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Towards an Ambidextrous, Robust and Resilient Impact Assessment of Sustainable Smarter Specialisation Strategies (AR2IA/S4)

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Abstract

ΤΑ ΠΑΝΤΑ ΡΕΙ. (*Everything Flows, Heraclitus of Ephesus, 535–475BC*). When the EU Framework Program designers and policy makers were creating the Horizon 2020 program, they could never imagine or anticipate that 2020 would turn out to be the *ANNO HORIBILIS GLOBALIS* due to COVID-19 depredations with socio-economic, socio-political and socio-technical impacts and implications for policies, practices and politics. In this paper, we provide an approach that builds on recent developments and insights based on efficacious multi-criteria approaches that leverage design thinking philosophies and agile methodologies. This is in order to achieve an ambidextrous, robust and resilient architecture of impact assessment of S3 and thus set the stage for the next generation of S3 that should be aptly framed as Sustainable (Triple Top and Bottom Line) Smarter (Efficacious) Specialisation Strategies (AR2IA/S4). In a more concrete manner, we identify and illustrate cases in the context of S3 formulation and implementation at the sectoral and regional levels where AR2IA could help engender S4 especially in the context of the pandemic disruptions so as to be better prepared and enabled to cope with such future challenges and identify within them endogenous opportunities.

Keywords Ambidextrous robust and resilient impact assessment (AR2IA) · Sustainable smarter specialization strategies (S4) · Triple top and Triple bottom line sustainability · Design thinking · Agile methodology · Quadruple and Quintuple innovation helix frameworks

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Introduction

Smart specialisation is an innovative approach that focuses on policy support and investments on key regional priorities and encourages stakeholders' involvement, while taking into account region's strengths, competitive advantages and potential for excellence (Foray et al., 2012). It is characterised as an 'integrated, place-based economic transformation agenda' aiming to the sustainable development of European regions (S3 Platform, 2018b).

The concept of Sustainable Smart Specialisation Strategies (S4) has recently gained attention in the long-term growth strategies supported by EU funds. Smart specialisation should give emphasis on all the three major pillars of sustainability (society, economy and environment), emphasising the stakeholders' involvement, the regional economic competitiveness and the environmental sustainability dimension (e.g. SDGs, European Green Deal).

The impact assessment of the implementation of S4 is crucial for the further development and evolution of smart specialisation (Crescenzi et al., 2018). Impact assessment is related to the required structural changes and the final objective of regional economic transformation. Given the flexibility of the smart specialisation concept, it is difficult to develop a universal impact assessment framework. In addition, smart specialisation is a relatively new concept and its key elements are still discussed in the relevant literature (see for example Carayannis, 2019). Furthermore, S4 dynamics may affect the impact assessment process. As noted by Foray (2015) '*the development process is triggered by an entrepreneurial vision, the discovery of a new domain and the integration of different types of knowledge to turn this discovery into reality. It is then stimulated by the spillovers generated by this discovery, the entry and agglomeration of firms around the new activity and then the growth of the latter, allowing structural change (diversification, modernisation, transition)*'.

Carayannis (2019) provides an overview of different assessment approaches that evaluate the impact of Research and Innovation Strategies for Smart Specialisation (RIS3). The first stream of studies is mainly based on indicators that focus on the territorial impact of S4. They include a multi-stage approach, where standard input and output indicators of policy interventions are usually used. These indicators reflect the potential effects of S4 in economy (economic growth, number of innovative SMEs, etc.), society (employment, income, poverty, social exclusion, etc.), governance (e.g. regional competitiveness index) and environment (e.g. emissions). The second major stream of research efforts is focused on macroeconomic studies. They refer to the development of macroeconomic models, adopting usually a simulation-based approach and aiming to assess and analyse the implication of smart specialisation policies in terms of regional economic performance, while accounting for their interrelations and controlling for other relevant determinants. The adopted measurement approaches are based on the development of a simulation model, where a series of dynamic relations among the examined variables have to be defined. Finally, other studies are linked to the smart specialisation monitoring and evaluation process (e.g. self-assessment approaches) or refer to individual research efforts for a particular set of regions or SMEs. These studies can enhance current

RIS3 monitoring systems, which should not be considered as external controlling systems that monitor quantitative targets, but also, and perhaps most importantly, as diagnostic approaches that can support the regions' open-ended and evolving strategies (Kroll, 2016).

The previous studies cannot usually lead to clear and specific results about the impact assessment of smart specialisation, as argued by Carayannis (2019), since the employed approaches are rather simple compared to the complexity of S4. Moreover, the validity of these models to cover different regional strategic priorities is still a challenge. The difficulties for validating the incorporated assumptions are also significant in many cases. Also, as emphasised by several scholars, regions need to move beyond the usage of a simple set of impact assessment indicators (input/output indicators, structural change and context indicators) (see for example Griniece et al., 2017). Finally, most of the aforementioned studies do not provide an integrated framework.

Regions may be considered as open systems operating under conditions of substantial turbulence, risk (known unknowns) and uncertainty (unknown unknowns) and seeking to balance stability and coherence with flexibility and change in pursuit of higher levels of efficacy and excellence. The current COVID-19 crisis is a characteristic example, showing how endogenous and exogenous uncertainties and related disruptions may affect S4 implementation, and therefore, S4 impact assessment, having severe socio-economic, socio-political and socio-technical impacts and implications for policies, practices and politics.

The main aim of this paper is to outline an integrated methodology for Ambidextrous Resilient and Robust Impact Assessment (AR2IA) of S4 (AR2IA/S4 framework) under high risk and uncertainty (including pandemics and other disruptions). In particular the proposed AR2IA/S4 framework is a toolbox that can achieve a functional and organic integration of ambidextrous higher order learning in S4, having the following specific objectives:

- Develop an S4 impact assessment approach based on the 3P (Posture, Propensity and Performance) framework (3PS4 framework).
- Propose a fuzzy Multiple Criteria Decision Analysis (MCDA) in order to consider vagueness and imprecise information during the impact assessment processes (3PS4/MCDA framework).
- Examine the different aspects of this S4 impact assessment (efficiency and efficacy).
- Link the previous 3PS4 impact assessment framework with the Quadruple and Quintuple Innovation Helix (Q2IH) model (quadruple plus environment) and the Regional/Sectoral Innovation Ecosystem (RSIE) perspective.
- Link the 3PS4 framework with the concept of ambidexterity in order to achieve the balance between exploration (i.e. explore new opportunities) and exploitation (i.e. exploit regional competencies) in S4.
- Adopt an ambidextrous 7P stage gate model (Patient, Persistent, Persevering, Proactive, Predictive, Preventive and Preemptive) that can strategically integrate the efficiency frontier, taking into account regional ambidexterity and learning capabilities.

- Adopt a Design Thinking approach in order to integrate the needs of people, the possibilities of technology and the requirements for business success in the development of the impact assessment framework.
- Adopt an agile (iterative and evolutionary) approach in the implementation of the impact assessment framework in order in order to increase value, adaptability and involvement of regional stakeholders, while reducing risks.
- Integrate all of the above in an Ambidextrous, Robust and Resilient Impact Assessment for Sustainable Smarter (Efficacious) Specialisation Strategies framework (AR2IA/S4 framework).

COVID-19 Effects and the Transformation of RIS3

RIS3 and R&I Efforts

This section presents a review about the possible effects of COVID-19 pandemic outbreak, while focusing on the reform of RIS3 approach, the relevant adopted policies, the proactive steps and the structural changes. The review identifies the reform of S3 towards the formulation of the Sustainable Smart Specialisation Strategy (S4) approach, as a key process for the recovery from COVID-19 crisis. Furthermore, two key factors are identified: the need for SMEs digitalisation and the enhancement of entrepreneurial efforts.

Regarding the response to socio-economic impacts of COVID-19, Wilson et al. (2020) recognise two major stages in the policy making process in the Basque Country: the 'pandemic resistance stage', where regulatory and macroeconomic policies are the main priorities, and the 'renewal stage', where proactive policies are formulated to enhance regions' resilience. Regarding the initial 'resistance stage', the relevant reactive policies for health crisis mitigation and maintenance of productive capacity should be centred on the effective management of the following criteria:

- Timing in policy making processes
- Risk sharing among stakeholders
- Prioritising of recourses allocation

On the other hand, the proactive policies included on the 'renewal stage' should be formulated within a framework oriented towards the optimisation of the following factors (Wilson et al., 2020):

1. Optimisation of timing in policy making processes through the effective estimation of COVID-19 effects on different stakeholders for multiple scenarios.
2. Revision of value chains and optimal management of global and local value chains combination.
3. Effective management of the conflictive activities of stabilisation of current fluctuations and formulation of new policies leveraging key concepts emerged during the COVID-19 era (collaborative economy, telecommuting, robotics, etc.).

4. Capability to identify and manage emerged structural challenges (digital transformation, demographic changes, etc.).
5. Design of new interaction channels among governments, firms and universities, leveraging different organisations and platforms as intermediaries.

For the efficient coordination of the 'resistance' and the 'renewal' stage, the following actions should be followed (Wilson et al., 2020):

1. Assessment of COVID-19 impact on selected sectors and industries for each of the implemented scenarios (forecasts for multiple scenarios).
2. Effective management of the global-domestic value chains mixture in order to mitigate employment issues in the short term, while supporting the capability to adopt renewal policies in the medium term.
3. Efficient balance between the effort to recover from the socioeconomic crisis and the formulation of renewal strategies.
4. Leveraging support organisations (e.g. chambers of commerce) to enhance various activities, such as the creation of resilient value chains, actions' reconfiguration under the framework of the emerging socioeconomic and socio-technical systems.
5. Collaboration of SMEs with other stakeholders involved in the domain of production for the efficient assessment of their current financial status.
6. Formulation of policies and strategies for the medium and the long term that are sufficiently sensitive in respect to the different scenarios of possible COVID-19 effects.
7. Proactive prediction of multiple beneficial scenarios for the socioeconomic renewal process, that could derived from the emerging structural challenges (digital transformation, demographic changes, etc.), in order to connect individual activities for the formulation of a shared strategy.

The research and innovation (R&I) efforts could be beneficial for both the aforementioned stages, potentially providing support towards the recovery process, the resilience of production domain and socioeconomic transformation (DG for Research and Innovation, 2020). In the recovery package of the EU commission (sizeable policy and funding instruments, May 2020), the two-staged scheme is once again observed, where initially the 'Next Generation EU' funding instrument for recovery, i.e. €750 billion of fresh financing from the financial markets, and subsequently a long-term reinforced budget for the period 2021–2027, are proposed (DG for Research and Innovation, 2020).

Regarding the RIS priorities focusing on R&I goals (areas of health, environment, etc.) in the context of EU's recovery, the European Commission aims on the enhancement of member states' policies reforms, focusing on lagging regions and regions affected the most by COVID-19 crisis (DG for Research and Innovation, 2020). The key emerging structural changes, i.e. health tech, green transformation and digital transformation, require the integration of regional and national R&I policies and programs, and the co-management of R&I policies with other relevant horizontal policy areas (circular economy, biodiversity, ecosystems, etc.). The established RIS3 governance structures could be leveraged for this specific co-management, enabling the collaboration of universities, research institutions and industries. Furthermore, R&I activities for Europe's recovery should focus on the enchantment of the ecosystems' resilience. The exploitation of smart specialisation concept is highly valuable towards this direction, since place-based innovation approaches positively affect innovation ecosystems and regional research (DG for Research and Innovation, 2020).

On a global level, Science, Technology and Innovation (STI) could be adopted as a valuable tool to reach Sustainable Development Goals (SDGs), and thus, it could be leveraged for the sustainable recovery from COVID-19 effects (DG for Research and Innovation, 2020). The smart specialisation approach tends to broaden its main objective, i.e. identification of strategic areas for interventions, and starts to embrace the sustainability principles (TWI2050, 2020). The key feature of smart specialisation is that the stakeholders participate in the prioritisation process, based on a bottom-up scheme, which fosters the sustainability and socioeconomic transformations. Thus, smart specialisation could be a key driver for the achievement of SDGs [3]. However, the integration and co-management of RIS3 and STI to achieve the SDGs demands the formulation of harmonised roadmaps, effective action plans and synergies on regional, country and EU level (TWI2050, 2020). Since the STI concept is the basic strategy for the long-term control and resilience on COVID-19 effects, expanding the scope of RIS3 approach towards the inclusion of SDGs is highly significant.

