of a technical system or a national economy. In each case, however, resilience means the ability to withstand even severe shocks and not to break as a result of them.

In addition to coping with shocks and disruptions in the short term, resilience is also measured in terms of what happens after a crisis. For example, the education system in Germany was hit by the COVID-19 pandemic while it was tackling the challenges posed by the ongoing digitization process. It is foreseeable that the "recovery" following the Corona shock will involve schools and colleges institutionalizing new, digital formats of instruction. The same applies to the digitization of healthcare, including the telemedical diagnosis and consultation concepts that are now becoming widespread. These examples show how responding to crises also means realigning systems in the long term, and developing them without shying away from far-reaching structural changes where necessary.

Resilience therefore encompasses the interaction of the various components with the aim of strengthening the adaptive capacity of the system. Ongoing adaptation, however, is sometimes not enough to ensure the continued existence of a system. In such cases, resilience also includes the ability to transform the entire system. One example of this is dealing with the challenges of the climate crisis: being resilient in this context means adapting to changing climate conditions, but at the same time also initiating the transformation of important socio-technical systems (including energy supply, mobility systems, and food production) in order to limit global warming. How can resilience be applied to achieve the goals of adaptation and transformation? What tools are available?

Research into resilience has already identified some characteristics of resilient systems. However, these characteristics differ depending on the type of system: the more complex the system, the less specific the characteristics. This is shown by comparing the metrics of technical resilience (Altherr et al. 2018) and of social systems (Stone-Jovicich 2015). Resilient technical systems generally possess the so-called "four R's": they have a high degree of *robustness*, sufficient *redundancies*, and distributed and networked *resources* in the system to respond to shocks and *rapidly* restore their functionality (Bruneau et al. 2003). In comparison, resilience at the societal level is to be understood as an even more complex, multidimensional concept. Research on socio-technical and socio-ecological systems has already been able to identify resilience indicators that also take into account the system's long-term ability to evolve and prosper. Accordingly, the degree of resilience is influenced, among other things, by whether a system has sufficiently diverse capacities to be able to respond to different challenges with different solution strategies. An excessive fixation on maximizing efficiency, on the other hand, is associated with lower resilience (Carpenter et al. 2001, Lorenz 2013, Walker 2020). Studies on the resilience of economic regions have shown that economic systems can cope particularly well with shocks if they are closely interconnected, have a high degree of diversity, and efficient political institutions (Boschma 2015). Other research has examined the impact of different disasters on local social structures: For example, studies identified different characteristics of communities that are able to absorb such shock events, learn from experience, and prosper in the long term. The focus here is on different resources and capabilities to enable quick and flexible responses to unexpected developments (see box "The dimensions of community resilience"). Each crisis is unique and requires new solutions, often involving a high degree of improvisation and creativity.

The dimensions of community resilience

Local knowledge: The ability of society or the population to acquire relevant knowledge, but also to strengthen education and training, and to build a collective sense of self-efficacy and empowerment.

Community networks: Play a significant role in the emergence of resilience, where it is particularly important that the links and relationships within the networks are cohesive and connective.

Efficient communication: Should include specific risk and crisis communication in order to promote resilience.

Infrastructure: Investments in infrastructure (for example expansion of the healthcare system) have an impact on resilience, whereby the support of governance and leadership through infrastructural resources in particular represents a dimension of resilience.

Resources: The availability of different resources (physical, human, financial, social), their fair allocation and the ability to use existing resources effectively are important prerequisites for resilience.

Reconstruction: After a shock or a crisis, one of the biggest challenges is often to revive the local economy. Smart, forward-looking investments not only enable a rapid recovery of the local economic base, but can also help to mitigate future risks.

Preparation: Risk-oriented, proactive and participative precautionary measures enable sustainable crisis response and recovery and reduce the likelihood of severe impacts from shocks and disruptions.

Dealing with uncertainty: The human ability to process past crises productively and learn from them on the one hand, and not to ignore the possibility of future crises and to derive strategies for action on the other hand, strengthens societal resilience.