Sustainable Smart Specialisation Strategies

Reforming the smart specialisation towards the formulation of sustainable smart specialisation (S4) is a key activity for the recovery in post-pandemic era. For example, regarding the impact of COVID-19 crisis on the tourism sector, Marques Santos et al. (2020) note that crisis affects consumers' destination preferences and consumers' motives to travel. Moreover, for the EU27 countries, a decline of 38 to 68% in arrivals is estimated, while 6.6 to 11.7 million jobs could potentially be at risk. Concerning the R&I policy-making on the short term, the different scenarios of S4 implementation through funding synergies should be identified. On the other hand, diversifying tourism value chains could be a valuable policy to enhance resilience on the long term. Generally, changing consumers' preferences could lead to a more diversified and sustainable tourism. Under this scope, S3 governance model for place-based innovations (involvement of all stakeholders) is a valuable mechanism for effective multi-level governance of sustainable tourism (Marques Santos et al., 2020). These findings can be valid to other sectors too and the effective adoption of support programs can foster short-, medium- and long-term recovery.

Regarding S4, the potential industrial policies will emerge in cohesion policy connected with a collaborative approach to global value chains in Europe level by clusters. Additionally, the digital, green and socio-economic transformations demand effective multi-level governance, where leaders of S4 and regional actors are coordinate on regional, national and Europe level. It is worth mentioning that the level of COVID-19 socio-economic effect on a specific region depends on the area of its specialisation (Sillero, 2020). Moreover, regional S4 should be sensitive on actions at regional level in respect to strategy adoption and recovery policies, while also being coherent with the national/EU recovery actions, and vice versa.

Concerning the proposals for the New Cohesion Policy (EU budget 2021–2027), 'Smarter Europe' is one of the five main objectives that motives EU investments. Under this framework, the governance of S4 and the European Regional Development Fund will provide to clusters, regions, firms and R&D organisations a certain role. Towards S4 formulation, clusters together with regional development agencies could be beneficial towards the following actions (Sillero, 2020):

1. Being catalysts for place-based innovation
2. Supportive towards the scaling up at EU Level
3. Enhancement of EU technological development
4. Formulation of European strategic autonomy

Several case studies published in the S3 Platform Repository,[1, 2] show that connection and coordination among actors is a key enabler for the reinforcement of innovation ecosystems in the post-pandemic situation. S4 should support the innovation ecosystems' efforts to re-focus on different actions when this is necessary, while the forthcoming smart specialisation approach (2021–2027) should focus on the enhancement of collaborations and on its connection with other ecosystem. Integrating the territorial dimension into a smart specialisation initiative could be supportive towards the identification of (regional) smart priorities and the enhancement of the coordination for innovation delivery. Moreover, the processes of 'resilience' and 'recovery' require the recognition of regions' strengths and weaknesses.

Transformational Roadmaps and Future Action

The pandemic outbreak seems to intensify structural transformations, decreases the demand on various industries and challenges the established supply chains (i.e. reconfigurations in 'local/global' and 'cost/security' mix). However, focusing on the post-pandemic period, opportunities could possibly emerge. Specifically, this process of structural changes could be leveraged, in order to refocus smart specialisation priorities towards the promotion of the following beneficiary areas: 'smart industries', 'personalised health', 'clean energy', 'creative regions', 'sustainable regions', 'eco-innovation' and 'healthy food' (Wilson, 2020). For the enhancement of RIS3's experimental aspect, innovation activities on the institutional dimensions of smart specialisation should be adopted. Innovation in the institutional context

[1] https://s3platform-legacy.jrc.ec.europa.eu/-/smart-story-adaptation-of-regional-innovation-ecosystems-to-the-covid-19-health-emergency-situation-the-case-of-castilla-y-leon?inheritRedirect=true&redirect=%2Fs3-governance.

[2] https://www.interregeurope.eu/foundation/news/news-article/8480/irish-regional-economic-impact-of-covid-19/.

could be a beneficial tool for RIS3 reform, shifting from ‘linear planning’ to ‘living strategies’. Innovation activities should be implemented on two discrete interacting levels, i.e. ‘overall governance architecture’ (adoption of an overarching framework for entrepreneurial discovery processes, creation of an overall assessment framework, etc.) and ‘micro-processes of particularising and leveraging priorities’ (efforts for high granularity in strategic actions, deploying emergent and diverse EDPs, etc.) (Wilson, 2020).

The decentralised characteristics of entrepreneurial discovery process (EDP) and the emerged difficulties in communication due to COVID-19 require the readjustment of EDP’s support tools. For the encouragement of innovation actions by RIS3 throughout the U-process of innovation, i.e. the stages of ‘Co-initiating’, ‘Co-sensing’, ‘Co-discovering’, ‘Co-creating’ and ‘Co-evolving’, tools suitable for online events could the leveraged. Some of those tools are: Open Space Technology (OST) method, World café methodology, AOH-approach, Appreciative Inquiry approach, Ecosystem mapping tool and Design Thinking. Generally, online channels could be leveraged to enhance public support towards EDPs, while online communities of practice for every respective domain could be formulated, as pinpoint in a recent webinar of the SMARTER 2020 conference.[3]

The pandemic outbreak has a significant negative effect on established value and supply chains. Regarding the disruption on supply chains, the formulation of effective supply chain management frameworks is vital. An effective framework could focus on the following activities (Queiroz et al., 2020):

- ‘Preparedness’, i.e. pre-allocation of resources, emergency distribution planning and product diversification
- ‘Digitalisation’
- ‘Adaptation’, i.e. re-allocations of supply/demand and formulation of technologies needed in COVID-19 era
- ‘Recovery’, i.e. recovery on capacities, workforce and infrastructures and formulation of forecasts
- ‘Ripple effect’, i.e. control the propagations of distributions and modelling impact scenarios
- ‘Sustainability’, i.e. viability analysis and facilitating SC ecosystems

During the pandemic era, the development of innovative digital technologies as mechanisms to respond to the COVID-19 effects is a crucial necessity. The digital innovation hubs (DIHs) could be beneficial tools towards this direction, since they support SMEs’ digitalisation. Under this scope, Kalpaka et al. (2020) propose the formulation of new DIHs or the reformation of existing ones. The DIHs could be leveraged as a horizontal process, i.e. enhancing digital transformations across all the relevant sectors, and as vertical process, i.e. participation on processes that enable the efforts of RIS3 stakeholders in respect to digital techs or by enhancing regional specialisation

[3] https://s3platform.jrc.ec.europa.eu/en/w/smarter-2020-conference-1st-webinar-place-based-responses-to-the-covid-19-economic-crisis-1.

in priority areas related to digital transformation (Kalpaka et al., 2020). Furthermore, since DIHs consist innovation ecosystems (including RTOs, tech-firms, startups, universities, institutions, etc.), they can be supportive towards the progress of regional innovation ecosystems, firms' growth and promotion of local suppliers. In situations where DIHs' specialisation areas in line with the smart priorities of RIS3, the interregional networks of DIHs could be leveraged, so if the capabilities of a local DIH are limited, the capabilities of another hub could be utilised (Kalpaka et al., 2020).

The smart specialisation process includes the following actions: (a) identification of priority areas, (b) creation of transformational roadmaps in order to implement specific activities and (c) identification of an action plan for activities' implementation. For the formulation of transformational roadmaps, policy makers should estimate the existing regional capacities and the possible opportunities for each of the identified projects. In order for transformative activities to be beneficial, the concept of 5Ds should be adopted in an efficient manner (Foray et al., 2020):

- 'Direction of change': activities should explicitly specify the orientation of the desirable structural changes which are initially defined by the priority areas.
- 'relational Density': an effective transformative activity enhances relational density and thus increases also the likelihood of leveraging the benefits of projects' and actors' coordination.
- 'regional Differentiation': transformative activities are formulated to mitigate specific problems and to create opportunities related to the characteristics of the examined region.
- 'entrepreneurial Discovery': transformative activities are designed and developed in the context of the EDP.
- 'Distributed capacities': transformative activities consists a set of distributed projects and capacities.

The identification of transformational roadmaps is a challenging process requiring for optimal management in relative frameworks, such as the 5Ds properties, while in the pandemic era, policy makers should analyse the effects of COVID-19 on this aspect of the RIS3.

Due to COVID-19, entrepreneurial efforts are significantly reduced since SMEs are mainly focusing on their survival. However, as mentioned above, developing innovations is vital in order to respond on the pandemic's effects. Facing this specific problem, police makers could focus on the coordination of RIS3, entrepreneurial activities and Quadruple Innovation Helix models in order to identify beneficial policy implications (Carayannis et al., 2020). As analytically discussed in the '3PS4 Framework and Q2IH Model' section, focusing on the adoption of a Quintuple/Quadruple Innovation Helix system could be highly beneficial towards entrepreneurial efforts. Specifically, such an approach could be leveraged as an enabler and enactor of regional innovation ecosystem, while policy makers could deploy policy initiatives on regional level. As noted by Carayannis et al. (2018b), adopting Quintuple/Quadruple Innovation Helix model could foster a 'locus-centric' and 'triple-bottom-line-centric' EDP, leading to sustainable innovations with high quality.

3P Framework for S4 Impact Assessment

Background and Framework

The proposed Sustainable Smart Specialisation Strategy (S4) impact assessment framework is based on the 3P model of Carayannis and Provance (2008) that simultaneously considers the Posture, Propensity and Performance related to innovation capabilities. The framework assumes that S4 impact assessment should be based not only on the final outcome of potential smart specialisation interventions, but also on the current conditions and future capabilities of regional entrepreneurial ecosystems. Such approach underlies a cause and effect relation between current performance and future capabilities on smart specialisation evaluation.

The 3P framework for S4 impact assessment focuses on the knowledge transfer mechanisms within a regional entrepreneurial ecosystem that may create new ventures, technologies or structures that affect future performance (Nelson & Winter, 1982). In this sense, knowledge is considered as the most important intangible resource, and this is consistent with the concept of organisational innovation from a resource-based perspective of the firm (Barney, 1991; Penrose, 1959). As noted by Carayannis (2019), '*in the 3P conceptual model innovation routines are considered as a procedural model, while intangible resources contribute inputs to the innovation process*'.

The 3PS4 framework shown in Fig. 1 assumes that innovation is a configuration of ecosystem's innovation capabilities and conceived by S4 with the intent of producing positive outcomes. This configuration may also cover the nature and dynamics of both discontinuous and disruptive innovations (Carayannis et al., 2003).

The three major elements of the 3PS4 framework are defined as follows (Carayannis, 2019):

1. Posture: It refers to the ability of regional entrepreneurial ecosystems to engage in innovative activities as an exogenous factor to the smart specialisation interventions. It characterises the 'starting point' of the S4 implementation emphasising the current culture, competition and knowledge of the regional ecosystem. This current position

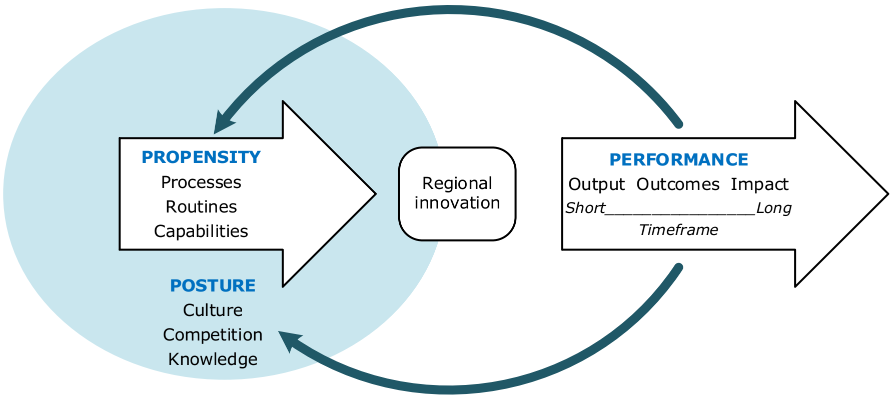


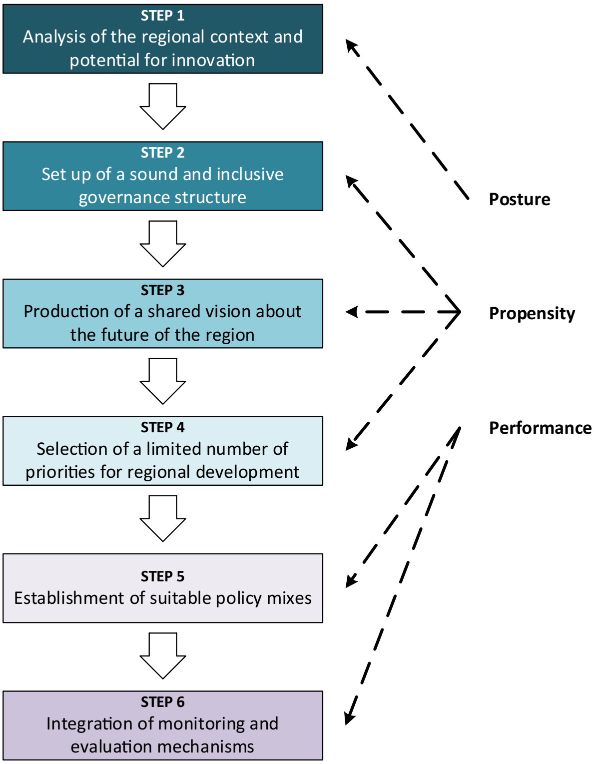
Fig. 1 The 3P framework for impact assessment of Smart Specialisation Strategies (Carayannis, 2019)

is examined within the greater global or European innovation system and reflects the region's readiness to both engage and benefit from innovation. Posture comprises a region's state along different dimensions (e.g. organisational, technological and market).