Source: Patel et al. (2017)

Simultaneously, the question arises as to how to foster the ability to blaze new trails in times of crisis and uncertainty. Can the resilience of complex socio-technical systems be planned at all, or should they be left to develop organically? In what follows, we argue that, while the resilience of such systems cannot be comprehensively managed, there are numerous approaches and measures to specifically promote both adaptive and transformative forms of resilience.

Based on innovation research approaches, we show how the systemic capacity to adapt and transform can be strengthened. In particular, these approaches include fostering networks and participation processes to develop innovative solutions; methods to develop a comprehensive system of understanding for strategic governance; ways to increase the ability to anticipate and to deal with uncertainty; and the ability to prepare while preserving basic competencies.

What role can innovation research play?

Innovation research has often shown what distinguishes innovation systems that continue to develop successfully for a long time despite changing framework conditions.

Since the 1970s, innovation research has been concerned with the question of what prerequisites are necessary for organizations (research institutions and companies in particular), regions, sectors or entire economies in order to successfully develop and apply solutions to specific challenges.

In innovation research, innovation capacity is understood as a system characteristic. This means that not only the individual system elements determine successful innovation, but also how they interact and the quality of their interconnections given the increasing complexity of innovation processes. For example, knowledge of the necessary complementary competencies and flexible access to them is crucial for the development of efficient, effective and responsive innovations. In this context, transparency and a high level of trust between actors are characteristic for strong innovation systems. "Systemic instruments" have become established in innovation policy, which link actors flexibly in ever-changing constellations, but still pay particular attention to the quality of the interconnections (Daimer et al. 2012, Smits and Kuhlmann 2004). Examples include network formation, fostering knowledge flows through platforms or forums, and funding innovative clusters. The established, broad understanding of innovation suggests that systemic instruments must appeal to societal actors far beyond the classic "triple helix" of academia, industry, and government, as they make significant contributions to the innovation process (Warnke et al. 2016).

Through an understanding of why innovation systems permanently evolve and function for many years, we can learn important lessons for how to promote resilience in social systems. Insights into the factors that determine the success of innovation policy instruments are useful when aiming to build up resilient system structures. Two basic forms of innovation policy can be distinguished: First, in the last four to five decades, the focus has been on supporting actors in innovation systems in developing innovations and bringing them quickly into widespread use. The basic assumption here is that innovations generally benefit the economy and society. A variety of interventions serve to make individual actors and their interactions more effective and responsive, thus strengthening the system as a whole. Second, more recently, innovation policy has increasingly been used to achieve specific, politically defined societal goals, often defined as "missions" (Lindner et al. 2021, Mazzucato 2018 and 2021). The background to this mission-oriented innovation policy is usually a set of global challenges such as climate change, digitalization or demographic change. The goal here is direct or indirect transformation in the sense of restructuring entire socio-technical areas, such as establishing sustainable mobility or food systems. (Breitlinger et al. 2021).

In the following, we outline five approaches from the field of innovation policy that we believe are also relevant for strategies to strengthen systemic resilience, as they address the following key requirements for resilience:

01
The development of local resources

02
Strengthening diverse networks and relationships

03
Strategic intelligence for the governance of transformations

04
Fostering anticipation

05
Providing broad competencies

01

The development of local resources

The ability to tap into specific local resources and capacities throughout the innovation system in a broad manner is a decisive factor for innovation capacity. Accordingly, the analysis of regional innovation systems has a long tradition in innovation research and policy (Braczyk et al. 1998, Cooke 2009, Koch and Stahlecker 2006 and 2019). Innovation systems are more effective and responsive if they have strong competencies which are widely dispersed and can react to local conditions and developments, but at the same time are interconnected across the overall system to take advantage of complementarities. In this way, specific spatial and contextual knowledge can be integrated and suitable solutions can be developed in the context of an (overarching) regional strategy. Successful and innovative companies form the core of local innovation systems. They are strengthened by research services, education and supportive policies. The ability of innovation systems to change and remain sustainable depends to a large extent on how regional resources can be used and (further) developed with regard to external changes in the framework conditions. In innovation research, holistic and analytical approaches have become well established. These bring together the existing potentials (actors, industries, qualifications, etc.) by combining capability and strategy analysis and development with strategic development possibilities and thus enabling conclusions to be drawn about suitability of fit (cf. Barca 2009). For example, the smart specialization approach (Foray 2014) enables the search for comparative advantages based on existing local resources and potentials and taking into account the respective regional context.

The insights and tools from innovation research to strengthen local innovation systems can also be applied to strengthen societal resilience. The capabilities and responsiveness of the overall system are increased if sufficient interconnection and transparency allow different local experiments and competencies to be mobilized in the system. This is based on a variety of learning effects that take place through local operational crisis management, and consider location-specific conditions. These learning effects, which are achieved jointly, can be used to overcome further challenges. On the one hand, the readiness to embrace external ideas is increased, and on the other hand, direct dependency on external systems is prevented if innovation systems are able to autonomously generate diverse local innovations. Both factors contribute to flexibility, responsiveness and resilience.

Box 01

Regional development strategy "Technologie-Region Karlsruhe" 2030

Under the umbrella term "TechnologieRegion Karlsruhe", 28 partners have joined forces from business, academia and the local authorities from the federal states of Baden-Württemberg and Rhineland-Palatinate as well as the Département Bas-Rhin in France. With the support of Fraunhofer ISI, a vision and a development strategy were drawn up in a series of participatory workshops. Numerous concrete projects were also developed and initiated that included targeted measures for implementing the strategy. The starting point was a detailed analysis of the regional innovation system and its potential against the backdrop of global developments. In the context of the Regional Innovation Strategies for Smart Specialization, similar projects have been or are being carried out for the regions of Upper Austria, Mecklenburg-Western Pomerania, Heilbronn-Franconia and South Tyrol.

02

Strengthening diverse networks and relationships

Identifying stakeholders and actively including them in strategic processes has been an integral part of innovation research for many decades and an important element of innovation policy. This is only to be expected since the success of innovation policy strategies depends to a large extent on the active participation of innovation system actors. For a long time, these participation structures principally considered industry and research organizations, which were traditionally regarded as the main actors in the innovation system and therefore also as the main stakeholders. This has changed in more recent years with the growing awareness of the crucial contributions made by societal actors and the public sector to innovation. Current participatory innovation strategies often target broad-based citizen involvement. For instance, in the Netherlands, more than 12,000 citizen contributions were used as input for research strategy (Graaf et al. 2017). In this way, the more recent instruments of innovation policy strengthen not only existing networks, but the ability to include different horizons of expectation, forms of knowledge and problem-solving

Box 02

Participation process for the High-Tech Strategy

As the German government's current research and innovation strategy, the High-Tech Strategy 2025 is the overarching guideline for German innovation policy. In 2020, a participation process was launched to integrate new perspectives from society into the strategy's further development. Seven regional dialogues were held from June to August 2020 across Germany. These brought together established innovation actors and other actors from academia and society, not previously considered in the innovation context, to jointly develop regionally-specific solutions to societal challenges in line with the co-creation principle. The results were discussed in a supraregional dialogue with different stakeholders and innovation experts, and this led to impulses for the further development of the High-Tech Strategy. These were presented and discussed at a state secretary roundtable with representatives from all the ministries. In parallel, an online platform provided citizens with a forum to actively participate in the further development of the High-Tech Strategy 2025. From the viewpoint of the German Federal Ministry of Education and Research (BMBF), the participation process was "driven by the conviction that innovations are increasingly emerging from the midst of society and that knowledge is being applied in society" (see https://www.mitmachen-hts.de/informationen for information in German).