2. Propensity: It is an intangible reflection of processes, routines and capabilities established within an ecosystem. Therefore, propensity may be considered as an ability to capitalise posture based on cultural acceptance of innovation. In this context, adequate resources and structures cannot guarantee a fully developed innovation capacity if cultural or other constraints are strong in the regional innovation ecosystem.
3. Performance: It is the lasting result of innovation and comprises three different levels: outputs, outcomes and impacts. Outputs are the immediate internalised results of smart specialisation and cover both innovation activities (e.g. innovative SMEs in sectors of intervention, patents, trademarks or design applications) and S4 outputs (e.g. funds executions, employment, enterprises collaborating with universities and research institutions). Differently, outcomes refer to mid-range results, such as business outcomes (e.g. exports, sales) and structural changes (employment and labour productivity, R&D intensity in sectors of intervention, added value, investments). Finally, impacts represent more lasting, long-range benefits, focusing on regional economic, social and environmental sustainability.

The 3PS4 framework is consistent with the RIS3 design and implementation steps (see Foray et al., 2012; S3 Platform, 2018c), as shown in Fig. 2. Specifically, Posture

Fig. 2 3PS4 framework and RIS3 steps



is directly linked to the first step that refers to the analysis of the regional context and potential for innovation. This step aims to analyse the regional economy, society and innovation structure in order to determine current situation (e.g. assess existing regional assets) and identify potential future development (e.g. regional competitive strengths and weaknesses). On the other hand, Propensity includes the capabilities of the regional entrepreneurial ecosystem (e.g. policy, entrepreneurial support), as well as the major smart specialisation intervention inputs. In this context, Propensity is linked with the RIS3 steps related with the establishment of governance structures, the development of a shared vision and the selection of regional development priorities. Finally, Performance is directly linked with the integration of monitoring and evaluation mechanisms.

Taking into account the cause-effect relations, the 3PS4 framework adopts the 'Balanced Scorecard' philosophy of Kaplan and Norton (1996):

- It provides not only a performance measurement system, but also a management system that enables regions to translate their vision into action.
- It is able to consider different types of indicators and metrics: short term and long term, external and internal, leading and lagging, financial and non-financial.
- It analyses not only the innovation results, but also the innovation enablers, as well as the learning feedback loops.
- It is suitable to analyse the concepts of differentiation and specialisation, which formulate a dual problem in smart specialisation design and implementation (see for example Eichler & Foray, 2018).

Given that innovation is not an isolated phenomenon but an ongoing system within a regional innovation ecosystem, the 3PS4 framework can be used to manage and optimise the innovation process. However, the innovation Posture, Propensity and Performance is a rather complex dynamic system that is not presented in the simplified model of Fig. 1. Regional innovation ecosystems can be considered as dynamic learning systems, and therefore, certain triggers, drivers and impediments may heavily affect the whole innovation process either at the input side, during the production or service process or on the output side (see for example Carayannis & Alexander, 1999; Carayannis et al., 2003). The 3PS4 framework emphasises the importance of analysing the innovation processes within the regional ecosystem in order to generate knowledge and improve the management of innovation activities. It also gives emphasis on developing a unique innovation ecosystem (i.e. adopting a place-based approach) and monitoring the whole innovation process. As noted by Carayannis and Provance (2008), the essential element of this perspective is that learning can occur from innovation processes, regardless of organisation's and ecosystem's characteristics.

S4 Impact Assessment Under Uncertainty

Under the 3PS4 framework it is possible to define a set of major pillars, dimensions and indicators that may be used to evaluate the Posture, Propensity and Performance of RIS3 implementation. Such an approach is consistent with the 'Guidance on Monitoring and Evaluation' of the European Cohesion Fund and the European Regional Development Fund that links outputs, results and impact in relation to programming, monitoring and evaluation (EC, 2014a, b). Thus, taking into account regional needs, the framework suggests to compare specific objectives with intended results in the regional strategy development phase. In addition, the proposed framework is able to compare allocated and actual inputs, as well as targeted and achieved outputs in order to assess the impact of interventions.

Posture refers to the position of the regional entrepreneurial ecosystem within the globalised entrepreneurial system and it is linked with the regional entrepreneurial capabilities. In this context, as shown in Fig. 3, Posture consists of two main pillars and five specific dimensions (Carayannis, 2019):

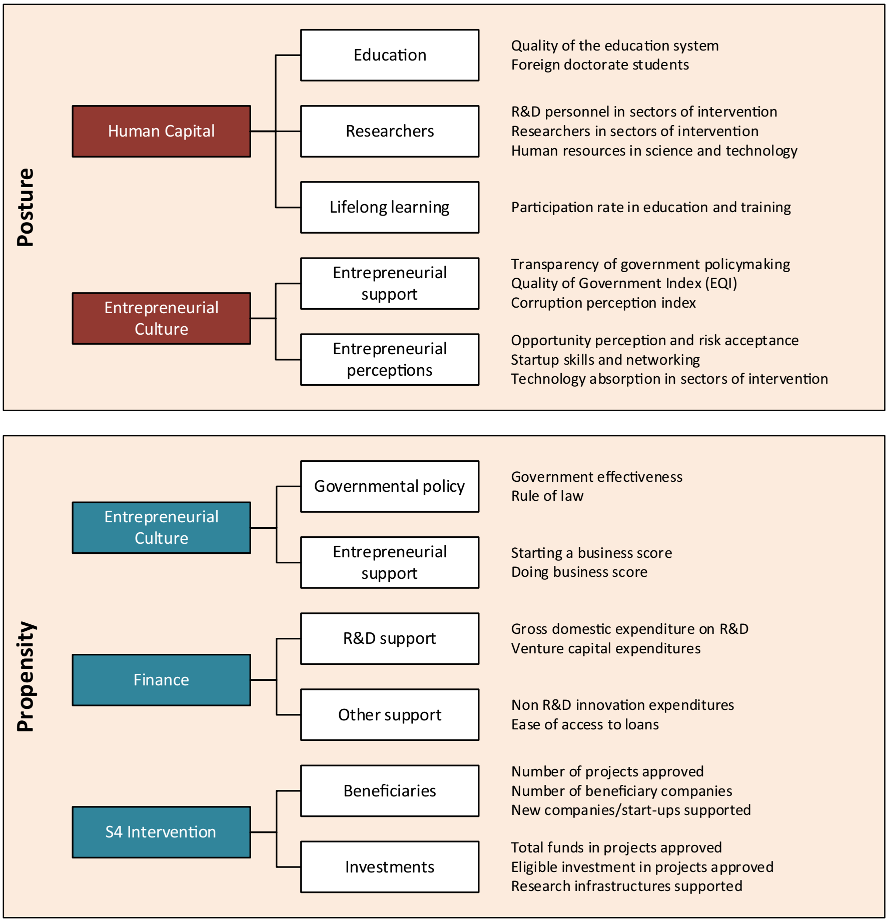


Fig. 3 Examples of Posture and Propensity pillars, dimensions and indicators

- Human capital

  o Education (quality of the education system, foreign doctorate students as an indicator of networking and extroversion of regional education)
  o Researchers (R&D personnel and researchers in sectors of intervention, human resources in science and technology)
  o Lifelong learning (participation in lifelong learning activities)

- Entrepreneurial culture

  o Entrepreneurial support (transparency and quality of government, corruption)
  o Entrepreneurial perceptions (opportunity and risk perceptions, startup skills, networking capabilities, technology absorption in sectors of intervention)

Similarly, given that Propensity refers mainly to the capabilities of the regional entrepreneurial ecosystem, Fig. 3 suggests three major pillars and six dimensions that refer to particular aspects of the these pillars (Carayannis, 2019):

- Policy

  o Governmental policy (government effectiveness, rule of law)
  o Entrepreneurial support (ease of starting and doing business)

- Finance

  o R&D support (R&D and venture capital expenditures)
  o Other support (non R&D innovation expenditures, ease of access to loans)

- S4 intervention

  o Beneficiaries (number of projects approved, number of beneficiary companies, new companies/startups supported)
  o Investments (total funds and eligible investment approved, research infrastructures supported)

On the other hand, given that Outputs are the short-range results of smart specialisation, they may cover the immediate effects of interventions. Although regions can select their own smart specialisation Outputs, Fig. 4 shows a list of characteristic Output pillars, dimensions and indicators that covers the following (Carayannis, 2019):

- Innovation activities

  o Innovators (SMEs in sectors of intervention with product, process, marketing or organisational innovations; SMEs in sectors of intervention innovating in-house; Total Early Stage Entrepreneurial Activity in sectors of intervention)

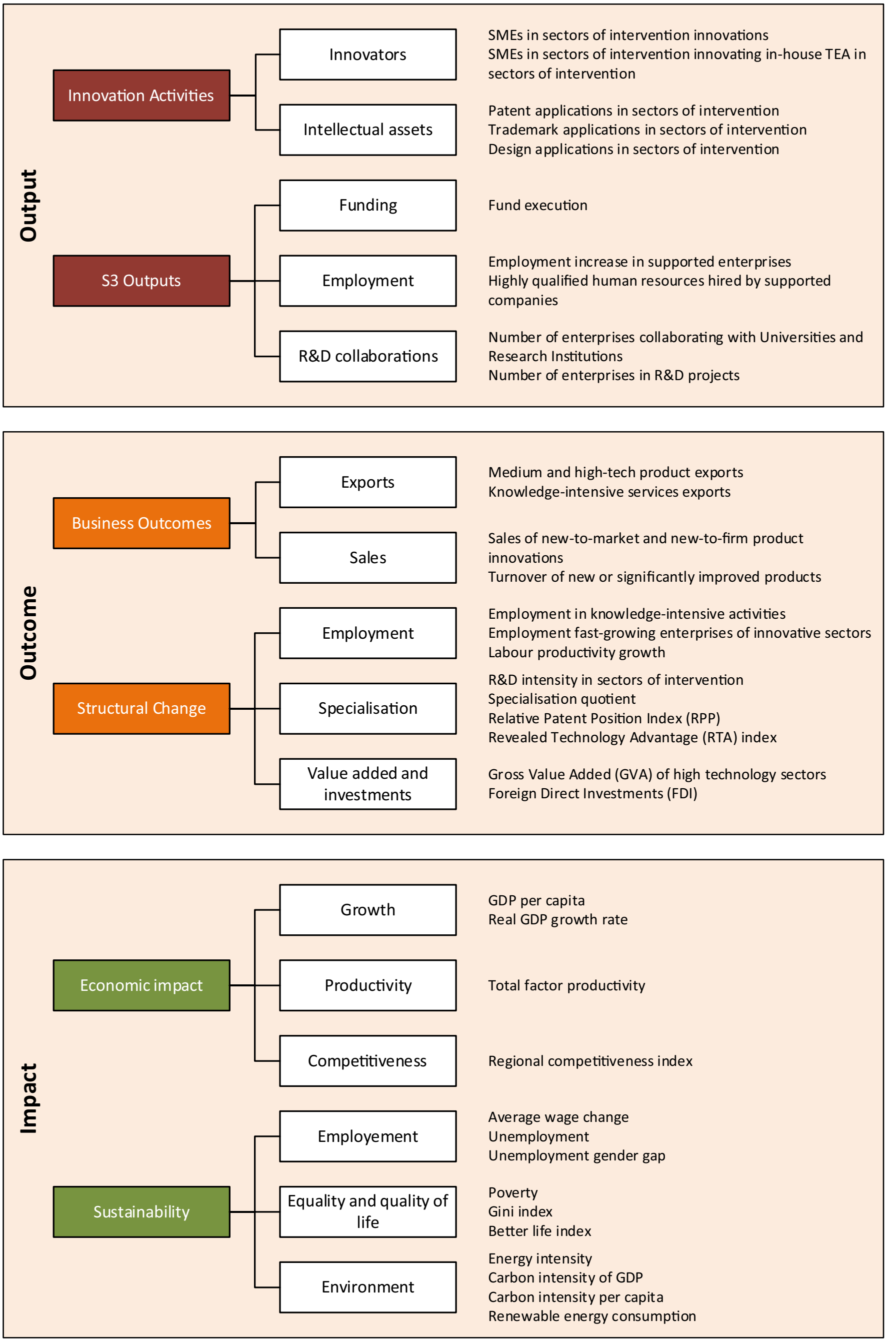


Fig. 4 Examples of Performance pillars, dimensions and indicators

o Intellectual assets (patent, trademark or design applications in sectors of intervention)