expertise, which is particularly important in terms of resilience ("participative capacity", Lorenz 2013). This degree of inclusion requires that diversity is considered and can be represented as a network. Numerous studies in innovation research have demonstrated that diverse teams develop more creative ideas and solutions. They contribute different perspectives, which often lead to faster results and innovative approaches (Garcia Martinez et al. 2017). Diverse teams are more likely to explore alternative approaches, but also potential obstacles. Integrating diverse perspectives is therefore an established approach to strengthen innovative capacity. A series of concrete instruments in foresight and innovation management, for instance, aim at increasing the diversity of innovation teams or gathering external perspectives. Analyzing sectoral or regional innovation systems has also repeatedly shown that diversity and actively mobilizing interfaces strengthens innovative capacity and helps to avoid lock-in situations. A high degree of diversity in terms of perspectives and the capacity for solutions together with participation can therefore contribute to the formation of networks and relationships and is one way to strengthen resilience.

The participation instruments of innovation policy address aspects that also contribute to strengthening resilience: They strengthen the bonds between actors across different fields, and enhance trust in institutions – both capabilities that contribute to finding and pursuing new paths in the event of a crisis.

03

Strategic intelligence for the governance of transformations

As outlined above, in the wake of mission orientation, innovation research is also increasingly concerned with the targeted guidance and strategic support of the usually longer term transformations of entire sub-systems. The challenge here is to provide continuous guidance that steers all the elements of a system in the right direction and equips decision-makers with the best possible skills. Resilience approaches assume that, in a globalized, dynamic world, technological, environmental and social developments are difficult to predict, let alone control. Instead, decisions to act are always associated with deep-seated uncertainty. To counter this uncertainty, factors have proven helpful that reduce uncertainty through clear strategy and continuous support. This is why leadership and strategy factors, such as strong decision-making, are shown to promote resilience (Niessen 2021). Strong decision-making here does not mean per se that decisions have to be made particularly quickly, but rather that all those involved are clearly aware of the decision – as a rule, the more effective the networking and communication in a system, the greater the awareness of decisions and strategies. The governance of systems in a crisis is particularly challenging in the case of non-linear changes, so that intelligent support is absolutely essential. Distributed strategic intelligence provides a helpful basis for strong decision-making and reducing uncertainty. This is defined as the sum of all the analytical and discursive processes used to support decision-making and reflect on the impacts of decisions (Kuhlmann et al. 1999).

Strategic intelligence in the context of transformation processes is therefore a permanent process of monitoring, analyzing the potential for innovations and behavioral changes, and the

Box 03

Supporting the Mobility and Fuels Strategy (MFS) of the German Federal Ministry of Transport and Digital Infrastructure (BMVI)

The German government's Mobility and Fuels Strategy (MFS) is the pivotal instrument for implementing a successful energy transition in the transport sector. Fraunhofer ISI provides scientific monitoring and support for the MFS, and an important discussion platform for the sustainable mobility of the future that incorporates all the key stakeholders. Among other things, this includes quantifying the potentials to achieve the transformation of the transport sector by analyzing technologies, energy and fuel options as well as innovative transport concepts. This will create a foundation for the political process to bundle the relevant packages of measures in order to achieve the defined energy and climate policy goals. In addition, the scientific consultation will also estimate the impact of the measures taken on the final energy consumption and greenhouse gas emissions of transport and in this way provides a constant anchor for strategy development.

accompanying evaluation of the decisions made on governance. Such a system allows stakeholders to jointly reflect beyond the boundaries of their own perspectives, interests and levels of data access. The evidence this process generates, as well as opening up the perspectives and broadening the awareness of those involved, increases the legitimacy and improves the fit of transformation decisions.

04

Fostering anticipation

Among the various systemic instruments, foresight processes play a special role in which different actors of an innovation system explore different "futures" together. The objective here is not to predict the future, but rather to enhance the ability of those involved to question their own often linear future assumptions and expectations ("Futures Literacy", Miller 2018), to hone their perception of "weak signals" (Warnke and Schirrmeister 2016), to open themselves up to change, and to jointly develop new goals. At the same time, foresight processes forge new future-oriented links between actors from very different areas of the system and bring together different forms of knowledge.