- S4 outputs

o Funding (fund execution)
o Employment (employment increase in supported enterprises, highly qualified human resources hired by supported companies)
o R&D collaborations (enterprises collaborating with universities and research institutions, enterprises in R&D projects)

Outcomes are related to S4 mid-range results and, as shown in Fig. 4, they may consist two main pillars and five specific dimensions (Carayannis, 2019):

- Business outcomes

o Exports (medium and high-tech product and knowledge-intensive services exports)
o Sales (sales of new-to-market and new-to-firm product innovations, turnover of new or significantly improved products)

- Structural change

o Employment (employment in knowledge-intensive activities and fast-growing enterprises of innovative sectors, labour productivity growth)
o Specialisation (R&D intensity and employment specialisation quotient in sectors of intervention, Relative Patent Position index, Revealed Technology Advantage index)
o Value added and investments (FDI, GVA of high technology sectors)

Finally, impacts refer to more lasting, long-range benefits based on the previous components of the 3PS4 framework. In this context, Fig. 4 suggests two major dimensions and six dimensions towards the sustainable economic growth (Carayannis, 2019):

- Economic impact

o Growth (GDP per capita, real GDP growth rate)
o Productivity (total factor productivity growth rate)
o Competitiveness (regional competitiveness index)

- Sustainability

o Employment (average wage increase, unemployment, unemployment gender gap)
o Equality and quality of life (poverty, Gini index, Better Life Index)
o Environment (energy intensity, carbon intensity of GDP, carbon intensity per capita, renewable energy consumption)

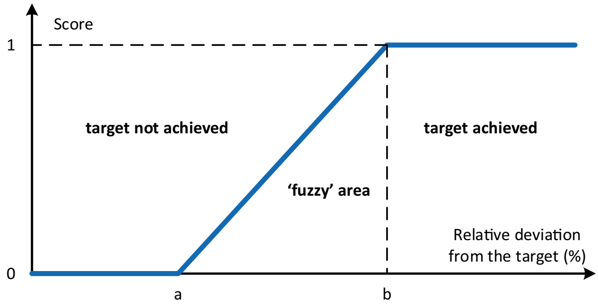


Fig. 5 Example value function

Based on the 3PS4 framework, Carayannis (2019) proposed a MCDA (Multicriteria Decision Analysis) approach that assesses the impact of S4 based on specific targets for the set of abovementioned indicators. More specifically, in the 3PS4/MCDA approach the score of each indicator is assessed as the value of the relative deviation from a predefined target. Figure 5 shows an example of a value function that gives the score of a specific indicator, in a 0–1 scale, according to the relative % deviation of a target. As shown, if the actual performance of the indicator is larger than b% of the target, the score is 1 (best performance), while if the actual performance is lower than a% of the target, the score is 0 (worst performance). On the other hand, if the relative deviation from the target is between b% and a%, the score is decreasing linearly. Figure 5 shows a value function with linear preference, while other alternative value functions (step functions, Gaussian functions, etc.) are given in Fig. 6 (see also Carayannis, 2019).

The 3PS4 framework may be considered as a 'fuzzy' approach, given its ability or represent vagueness and imprecise information. Specifically, fuzziness may be incorporated in the assessed targets, the examined data or the evaluation process. More specifically, as shown in Fig. 5, instead of defining a single target, the 3PS4 framework uses two different targets: a parameter (a) when target is achieved and a different parameter (b) when the target is not achieved. The range between parameters a and b defines a 'fuzzy' area. In addition, the 3PS4 framework is a target-based approach, and thus, it is rather flexible: it allows revisions in the desired targets in cases where exogenous may heavily affect the S4 impact assessment. Such an approach gives the ability to consider potential endogenous and exogenous uncertainties and related disruptions (such as pandemics) during the S4 implementation that affect the desired targets.

The previous value functions are used in order to measure the score of the deviation from the target and have a pre-defined form that is able to reflect the decision-maker's preferences. Such value/preference value functions are also common in other MCDA methods (see for example the PROMETHEE method in Brans et al., 1985, 1986; Brans & Mareschal, 1994, 2005).

The major steps of applying the 3PS4/MCDA approach are the following (Carayannis, 2019):

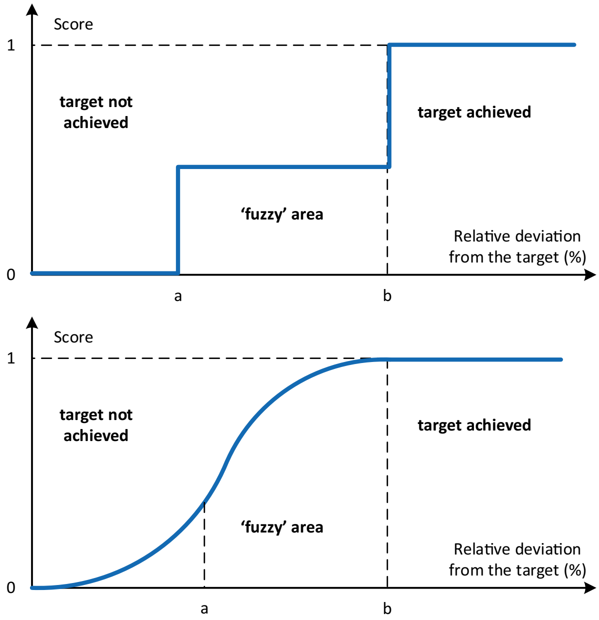


Fig. 6 Alternative value function

1. Define (minimum and maximum) targets of each indicator.
2. Having the actual performance of indicators, calculate the % deviation of the previous targets.
3. For each indicator, select an appropriate type of value function that better reflects decision-makers' preferences.
4. Calculate the scores for each indicator, based in the previous value functions.
5. Present the results is a series of radar diagrams for each element of the 3PS4 framework.

The major advantage of the 3PS4/MCDA approach is its simplicity that allows different S4 stakeholders to understand the results of a quantitative impact assessment model. Moreover, it is consistent with the S4 architecture (e.g. ability to consider specific targets in smart specialisation impact assessment). In addition, the 3PS4/MCDA approach is able to overcome the major shortcomings of composite indicators (see for example Munda & Nardo, 2011). Finally, it should be emphasised that the 3PS4/MCDA approach is a non-weighting and non-aggregation method: the scores of each indicator are simply depicted in a series of spider diagrams related to Posture, Propensity and Performance (Output, Outcome, Impact). Under this approach, it possible to overcome several problems and avoid the major criticism that can be found in the MCDA literature (see for example Greco et al., 2019). More specifically, in MCDA literature, criteria weights have a specific meaning, which is often ignored (e.g. in a weighted sum method, weights are value tradeoffs among criteria). Therefore, it is rather difficult to define meaningful weights, while it seems inappropriate to have a common set of weights in regional innovation ecosystems. As noted by Gianelle and Kleibrink (2015), different regions and stakeholders have different priorities in RIS3 implementation. In addition, a non-weighted approach can avoid the problems of subjectivity and compensation (e.g. the good performance in one indicator can compensate the poor performance in other indicators).

3PS4 Efficacy Framework

The previous 3PS4 framework is a performance-based approach, since it focuses on measuring the impact of RIS3 implementation, taking into account, however, the posture and propensity of regional innovation ecosystems. On the other hand, efficiency is a concept that focuses on the results or outputs of the innovation process, taking into account the drivers or the resources used (see for example Hollanders & Celikel-Esser, 2007). Efficiency is related to productivity, since it is defined as the ratio of outputs over inputs. Efficiency and performance are not necessarily related, since low performers may achieve high efficiency if inputs are relatively low compared to outputs.

As shown in Fig. 7, efficiency and effectiveness levels may propose a typology of S4 implementation, where:

- Effectiveness refers to 'doing the right things' (e.g. high impact of S4, regardless of the resources used).
- Efficiency is related to 'doing things right' (e.g. appropriate usage of regional resources).

The lower left quadrant of Fig. 7 refers to low performance and low efficiency. This is a case with regions that do not have the right strategy to achieve the RIS3 goals. They may also suffer from poor managed process discipline. The lower right quadrant refers to low performance and high efficiency. In this case, although

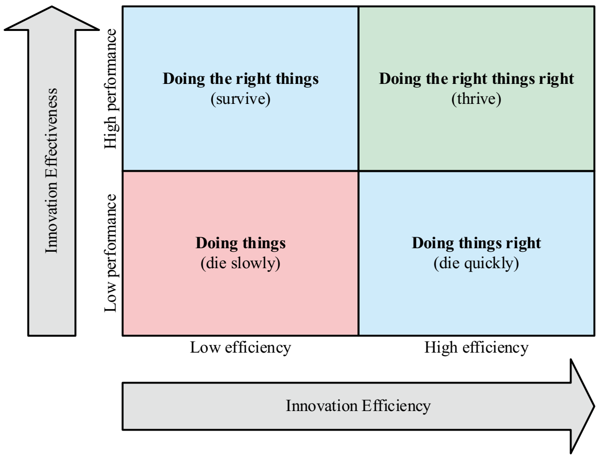


Fig. 7 Effectiveness vs efficiency

regions may have invested in efficient processes, they share a lack of management awareness. Most probably, the vision driving their S4 does not match the realities of the regional ecosystem. On the other hand, the upper left quadrant is related to high performance and low efficiency. This is probably the most common case, where regions do show potential, but never meeting their growth targets due to poor management or inefficient practices. Finally, the upper right quadrant refers to high performance and high efficiency (regions that implement the right strategy efficiently). This is the case of ‘efficacy’, i.e. ‘doing the right things right’ (e.g. highly impactful as well as parsimonious S4).

The previous gap analysis may be used to compare different regional ecosystems. Innovation ecosystems that pursue the right strategy efficiently thrive, since they manage to meet performance targets efficiently. If high performance is not complemented with high efficiency, ecosystems may not attain the growth that they are capable of, while in the opposite case too much attention is given on efficiency and short-term results. Finally, ineffective and inefficient ecosystems may lack a clear vision and strategy.

As an example, the innovation performance/efficiency diagram for a large set of European regions is given in Fig. 8. The relative overall innovation efficiency, as estimated by Carayannis et al. (2015), is represented in the vertical axis, while the horizontal axis refers to regional innovation performance (ordinal categories) provided by RIS (EC, 2014a, b).

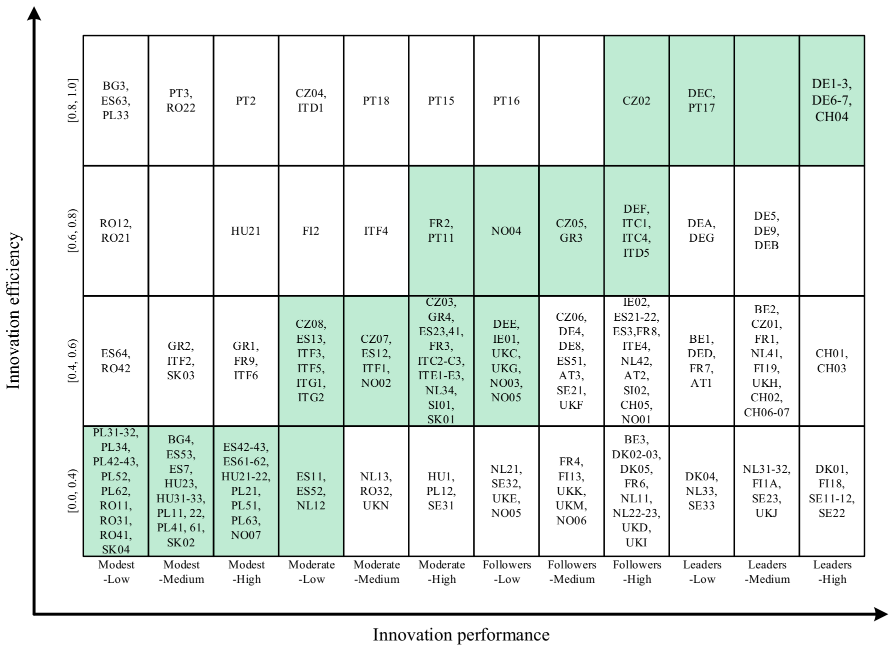


Fig. 8 Relative performance/efficiency diagram for regional innovation systems

The gap between efficiency and effectiveness has been widely discussed in the innovation literature (see Carayannis et al., 2015, 2016). The existence of this gap is justified by the complexity of the innovation process that cannot be accurately modelled. As emphasised by Mahroum and Al-Saleh (2013), it is rather difficult to model the learning, adoption and adaptation of knowledge that take place within the process of innovation (see also Carayannis & Alexander, 2002). Thus, modest investments in innovation inputs may enjoy high innovation outputs and therefore high innovation efficiency (Andersson & Mahroum, 2008). Adopting the existence of such a gap between innovation efficiency and performance, Mahroum and Al-Saleh (2013) propose the measurement of innovation efficacy. They note that while the term innovation efficacy refers to the degree of success of an innovation, innovation efficiency reveals the effort made to achieve that degree of success.

The previous concepts can be adopted in the S4 impact assessment process, by expanding the aforementioned 3PS4 framework. Given its flexibility, the concept of 'effective efficiency' or 'efficacy' of S4 impact assessment can be incorporated in the 3PS4 framework, putting emphasis not only on the impacts but also on the resources used to achieve these impacts.

The previous 3PS4 approach is able to assess RIS3 impact effectiveness. On the other hand, RIS impact efficiency can be estimated as the ratio of Posture, Propensity and Performance to the resources used in RIS3 implementation (i.e. funding). Estimating the ratio of Output, Outcome and Impact to the resources used, it is possible to estimate short-, medium- and long-term RIS3 impact efficiency.

The concept of innovation efficiency and the gap between innovation efficiency and performance is discussed in Mahroum and Al-Saleh (2013) and Ausenda (2003). In the context, RIS3 efficacy refers to the combined levels of efficiency and effectiveness of RIS3 impacts:

- RIS3 Efficacy = Effectiveness + Efficiency or
- RIS3 Efficacy = Effectiveness $\times$ Efficiency

However, as mentioned by several scholars, efficiency tends to have an inverse relationship with performance, i.e. increase in performance is costly in terms of resources used to achieve such improvement.

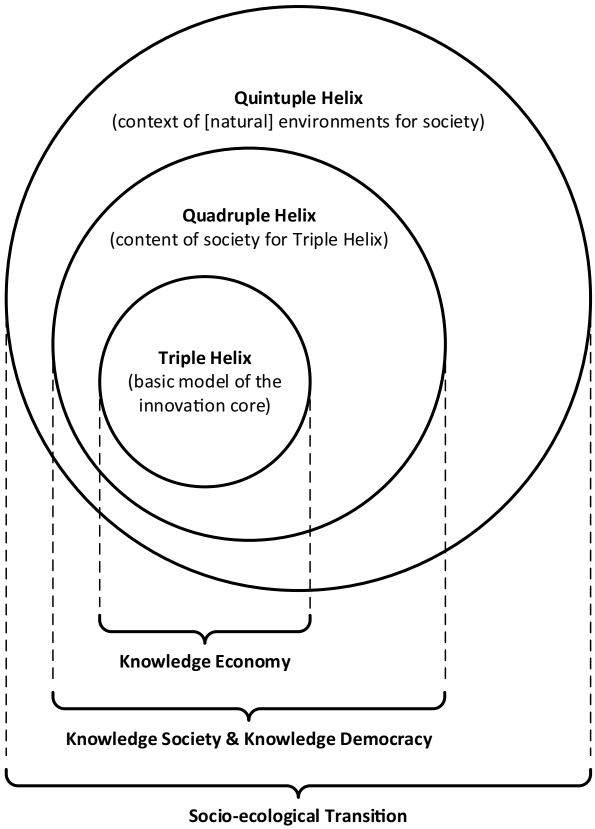
3PS4 Framework and Q2IH Model

The Quadruple Helix model can be considered as an extension of the Triple Helix model of knowledge production, developed by Etzkowitz and Leydesdorff (2000). The Triple Helix may be regarded as a 'core model' for innovation, resulting from interactions in knowledge production referring to universities (higher education), industries (economy) and public authorities (government). On the other hand, the Quadruple Helix model proposed by Carayannis and Campbell (2009a, b) adds to the above stated helices a 'fourth helix' that is identified as the 'media-based and culture-based public'. This fourth helix is associated with 'media', 'creative industries', 'culture', 'values', 'life styles', 'art' and also the notion of the 'creative class'

(Fig. 9). This fourth helix represents bottom-up actions and views of the civil society and it is associated with social networking capabilities that can increase the likelihood and impact of knowledge serendipity and knowledge arbitrage events (happy accidents). '*These happy accidents would then act as triggers, catalysts, and accelerators of exploration and exploitation dynamics that could substantially empower any Quadruple Helix strategy*' (Carayannis et al., 2018b).

The concept of the Quintuple Helix as a model of innovation that can tackle existing environmental challenges has been proposed by Carayannis and Campbell (2009a, b) and Carayannis et al. (2012) (see also Fig. 9). It is based on the application of knowledge and know-how as it focuses on the social (societal) exchange and transfer of knowledge inside the subsystems of a specific state or nation-state. As emphasised by Carayannis et al. (2012), "*the 'nonlinear' innovation model of the Quintuple Helix, which combines knowledge, know-how, and the natural-environment-system together into one 'interdisciplinary' and 'transdisciplinary' framework, can provide a step-by-step model to comprehend the quality-based management of effective development, recover a balance with nature, and allow future generations a life of plurality and diversity on earth…the Quintuple Helix represents a suitable model in theory*

Fig. 9 Knowledge production and innovation (Carayannis et al., 2012)



and practice offered to society to understand the link between knowledge and innovation, in order to promote a lasting development".

The Quadruple/Quintuple Innovation Helix (Q2IH) framework may serve as an architectural innovation blueprint that engages simultaneously five sectoral perspectives: inter-sectoral and intra-sectoral, as well as inter-regional and intra-regional knowledge and learning interfaces. Such a Q2IH approach may empower civil society participation and connect eco-systemic value creators, i.e. innovation users who can become innovation co-creators such as entrepreneurs, inventors, artists and other value generators and do so in an environmentally sustainable (green) manner.

The Q2IH framework has started to gain attention in an attempt to further deepening RIS3 within the EU. In a recent editorial entitled '*From S3 to S4: Towards Sustainable Smart Specialisation Strategies*', Mikel Landabaso Álvarez, Director of Growth and Innovation at the Joint Research Center, Seville, emphasises the prioritisation, governance, stakeholder involvement, and monitoring and evaluation in RIS3 development and implementation (Álvarez, 2020). He also emphasises the sustainability dimension, which is extremely important in order to deliver on the agenda of the EC and achieve competitive sustainability. Specifically, in addition to its economic and social dimension, RIS3 should consider the green dimension of smart specialisation. This is consistent with the current Sustainable Development Goals and the European Green Deal. A Q2IH approach allows to design economically, socially and environmentally robust and modern smart specialisation strategies.

Knowledge production is an important concept in Triple, Quadruple and Quintuple Helix models (Fig. 10). On one hand, the Triple Helix concept is associated with the 'Mode 1' and 'Mode 2' knowledge production. Mode 1 focused on the traditional role of university research in an elderly 'linear model of innovation' understanding, while Mode 2 emphasises a knowledge application and a knowledge-based problem-solving and it is characterised by the following principles: knowledge produced in the context of application; transdisciplinarity; heterogeneity and organisational diversity; social accountability and reflexivity; and 'quality control' (Gibbons et al., 1994). On the other hand, Mode 3 is more inclined to emphasise the coexistence and coevolution of different knowledge and innovation modes (see also Carayannis et al., 2018a). It even accentuates such pluralism and diversity of knowledge and innovation modes as being

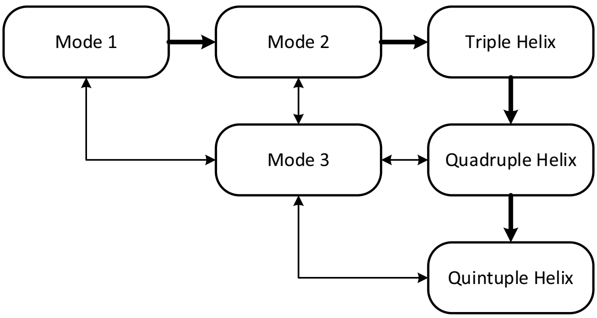


Fig. 10 The evolution of the models of knowledge creation (Carayannis et al., 2012)

necessary for advancing societies and economies. In this context, Mode 3 profiles the architecture of a helically conceptualised, dynamic, complex and non-linear knowledge creation, diffusion and use system endowed with higher order learning (Carayannis et al., 2018b).

The adoption of the Q2IH approach has been studied in the S4 and regional ecosystem literature. S4 aims to exploit the socio-economic assets of a region, which can be developed and exploited worldwide in order to rapidly disseminate knowledge, however, additional work is still needed in order to effectively operationalise entrepreneurial discovery in a way that allows for lessons to be learnt and good practices to be transferred across borders (Edwards et al., 2015). The 'RIS3 Guide' recognises the importance of the Q2IH approach, given that during RIS3 implementation, the activities, results and policy output should be continuously monitored in order to have an effective feedback in the strategy revision process. Such an approach aims to the conceptualisation, contextualisation, design, implementation and evolution of smart, sustainable and inclusive growth-driving entrepreneurship and innovation ecosystems at the regional level (Carayannis & Rakhmatullin, 2014).

The Q2IH approach gives the ability to study the roles of the innovation actors in a regional innovation system. By examining the success factors of a regional innovation system, these studies show evidence for the evolution of the Triple Helix model towards the Q2IH framework. However, as noted by Carayannis et al. (2018b), '*policymakers should ensure mechanisms such as crowd-sourcing and crowd-funding capabilities in instruments and initiatives…embedding these elements may allow for faster, broader, cheaper, and more resilient learning, learning-to learn, and learning-to learn-how-to-learn dynamics*'.

Lopes et al. (2020) presents an analytical literature review on the theoretical contribution of the triple, quadruple and quintuple helix evolution in regional innovation systems. They found that the number of published articles has been steadily increasing over the years (more than 400 articles in 2018) and identified four major research streams: R&D collaborations and innovation, entrepreneurial activity in entrepreneurial university, triple helix dynamics and quadruple helix in regional innovation systems.