Foresight processes such as that described in the context of the Commission on the Future of Agriculture help to sensitize actors to a broader range of developments and train them to question the continuation of the status quo in the context of dynamically developing requirements. At the same time, as heterogeneous stakeholders share their views and engage with each other, new connections are created and more perspectives are integrated into the formation of new expectations. This further develops the capabilities to rapidly develop new structures that are supported by different groups. These skills are crucial in crises that abruptly cut across established expectations. The ability to take crises seriously and to do so more quickly is also strengthened, as it increases the absorptive capacity for ideas that have already been thought about and above all jointly discussed. Foresight as a systemic instrument of innovation policy aimed at strengthening innovative capacity can therefore also be regarded from the perspective of enhancing resilience. In particular, this also increases the transformation capacity, since well-trodden paths and linear expectations of the future are systematically broken up and new patterns of thinking and reacting are practiced.

05

Providing broad competencies

Since the mid-20th century, it has been globally acknowledged that a state has to invest in initial research. This type of research searches for fundamental knowledge without direct, immediate links to a concrete application. Innovation research has clearly mapped the value of this type of research for society and for the economy since the middle of the last century (Martin and Nightingale 2000, Nelson 1959, Stokes 1997). While application-oriented research is geared toward clearly defined problems, initial research makes it possible to gather knowledge, the concrete application of which often only becomes clear over time. Initial research is essential, however, because it nourishes our future capability to solve problems with new findings and often enables completely new economic and societal applications. In addition, innovation research works on the assumption that initial research also strengthens an organization's own knowledge basis and thus the capacity to absorb complex information and utilize this for the organization.

Box 04

Commission on the Future of Agriculture

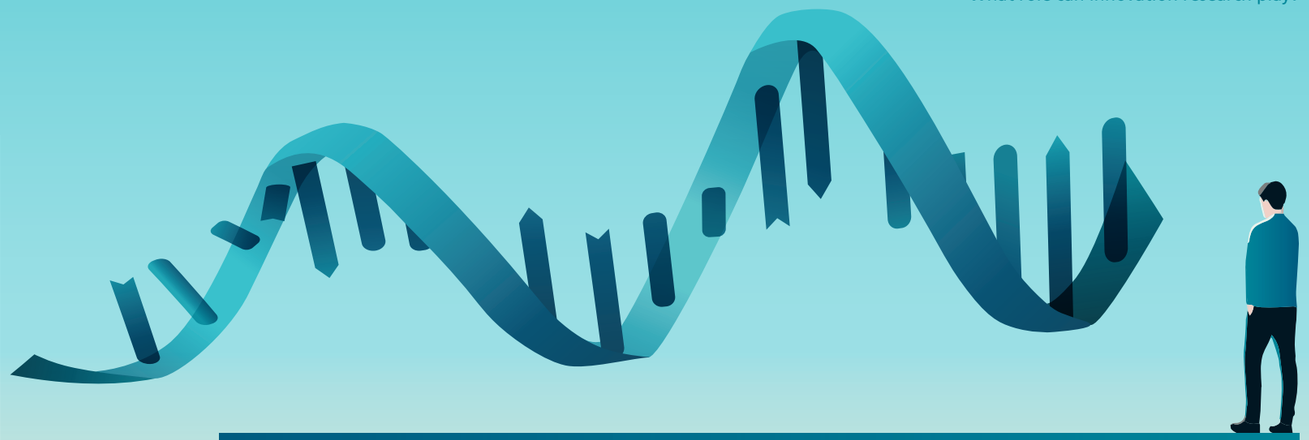
The German federal government established the Commission on the Future of Agriculture in July 2020. This comprised 31 representatives of the most important sectoral associations from agriculture, industry and consumers as well as environmental protection and animal welfare and six scientists from agricultural and environmental research. The "Futures" Working Group of this Commission was tasked with developing scenarios of possible future agricultural systems in a foresight process, with methodological support from Fraunhofer ISI. These scenarios were used to integrate very heterogeneous problems and supported a constructive exchange between the sometimes strongly conflicting positions of the representatives of the different interest groups.