However, the number of studies regarding the RIS3 implementation and evaluation under the Q2IH framework is rather limited. In one of few such studies, Chernova et al. (2020) discuss the problems of introducing the Q2IH concept in smart specialisation development in the industrial sector in Russia and Belarus. They present a system of quantitative indicators for assessing the innovative level of industrial development, which, however, do not consider all the aspects of the 3PS4 framework. The main results of the study emphasise the knowledge creation as the most important strategic resource when developing RIS3 and reveal the necessity for developing effective organisational and managerial mechanisms for the interactions of the main actors in innovation processes. In a similar context, Höglund and Linton (2018) and Hasche et al. (2020) investigate the regional smart specialisation initiative from a Q2IH perspective. The authors present a qualitative study regarding the interdependencies of actors, resources and activities in order to give insight to the relationships and the value created in the regional ecosystem. Their findings reveal the complexity of the fourth helix, which should not be limited to users or civil society. Instead, in addition to civil society, it includes triple helix actors in different value added relationships and different roles.

Regarding the RIS3 monitoring and evaluation, Finne (2013) examines the boundary spanning mechanism within the Q2IH framework. The study focuses on three different scopes: the regional specialisation scope (tracking areas of competitive advantages, etc.), the strategic process scope (inclusion of relevant actors, establishment of partnership, etc.) and the micro-level connections scope (knowledge transfer, clustering, etc.). Focusing on knowledge transfer, Finne (2013) notes that new sophisticated models, defining new knowledge as co-generated and innovation as complex interaction processes, are necessary. RIS3 focuses on realigning the functions of the Q2IH framework, which lead to market/knowledge co-evolutionary trajectories (lock-in effects) placed in institutions and practices in a region. In this context, Finne (2013) notes that the adoption of the Q2IH framework is challenging, given potential communication problems and conflicting interests among the actors of the regional innovation ecosystem.

Based on the previous studies, it is evident that additional research is needed in the RIS3/Q2IH framework. As noted by Roman et al. (2020), the Q2IH model is still far from a well-established concept in innovation research and policy, and civil society participation in RIS3 has remained low. Since civil society represents demand-side perspectives, such as innovation users and consumers, as well as non-profit organisations representing citizens and workers, the authors emphasise participatory nature of the entrepreneurial discovery process. In a Q2IH framework, the public and private sector must align their priorities for regional development, and thus, the effective EDP implementation requires the inclusion of civil society in RIS3 (see also Foray et al., 2012).

The Q2IH approach can be incorporated in the 3PS4 framework presented in the previous section. As shown in Fig. 11, a conceptual Q2IH matrix approach can map the different building blocks of the 3PS4 framework (Posture, Propensity, Output, Outcome and Impact) along the four helices (Government, Industry, Academia, Civil Society). For assessing the interdependencies between the four helices and the 3Ps, the major dimensions of the proposed impact assessment framework are included in the cells of this matrix, which correspond to potential impact assessment metrics.

Embedding the 3PS4/Q2IH architecture within a regional and sectoral innovation ecosystem context will allow to facilitate and enable the integration into the S4 impact assessment methodology a more effective and efficient approach with several dimensions such as dynamically complex socio-economic, socio-political and socio-technical configurations of tangible and intangible resources. These resources or assets encompass people, culture and technology attributes with an entrepreneurial and innovative predilection and propensity (see also Fig. 11).

Quadruple Helix

	Posture	Propensity	Output	Outcome	Impact
Government	Entrepreneurial support	Governmental policy Entrepreneurial support R&D support Other support	Funding	Specialisation Value added and investments	Growth Competitiveness Environment
Industry	Researchers Lifelong learning Entrepreneurial perceptions	Entrepreneurial support R&D support Other support Beneficiaries Investments	Innovators Intellectual assets Employment R&D collaborations	Exports Sales Specialisation Value added and investments	Productivity Competitiveness Employment Environment
University	Education Researchers	R&D support Investments	Intellectual assets Employment R&D collaborations	Specialisation	Environment
Civil society	Lifelong learning Entrepreneurial perceptions	Beneficiaries	Employment	Employment	Growth Employment Equality and quality of life Environment

Fig. 11 A quadruple helix perspective of '3P' framework

Towards an Ambidextrous, Robust and Resilient Impact Assessment for Sustainable Smart Specialisation Strategies (AR2IA/S4) Framework

This section studies the robustness and resilience of the 3PS4 impact assessment approach, taking into account the previous frameworks. Given that regions operate in a complex, dynamic, highly uncertain and even disruptive environment, using data analytics and decision-making, information and knowledge may increase intelligence in assessment (smarter impact assessment), resulting in higher resilience in impact assessment and planning (Carayannis et al., 2017).

The 3PS4/Q2IH model may also consider the basic elements of ambidexterity. The Ambidextrous, Robust and Resilient Impact Assessment of S4 (AR2IA/S4) relies on the simultaneous completion of two activities, i.e. the balance between exploration and exploitation. This emphasises the ability of S4 to exploit existing regional competencies while simultaneously exploring new opportunities.

Regions may be considered as open systems operating under conditions of substantial turbulence, risk (known unknowns) and uncertainty (unknown unknowns) and seeking to balance stability and coherence with flexibility and change in pursuit of higher levels of efficacy and excellence. Adopting the relevant innovation literature at the firm level, we may identify four primary regional innovation strategies: knowledge management, exploration, cooperation and entrepreneurship (see for example Reinmoeller & Van Baardwijk, 2005). In addition, as emphasised in the previous section, RIS3 and RIS3 assessment should incorporate social and environmental priorities.

The proposed 3PS4/Q2IH framework underlines the importance of environment and civil society in developing an interdisciplinary and trans-disciplinary framework of analysis for sustainable development. As noted by Carayannis et al. (2012), the Q2IH framework '*incorporates the principles of and requires a coevolution with the knowledge society and the knowledge democracy for knowledge creation and Innovation…it is ecologically sensitive as it emphasizes on the socioecological transition of society and economy*'.

A 3PS4/Q2IH framework that enables AR2IA/S4 via triple-bottom-line (financial, social, environmental) sustainable entrepreneurship and triple-top-line (ethical, effective, efficient) robust competitiveness is shown in Fig. 12. In this figure, a sectoral and regional socio-economic resilience and organisational intelligence cycle shows that commitment to resilience commonly leads to active awareness that corresponds to openness towards new information and disposition to assess context from different angles.

The 3PS4/Q2IH impact assessment approach incorporating design thinking and agile methodology modalities is at the heart of this framework, illustrating the connection between sustainable entrepreneurship, competiveness, knowledge acquisition and learning competencies.

More specifically, as shown in Fig. 12, given that the 3PS4/Q2IH framework aims to an effective and efficient RIS3 impact assessment, the linkages between resilience and intelligence are illustrated as a cycle, where knowledge acquisition and learning competencies form and enhance a region's intelligence, leading to robust competitiveness and sustainable entrepreneurship. This in turn advances resilience through new knowledge acquisition, which then enriches learning competencies (Carayannis & Campbell, 2009a, b, 2011). This resilience-intelligence cycle is consistent with several studies in organisation learning (see for example Levinthal & Rerup, 2006) that emphasise the importance of openness towards new information and disposition to assess context from different angles. As noted by Carayannis et al. (2017), '*higher-order technological learning competences along with exogenous and endogenous strategic knowledge serendipity and arbitrage dynamic capabilities that are linked and enabled by knowledge, information and data analytics tools, methodologies and modalities, reside at the heart of solving the dilemma of identifying and*

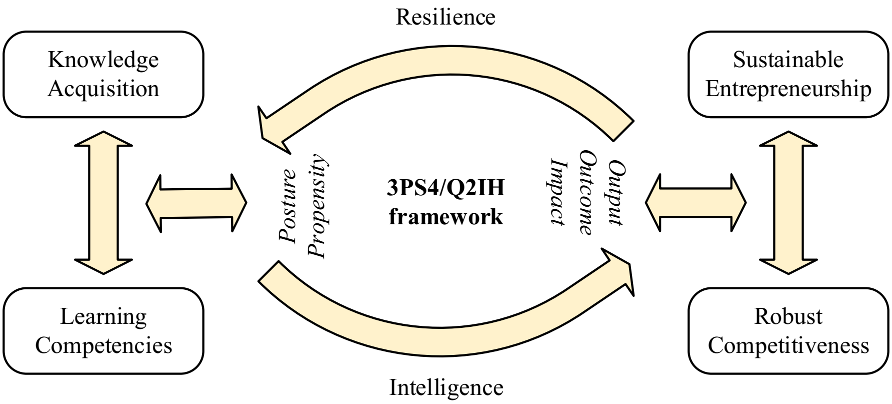


Fig. 12 A resilient 3PS4/Q2IH framework (adapted from Carayannis et al., 2017)

implementing sets of routines and supporting artifacts aimed at delivering specified results that might include, for example, organizational resilience, robustness or sustainability…these competences and dynamic capabilities help form and leverage organizational intelligence into superior resilience[4]'.

In the previous conceptual framework, assessing posture that are associated with the ability of regional entrepreneurial ecosystems to engage in innovative activities as an exogenous factor to the smart specialisation interventions may enhance and impact regions' knowledge acquisition and learning capabilities. Similarly, propensity, which is an intangible reflection of processes, routines and capabilities established within an ecosystem, is oriented to new knowledge and learning competencies. On the other hand, performance (short-, medium- and long-range results) in the context of the Q2IH framework is associated with sustainable entrepreneurship and competiveness.

The 3PS4/Q2IH model may also consider the basic elements of ambidexterity. The Ambidextrous, Robust and Resilient Impact Assessment of S4 (AR2IA/S4) relies on the simultaneous completion of two activities, i.e. the balance between exploration and exploitation. This emphasises the ability of S4 to exploit existing regional competencies while simultaneously exploring new opportunities.

In an ambidextrous context, both exploitation and exploration should be considered simultaneously.

Several scholars argue that despite their differences, exploration and exploitation are learning activities (Baškarada & Watson, 2017; Tushman & O'Reilly, 1996; Yigit, 2013). However, exploitation and exploration are linked to different concepts. As noted by Yigit (2013), '*exploitation is described as the things related to efficiency, production, refinement, choice, selection, implementation and execution while on the other hand, exploration is described as things which are related to innovation, flexibility, discovery, experimentation, search, variation, risk taking, play and choice*'. Based on this, the main challenge is to balance between exploration and exploitation. '*Systems involved in only exploitation without exploration are similar to trying to find out an optimum state within their own system internally… focusing on exploration too much may cause high expenses of experimentation without any financial output, while focusing too much on exploration it may lead organization to competence trap*'.

Although ambidexterity focuses on the aforementioned balance between exploration and exploitation, other studies give emphasis on the capability of managing complex and conflicting components, flexibility and efficiency, radical and continuous innovations, alignment and adaptation; thus, the major challenge is to simultaneously manage these inferring activities (Adler et al., 1999; Gibson & Birkinshaw, 2004; Tushman & O'Reilly, 1996). In the context of RIS3 implementation, ambidexterity demands the cooperation of the regional ecosystem actors. This is rather challenging, giving the competitive regional environment and the conflicting demands from adaptation and alignment.

[4] KID Analytics for Organizational Intelligence or KID4I (Carayannis, 1998).

Ambidexterity in a regional innovation ecosystem is closely related with spatial ambidexterity, which is defined as '*the extent to which firms jointly pursue technology exploration and exploitation in spatial proximity*' (Geerts et al., 2017). In this context, spatial ambidexterity examines how additional benefits are created when technology exploitation and exploration are closer geographically. This is justified by the integration of exploitative and explorative activities that can benefit from knowledge exchange within the regional ecosystem boundaries. However, effective ambidexterity is based on both separation and coordination: while coordination aims to co-create and share the vision about the future of the region to different actors, separation allows the two distinct processes of exploitation and exploration to develop separate cultures, processes and routines in subunits (Carayannis et al., 2019).

Based on the dynamic nature of ambidexterity, Carayannis et al. (2019) note that exploitation becomes more vital in a stable environment and exploration becomes more vital in an unstable environment. Figure 13 illustrates this dynamic balancing process of exploration and exploitation. This framework can consider external and internal uncertainties associated with the implementation of S4.

As noted by Fu et al. (2018), ambidexterity-oriented strategic decisions have a positive effect on innovative ambidexterity. Innovative ambidexterity is associated with both exploration (discontinuous innovations) and exploitation (incremental innovations). '*Ambidextrous-oriented decisions facilitate the enforcement of innovation oriented and cost oriented processes which act to counterbalance each other and ensure that a firm is both cost-effective and innovative. Cost-oriented and innovation-oriented decisions structure cultural implementation mechanisms that mediate the effect of ambidexterity-oriented decisions and innovation ambidexterity*' (Carayannis et al., 2019). Smart specialisation should be linked with innovative ambidexterity in order to increase regional adaptability (region's ability to react to changes in the global environment). In this context, regions' ability to effectively allocate resources, encourage collaboration within the regional ecosystem and maximise efficiency may lead to cost-effective policies.

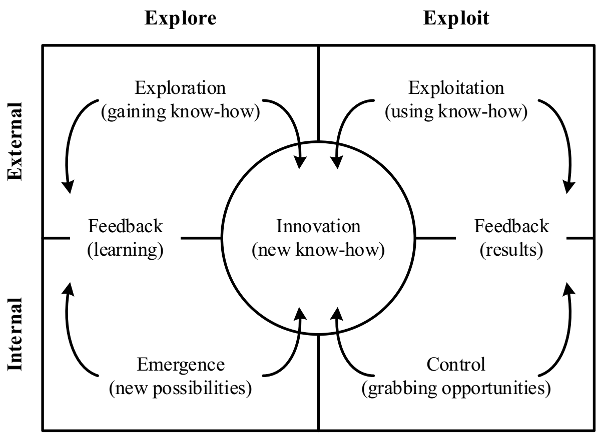


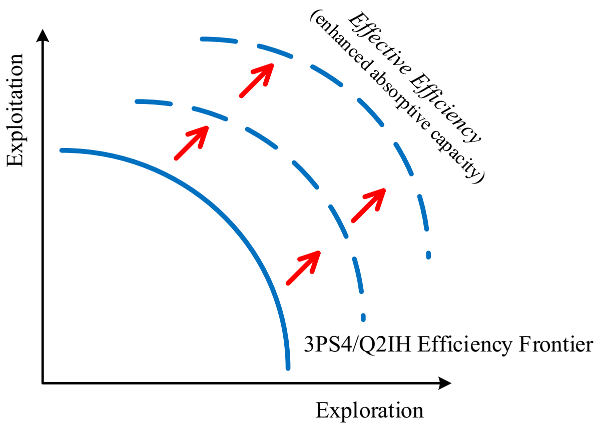
Fig. 13 The role of knowledge in balancing exploration and exploitation (March, 1991)

Knowledge flows and processes are important in the AR2IA/S4 framework. In this context, learning adoption gives the ability to look outside a region's closest sphere of knowledge, but this increases costs and uncertainties. Using the study of Chandler and Hwang (2015) that presents an understanding about the identification and process of knowledge, it is possible to examine alternative ambidextrous strategic orientations:

1. Local imitation (use internal experiences or imitate a geographically proximate region)
2. Distant imitation (rely on distant sources to imitate practices without adapting ideas in the regional context)
3. Local configuration (rely on internal or familiar sources to adapt ideas in the regional context)
4. Distant reconfiguration (rely on distant sources to adapt ideas in the regional context)

The efficacy concept is directly linked with the AR2IA/S4 framework, given that efficiency can be defined as the balance between exploration and exploitation. As shown in Fig. 14, efficiency regions are located in the 3PS4/Q2IH efficiency frontier. Efficient regions have optimised their ratio of outputs to inputs and appear to have a relative good competitiveness level. However, by pushing out the efficiency frontier, regions are able to reconcile exploration and exploitation on a higher level through the development of new technologies and innovations (see Birkinshaw & Gupta, 2013; Gusenleitner, 2016). These regions are able to innovate in such a way as to move the frontier outward creating higher ambidexterity. Moving the efficient frontier outward increases effectiveness, and therefore, Fig. 14 gives a graphical representation of the efficacy concept (i.e. effective efficiency). The 3PS4/Q2IH efficiency frontier is related to regional absorptive capacity, i.e. the ability to identify, acquire, assimilate and implement new knowledge to create new opportunities (Fig. 14). Higher levels of ambidexterity may lead to increased absorptive capacity (Chang et al., 2019).

Fig. 14 The 3PS4/Q2IH efficiency frontier (adapted from Carayannis et al., 2019)



The concept of ambidexterity has been linked with the role of design in strategic management. In this context, the concept of 'Design Thinking' (DT) has been developed, aiming to solve ill-defined and complex problems in a creative and innovative way (Brown, 2005). Although DT has been initially based on cognitive models as the basis for design activities that may be transformed into normative guidelines for creative problem-solving, the concept has been expanded in various disciplines. In innovation practice, for example, DT is defined as a human-centred approach to innovation that draws from the designer's toolkit to integrate the needs of people (desirability), the possibilities of technology (feasibility) and the requirements for business success (viability) (Brown, 2008), as shown in Fig. 15. In smart specialisation, following Hehn and Uebernickel (2018), the dimension of desirability emphasise the need for systematically involving the stakeholders of the regional innovation ecosystem, through the entire RIS3 development, implementation and revision processes. On the other hand, feasibility demands an exploration of regional capabilities to translate the human-centred requirement into an effective smart specialisation strategy. Finally, viability entails evaluating market opportunities and their compliance with the regional priorities that consider current and future strengths and weaknesses.

The five major stages of DT in complex problems that are ill-defined or unknown are the following (Dam & Siang, 2020):

1. Empathise (gain an empathic understanding of the problem, engaging and empathising with people to understand their experiences and motivations)
2. Define (define the problem as a problem statement in a human-centred manner)
3. Ideate ('think outside the box' to identify new solutions to the problem statement and look for alternative ways of viewing the problem)

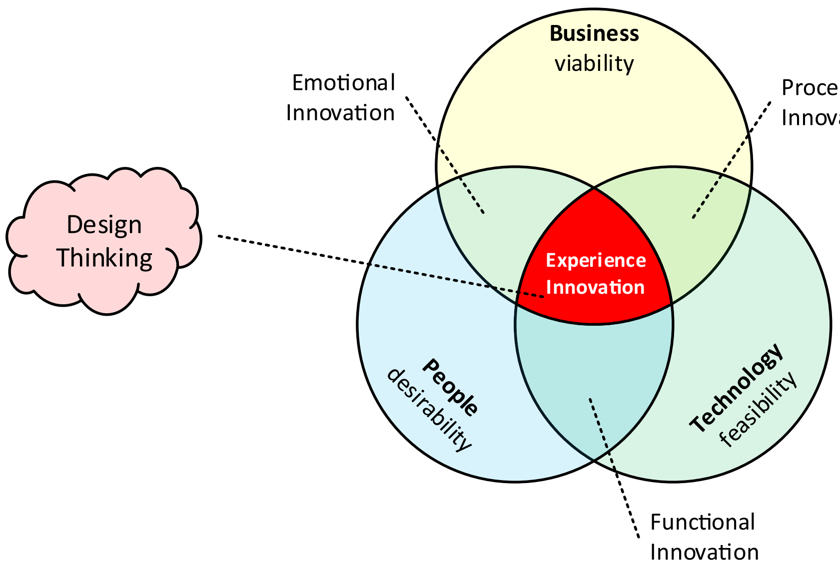


Fig. 15 Design innovation

4. Prototype (investigate the problem solutions generated in the previous stage in an experimental phase in order to identify the best possible solution for each of the problems identified)
5. Test (test the best solutions identified during the prototyping phase in an iterative process that can redefine one or more problems and inform the understanding of the users; the conditions of use; how people think, behave and feel; and to empathise)

It should be noted that DT is a flexible and non-linear process; thus, the previous steps are not always sequential. As noted by Dam and Siang (2020), the DT stages should be better considered as different modes in an innovative problem-solving procedure.

As previously noted, ambidexterity is new different learning behaviours (March, 1991): exploration (search, variation, risk-taking, experiment, innovation, etc.) and exploitation (refinement, efficiency, implementation, etc.). In this framework, Zheng (2018) examines ambidexterity under the lens of learning and innovation and suggests DT as a tool to balance and synergy exploration and exploitation. More specifically, ambidexterity is defined as the balance and interaction of exploratory learning and exploitative learning, while the antecedent of ambidexterity and the consequence of ambidextrous learning are suggested to be DT and ambidextrous innovation, respectively (Zheng, 2018). DT is able to tackle dualism since it is believed as the balance between analytical thinking and intuitive thinking (Brown & Martin, 2015). As Zheng (2018) argue *'it is reasonable to expect that DT is an approach to achieve ambidexterity'* and thus, by explaining DT with the lens of ambidexterity, DT may be examined from a strategic rather than a design perspective.

Agile development can also be associated with ambidexterity. Agile is defined as an iterative and incremental (evolutionary) approach to development which is performed in a highly collaborative manner by self-organising teams within an effective governance framework with 'just enough' ceremony that produces high quality solutions in a cost effective and timely manner which meets the changing needs of its stakeholders.,[5] Based on a systems development life cycle, the major stages of an agile approach include the following (Fig. 16):

- Initial planning (setting the overall direction and purpose of the project)
- Requirements (gather and document all the possible requirements)
- Analysis and design (analyse potential tools and solutions, and provide an easy to navigate structure that allows for scalability, efficiency and assurance of user experience)
- Implementation and testing (implement the previous planning, analysis and design stages in order to test solutions)
- Deployment (implement the selected developed solutions)

[5] http://agilemanifesto.org.

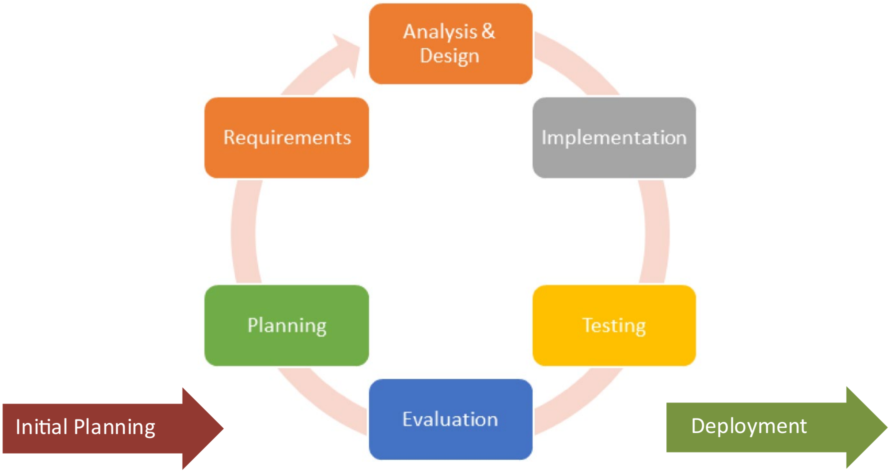


Fig. 16 Iterative and incremental agile development process

- Evaluation (evaluate the quality of the executed solution to stakeholder expectations and requirements)
- Planning (revise the scope and the purpose of the project based on the evaluation results)

Agile reduces risk by bringing understanding and development closer together. As shown in Fig. 17, compared to traditional development, the major advantages of an agile process can be summarised as follows (Royle, 2017):

- Visibility: It is related with the active involvement of end users in order to assure that that there is high visibility over the whole process and not just at the beginning and end (common in traditional development processes).
- Adaptability: Contrary to traditional development, where all of the specifications are written up front, agile development is able to adapt and change direction with minimal impact to the final result.
- Business value: The iterative nature of agile means that features are delivered incrementally, meaning that value may be released sooner. In general, an agile approach allows for business to fix costs and flex scope.
- Risk: Agile is able to manage and reduce risks, given its iterative nature (iterations are time-boxed; thus, the risk of developing an incorrect or incomplete feature is significantly reduced). Also, embedding quality and testing in an iterative development process can also reduce risks.

The 'agile innovation' concept has emerged by embedding agile approaches and innovation processes. In this context, agility focuses on the value and flow in all processes, freeing resources and integrating them in the innovation design and implementation process. As noted by Wilson and Doz (2011), agile innovation aims to optimise the efficiency and effectiveness of innovation activities. Castrén and Gylling

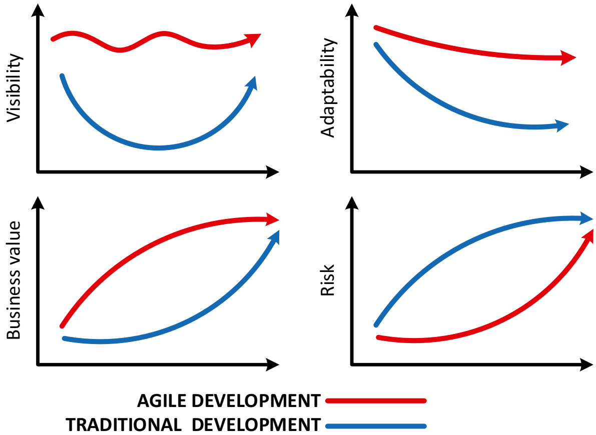


Fig. 17 Traditional vs agile development (Royle, 2017)

(2016) provide an empirical investigation of the linkages between agility and ambidexterity. Specifically, analysing several case studies, they propose that the characteristics of agile organisations lead to a specific approach to ambidexterity that further leads to business units, which are encouraged to simultaneously exploit and explore. These exploitative and exploratory activities can be further brought back and distributed to the organisational level and applied in the future.