Based on two scenarios, a target corridor for sustainable agriculture was defined, which all the stakeholders could agree on. An additional scenario was outlined, which describes a continuation of the status quo and which all the stakeholders considered unsustainable and therefore not resilient. The target corridor described in the scenarios shows the need for transformation and the scope for actions that require societal negotiation. The target corridor can be illustrated using the example of animal husbandry and meat consumption. While one scenario presumes reduced meat consumption and reduced livestock farming, which is largely in line with societal aspirations and animal welfare, a second scenario largely abandons animal farming in Germany as alternative sources of protein comprehensively replace meat consumption. For all the scenarios, it was also discussed which framework conditions are required for them to be realized, for example, in international trade or consumption behavior, so that not only different design options at the national level of the agricultural and food system are considered, but also uncertainties in the international context and beyond the boundaries of the analyzed system.

Economic innovation research (Arrow 1962, Peneder 2008) has clearly demonstrated that, for reasons of market failure alone, the market has a structural tendency not to invest enough in initial research as a public good. This is especially due to the lack of exclusion possibilities, because, by their very nature, the long-term benefits of basic or strategic research can never be completely exclusive to the organization conducting it. Furthermore, the prospects for possible applications are often very uncertain. This limits the incentive for privately funded initial research. This is why the public funding of long-term, not directly application-oriented research via university and non-university research is indispensable for promoting research and innovation.

These examples are directly relevant for the resilience of systems. Initial research provides undirected competencies and knowledge that can have unexpected benefits in the event of unforeseen disruptions. This is consistent with the requirements of holistic resilience. Since the type and likelihood of disruptive events occurring can only be estimated at best, but never precisely determined, basic research is used for exactly this, to strengthen the responsiveness of research and innovation systems and functional social systems. Broad, publicly funded initial research is therefore an important resource for the development of knowledge-based reactions to crises.

The above-mentioned reason for the necessity of state-funded initial research – its character as a public good– is especially valid for initial research on resilience itself. Compared to initial research that is conducted with expectations of contributing to innovative solutions and thus contributing indirectly to resilience, there are very few research funding programs that are explicitly aimed at increasing systemic resilience. For example, the resilience of infrastructures or of entire societies is a classic commons, where market failures repeatedly occur due to strong incentives for "free-riding", among other reasons. Finally, in many cases, too little is invested in resilience as such investments only pay off in the event of a shock or a crisis (the so-called resilience dividend, Fung and Helgeson 2017). Correspondingly, and analogous to initial research with (open-ended) innovation expectations, strengthening systemic resilience by means of a long-term policy mix to build up resources that are not earmarked for a specific purpose is an increasingly important field of government action, in healthcare and education among others.



Box 05

The Covid crisis and internet-based business models

The current Covid crisis or the history of the internet and internet-based business models have now been sufficiently well documented. Without the long-term funding of initial research to explore the immune system's reaction to cancer cells, it would not have been possible to develop the Covid vaccine based on stabilized mRNA.

Three decades of basic research at universities and state agencies, especially in the US, laid the foundations for the internet and the platform-based business models that rely on it, which no basic research scientist could have imagined. Evaluations of funding programs of initial research at Fraunhofer ISI, such as the Austrian Start/Wittgenstein program or the Robert Bosch Junior Professorship have repeatedly shown the delayed, often unexpected benefits of initial research, which often extend far beyond the originally envisaged field of application.

Conclusions

This policy brief shows how the insights, concepts, methods and instruments from innovation research and policy can also contribute to strengthening the resilience of socio-technical systems, as both share similar system characteristics that are particularly relevant.

This policy brief shows how findings from innovation research can help to develop policy measures that promote the resilience of socio-technical systems. Unlike strengthening resilience, innovation support is an established field of policy. Over the last decades, innovation research has developed its own concepts, methods and measurement instruments to identify the characteristics needed to maintain the dynamic ability of innovation systems to function and solve problems as well as to formulate clear recommendations for action. These instruments are suitable for supporting the development of local resources, strengthening networks and relationships, increasing strategic intelligence for governance, fostering anticipation and providing broad competence resources. Established approaches from innovation research and the innovation policy instruments based on them are therefore aimed at system properties that are also relevant in the context of strengthening the resilience of socio-technical systems. They affect a system's capacity to adapt and to transform which in turn fosters the emergence of resilience.

» At the same time, research on resilience provides important impulses for the further development of innovation systems

At the same time, findings from the research on resilience also provide an important impulse for the further development of innovation systems. This concerns in particular the complexity and predictability of key technical, environmental and social trends, which form the basis for many of the current innovation policy strategies. In fact, it is highly questionable to what extent it is possible to precisely predict the development of innovation systems and their contextual conditions over longer periods of time (innovation policy strategies often attempt to plan periods of ten to twenty years or even more). This does not mean that it is impossible to derive long-term goals under these conditions and to gear innovation policy toward achieving them; the goal of climate neutrality by 2050 makes this very clear. Instead, our intention is to express two things: First, at this point in time, there cannot be only one master plan to achieve the goal; changes will always be necessary. Second, it may be necessary to change key patterns of behavior to achieve these goals, which goes far beyond the traditional spectrum of innovation policy. New innovation policy approaches seem to be needed that make goal achievement appear realistic even under environmental conditions that are difficult to plan and that also consider any potentially negative side-effects. More recent approaches to innovation policy such as the "Anticipatory Innovation Governance" proposed by the OECD (Tõnurist and Hanson 2020) also point in this direction. These approaches converge with resilience research in recognizing the fundamental uncertainty and uncontrollability of complex socio-technical systems without relinquishing the aspiration to strengthen sustainable structures.

Systemic resilience approaches, in particular, emphasize the ability for self-organization as an important prerequisite for effectively processing environmental signals (including weak signals). They also highlight the capacity for experimental development of adaptation strategies under conditions of high system complexity and deep uncertainty (Carpenter et al. 2001). Innovation policy is also increasingly searching for instruments that enable experiments with an open outcome, although the aim here is to achieve a desirable development. In particular, high systemic controllability is a prerequisite for the approaches of the above-mentioned mission-oriented innovation policy. In principle, the goals of this mission-oriented innovation policy (MOIP) can be identified and negotiated in decentrally organized structures (for example by involving a broad basis of stakeholder groups), but the political reality is that the majority of the processes in both mission design and mission implementation are centrally controlled.

Currently, only a few approaches seem suitable for integrating the principle of self-organization more strongly into MOIP. Instruments that provide scope for experimentation appear particularly promising in this context, such as transformation labs and real-world labs, which can support the decentralized development of creative and innovative solutions for sociopolitical missions. Such freedom for experimental learning and innovation processes can be a valuable resource, especially during crises such as the current pandemic, in order to adapt quickly to new challenges, rapidly restore systemic performance and safeguard this in the long term (Paunov and Planes-Satorra 2021). At the same time, however, a certain degree of political control and coordination is needed to set up such experimental spaces in the first place, and to compile and evaluate their results. This shows how closely innovation and resilience are interwoven and mutually dependent, but also that both goals must be given strategic and long-term support.

» So far, very few approaches seem suitable for integrating the principle of self-organization into mission-oriented innovation policy

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Fraunhofer Institute
for Systems and Innovation Research ISI
Breslauer Strasse 48
76139 Karlsruhe

Contact
Dr. Florian Roth
Competence Center
Policy und Society
Phone +49 721 6809-537
florian.roth@isi.fraunhofer.de

Authors
Florian Roth
Philine Warnke
Pia Niessen
Jakob Edler

Graphic design
Sabine Wurst

Translation
Louise Blum
Gillian Bowman-Köhler

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