Based on the work by Carayannis et al. (2019), the AR2IA/S4 framework can be expanded, adopting a 7P approach. The ambidextrous 7P framework is a multi-stage approach that uses a 7P stage gate model (Patient, Persistent, Persevering, Proactive, Predictive, Preventive and Preemptive). The definition of the 7Ps in the context of a regional innovation ecosystem is given in Table 1 (see also Haned et al., 2014; García-Morales et al., 2008; Bateman & Crant, 1993).

The first three Ps (Patient, Persistent and Persevering) refer to attitudinal and the last four (Proactive, Predictive, Preventive and Preemptive) to behavioural attributes. Although the 7Ps constitute a multi-stage approach, each step corresponding to the 7Ps is associated with forward, backward and self-loops.

The 7Ps approach may extend the proactive components of regional behaviour (see the study of Bateman & Crant, 1993 for organisational behaviour). This architecture, as shown in Fig. 18, is a multi-stage approach providing a strategic integration of efficiency frontier, the different elements of organisational ambidexterity (i.e. exploration and exploitation) and learning capabilities. This multi-stage approach may be linked to the major RIS3 development steps. Figure 18 presents an example of such linkages, although several other alternative relations between 7Ps and RIS3 steps are possible.

Figure 19 shows the integration of the 3PS4, Q2IH and 7P frameworks that forms an ambidextrous and resilience approach, highlighting the nature and dynamics of the relationship between the components and stages of the AR2IA/S4 methodology in its configurations across an ambidextrous and resilient efficacy frontier driven by

Table 1 7Ps in the S4 context

S4 steps	Concept	Comments
Analysis **Governance**	**Patient**	Patience enables regions to realise internal and external obstacles whose resolution requires an extended period of time; patience is important in creating 'learning regions' and indirectly shows evidence regarding region's belief in a vision that leads to a consistent emphasis on purpose
Analysis **Governance** **Vision**	**Persistent**	Given that regional economic transformation is an important part of RIS3, persistent allows regions to transform their innovation ecosystem creating an environment conducive to innovation and persistence in both exploration and exploitation
Governance **Vision** **Priorities**	**Persevering**	Persevering allows the effective and efficient implementation of RIS3, since it refers to a continued effort to do or achieve something despite difficulties, failure or opposition; persevering is related to absorptive capacity, innovation and organisational learning
Priorities **Policy mix** **Monitoring**	**Proactive**	A proactive orientation may assess a situation and devise a course of action consistent with the values and beliefs within a regional innovation ecosystem; RIS3 impact assessment results are important to create proactive regions
Priorities **Policy mix** **Monitoring**	**Predictive**	Given the importance of considering future changes in strategy formulation, predictive regions have the ability to analyse emerging areas of business or potential internal and external disruptions; this is an effective way to consider high risk and uncertainty
Policy mix **Monitoring**	**Preventive**	Under RIS3, prevention enables regions to avoid undesirable situations and allows for faster adaptation in an evolving environment; preventive regions are characterised by high level of resilience
Policy mix **Monitoring**	**Preemptive**	Regions that transform preemptively, in anticipation of future change, are more successful than those that transform reactively; larger structural reforms are appeared to be necessary in preemptive regions

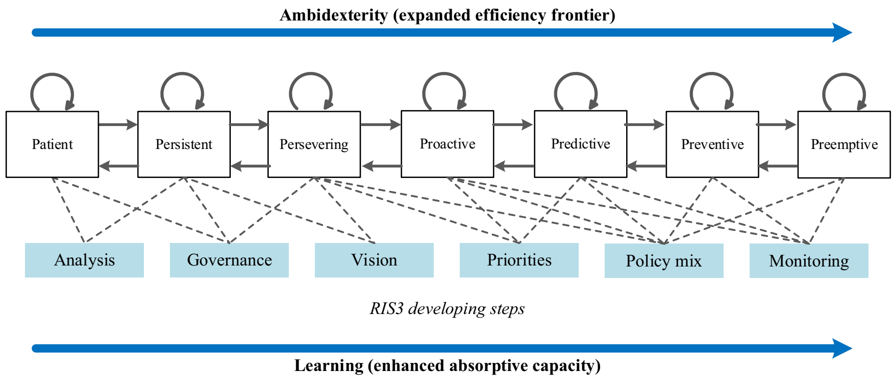


Fig. 18 Multi-stage ambidextrous 7Ps and RIS3 development

higher order learning. The AR2IA/S4 'cubes' consider the different components of the 3P, Q2IH and 7P frameworks, which for higher level of learning and ambidexterity can push out the efficiency frontier, achieving therefore an efficacy RIS3, by increasing regional exploration and exploitation capabilities.

This ambidextrous cybersecurity approach justify the need to move from 'tactical fragmentation' to 'strategic integration' of mindsets, behaviours and institutions to better enable effectiveness and efficiency (Carayannis & Korres, 2013). Under

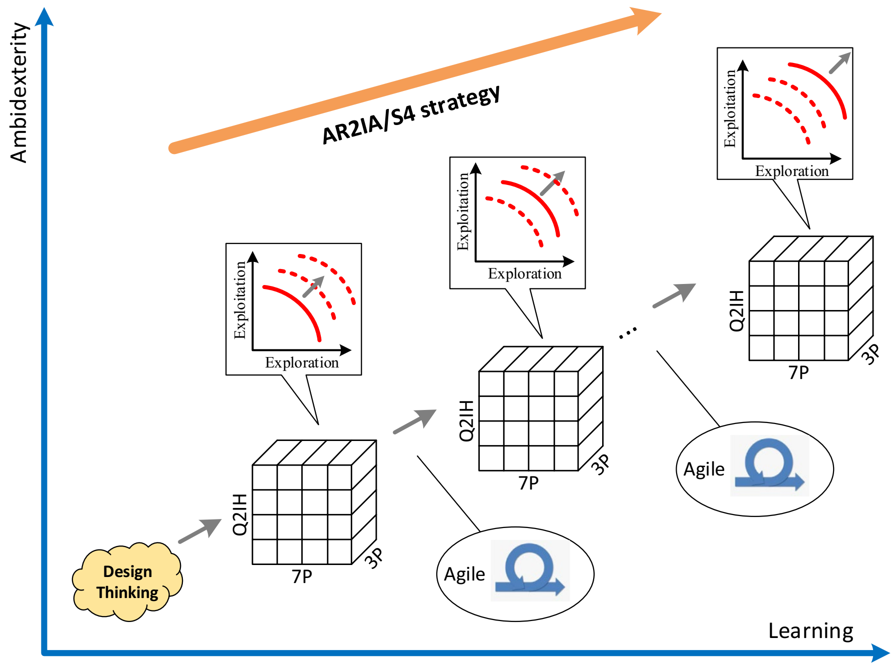


Fig. 19 Ambidextrous 7Ps and the AR2IA framework

the Q2IH framework and viewing a regional ecosystem as a helix, it is possible to model, explicate and predict the nature and dynamics of the role and behaviour of the constituent elements (i.e. government, university, industry, civil society and environment). As Carayannis et al. (2018a, b) note, '*such an approach links an ecosystem and the Q2IH framework and offers a facilitator and enabler of more effective and efficient socio-economic, socio-political and socio-technical dynamic and complex configurations of tangible and intangible resources with an entrepreneurial and innovative predilection and propensity*'.

The AR2IA/S4 framework can enable a locus-centric and triple-bottom-line-centric entrepreneurial process of discovery followed by development, exploration, exploitation and deployment (DEED). In this context, regions can be considered as eco-systemic agglomerations of organisational and institutional entities or stakeholders with socio-technical, socio-economic and socio-political conflicting as well as converging (co-opetitive) goals, priorities, expectations and behaviours that they pursue via entrepreneurial DEED actions, reactions and interactions (Carayannis et al., 2018a, b). All these intertwine via a helical, dynamic, complex, non-linear, self-similar (fractal) and self-organising higher-order learning architecture of a knowledge production system.

Fig. 20 The AR2IA/S4 toolbox

Concluding Remarks

Reforming smart specialisation towards sustainability is an attempt to further deepening RIS3 within the EU. The concept of sustainable smart specialisation (S4) focuses on the major three pillars of sustainability (society, economy and environment) in order to deliver on the agenda of the EC. In this context, smart specialisation should emphasise the stakeholder involvement, economic competitiveness and environmental sustainability (e.g. SDGs, European Green Deal).

Smart specialisation is an integrated, place-based economic transformation agenda, which is still in an 'experimental stage' (Foray et al., 2012). In addition, it may be affected by endogenous and exogenous risks and uncertainties. Such disruptions can have severe socio-economic, socio-political and socio-technical impacts. The recent COVID-19 crisis is a characteristic example that justifies the necessity of a new S4 approach with implications for policies, practices and politics. Reforming smart specialisation towards S4 is key in recovering in post-pandemic era.

In this framework, the impact assessment of S4 is crucial for the further development and evolution of smart specialisation. The main aim of this paper is to outline a methodology for Ambidextrous Resilient and Robust Impact Assessment (AR2IA) of S4 under high risk and uncertainty. The proposed AR2IA/S4 framework can been as a toolbox that can achieve a functional and organic integration of ambidextrous higher order learning in S4, thus attaining in a resilient and robust manner higher levels of efficacious performance. The AR2IA/S4, as presented in Fig. 20, includes the following components:

- 3P framework: The framework simultaneously considers the Posture, Propensity and Performance related to innovation capabilities. It based on the idea that S4 impact assessment should be based not only on the final outcome of potential smart specialisation interventions, but also on the current conditions and future capabilities of regional entrepreneurial ecosystems.
- Fuzzy MCDA: The proposed fuzzy Multiple Criteria Decision Analysis approach is able to represent vagueness and imprecise information during the impact assessment processes. Fuzziness can be incorporated in the assessed targets, the examined data or even the evaluation process.
- Q2IH models: The adoption of a Quadruple/Quintuple Innovation Helix approach aims to the conceptualisation, contextualisation, design, implementation and evolution of smart, sustainable and inclusive growth-driving entrepreneurship and innovation ecosystems at the regional level.
- Ambidexterity and efficacy: The AR2IA/S4 framework relies on the simultaneous completion of two activities, i.e. the balance between exploration (i.e. explore new opportunities) and exploitation (i.e. exploit regional competencies), which can increase S4 efficacy (effectiveness and efficiency).
- 7P framework: An ambidextrous 7P stage gate model (Patient, Persistent, Persevering, Proactive, Predictive, Preventive and Preemptive) provides a strategic integration of the efficiency frontier, the different elements of ambidexterity and learning capabilities.

- Design Thinking: Design Thinking is a human-centred approach to innovation aiming to solve ill-defined and complex problems in a creative and innovative way. It integrates the needs of people, the possibilities of technology and the requirements for business success in the development of the AR2IA/S4 framework.
- Agile methodology: The AR2IA/S4 framework can be implemented using an agile (iterative and evolutionary) approach in order to increase value, adaptability and involvement of regional stakeholders, while reducing risks.

The development of an impact assessment methodology is a challenging task, given the unavailability of data regarding the impact of the ongoing structural funds cycle and the fact that the major objective of smart specialisation, i.e. regional economic transformation, is long-lasting process and in most cases the impact has not been observed yet. In addition, each region has its own targets, priorities, preferences and different development levels. The outlined AR2IA/S4 toolbox, using a design thinking and agile methodology operationalization framework, is able to provide an ambidextrous, robust and resilient architecture of S4 impact assessment, considering risks and uncertainties, while taking into account an efficacy evaluation of sustainable smart specialisation strategies.

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