European Commission

Framing R&I for transformative change towards sustainable development in the European Union

R&I PAPER SERIES
WORKING PAPER 2020/11

Mario BIGGERI, Andrea FERRANNINI

Independent Expert Report

Research and Innovation

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European Commission
Directorate-General for Research and Innovation
Directorate A — Policy & Programming Centre
Unit A.1 — Chief Economist – R&I Strategy & Foresight

Contact Román Arjona, Chief Economist and Head of Unit A1
Roberto Martino, Unit A1

Email Roman.ARJONA-GRACIA@ec.europa.eu
Roberto.MARTINO@ec.europa.eu
RTD-ECONOMIC-ANALYSIS@ec.europa.eu
RTD-PUBLICATIONS@ec.europa.eu

European Commission
B-1049 Brussels

Manuscript completed in July 2020.

PDF ISBN 978-92-76-20816-7 doi:10.2777/503127 KI-BD-20-017-EN-N

Luxembourg: Publications Office of the European Union, 2020

EUROPEAN COMMISSION

Framing R&I for transformative change towards sustainable development in the European Union

Mario Biggeri[a] and Andrea Ferrannini[b]

[a]University of Florence and and ARCO (Action Research for CO-development)
[b]University of Ferrara and ARCO (Action Research for CO-development)

Working paper

2020 Directorate-General for Research and Innovation EN

TABLE OF CONTENTS

EXECUTIVE SUMMARY 3

1 Introduction 7

1.1 COVID-19 and sustainable development challenges 7

1.2 The importance of analysing the nexus between Research & Innovation and sustainable development 8

2 Reconciling Planet, People and Prosperity in the notion and measurement of sustainable development 10

2.1 The notion of sustainable development 11

2.2 The measurement of sustainable development 16

3 The linkage between R&I and sustainable development 17

3.1 A new framing on R&I 18

3.2 The Agenda 2030 for sustainable development as an overarching vision and direction for transformative R&I 21

3.3 A new collective awareness on R&I processes 23

3.4 The current measurement of R&I for sustainable development 24

4 A new overarching vision and narrative for R&I policy in Europe 25

5 Roadmap and policy recommendations for a new approach 30

6 Conclusions 39

7 References 40

8 APPENDIX 1: Selected datasets and indicators on sustainable development 49

9 APPENDIX 2: Selected datasets and indicators on R&I 52

EXECUTIVE SUMMARY

Nowadays, our global, national and local societies are at a crossroads. In the past few months, the COVID-19 pandemic has been making evident the vulnerabilities of our societies. Almost the whole world has been suddenly and simultaneously questioning – probably for the very first time in recent history – the capacity of our healthcare, food, housing, production, education, mobility, care and solidarity systems (among others) to meet people's needs. Therefore, we live in times urging deep structural transformations towards new ways of structuring our economies and production systems, a new social dynamics and more sustainable and inclusive forms of development.

Within an inevitable revamping attention on the need for public action and government intervention, the importance of Research and Innovation (R&I) policies to simultaneously dealing with economic competitiveness as well as with public health, social inclusion and environmental protection is undeniable.

In recent times and already before COVID-19, it was argued that R&I policy plays a pivotal role for the pursuit of – and transition towards – sustainable development, whose integrated notion balances the three dimensions of sustainability – i.e. the economic, social and environmental.

Within the global debate on sustainable development as an integrated and indivisible concept, a new framing on R&I for transformative change has been gaining momentum. This offers the opportunity to reconcile productivity enhancement and value-generation with inclusiveness, public health and environmental protection, in order to pursue shared prosperity and human flourishing.

This report discusses to what extent and how R&I policy in the post-COVID scenario can represent a leverage for transformative change by empowering individuals and communities to meet social needs and addressing the issues of sustainable and inclusive societies. In particular, it provides theoretical arguments and policy recommendations to design a roadmap for a new approach on R&I policies at European level.

Today, the overarching vision and narrative for R&I policies in Europe are surely given by the commitment towards a prosperous and sustainable Europe by 2030 and by the political guidelines and first strategies issued by the new European Commission 2019-2024: from the European Green Deal, the Annual Sustainable Growth Strategy 2020 and the European strategies on digitalisation to the EC proposal for a response to the COVID-19 outbreak and a major recovery plan.

A roadmap for a new approach on R&I policies is proposed in this report, in order to contribute to transforming the EU into a fair and prosperous society and putting its economy on a more sustainable and inclusive path.

This roadmap is composed by a set of policy recommendations conceived as preliminary suggestions for policy makers in the R&I policy domain at EU, national and subnational level.

Mission for R&I policy

- *We recommend to adopt a mission for R&I policy aiming at accelerating the transition towards a sustainable, fair and prosperous future for people and planet by achieving the desired scientific, technological and societal impact.*

Societal challenges and R&I fields

- *We recommend to discuss and select the main societal challenges through collective appraisal, participatory democracy and co-creation mechanisms, opening up for many priorities and keeping the policy space adaptive and timely responsive to changing conditions;*

- *We recommend to avoid a silos-based approach in terms of standard R&I fields, by combining investments in different fields to open up for new knowledge and new solutions.*

Vectors for action

- *We recommend to simultaneously pursue three vectors for action (i.e. on innovation, on processes, on behaviours and values) within an overarching R&I strategy, in order to advance a "collective/systemic human intelligence" able to process knowledge, information and data and apply new solutions.*

Principles for R&I policy design and implementation

- *We recommend to involve a wide set of actors within our societies to use collective intelligence for identification of evident and latent needs, knowledge brokering and social creativity, through co-creation, co-implementation, co-assessment, and citizen-oriented communication & dissemination;*

- *We recommend to continuously nurture the engagement of communities of inquiry, communities of practices, and communities of learners, opening-up to constructive dialogues within and among different generations;*

- *We recommend to link all R&I investments with specific, targeted and concrete goals for sustainable human development;*

- *We recommend to make R&I policies and investments adaptive, in the sense of evolving over time according to changing conditions and being able to face future and unpredicted crisis, in order to continue stemming unprecedented sustainability transformations;*

- *We recommend to build temporary spaces for actors working together on a variety of concrete pathways, in order for them to design and experiment new solutions and processes, acknowledging the importance of new shared expectations and visions, new networks, new markets to eventually challenge dominant practices in mainstream markets and institutions;*

- *We recommend to ensure the understanding, willingness for the uptake and absorption of new knowledge, novel solutions and management processes by public institutions, markets and citizens.*

Enabling conditions

- *We recommend to establish a clear, shared and long-term mandate underlying R&I policy towards an integrated vision of sustainable development;*

- *We recommend to ensure a systemic and multi-disciplinary perspective in research and in policy design, favouring the continuous combination of disciplines and knowledge caches and the pursuit and exploitation of inter-sectoral opportunities within missions to tackle societal challenges;*

- *We recommend to ensure that innovation policy for sustainability transitions is addressed in terms of policy mixes, as their comprehensiveness and cross-sectoral nature call for a "whole-of-government" engagement and a "whole-of-society" transformation;*

- *We recommend to ensure policy coherence within the on-going evolution of R&I policy, keeping all policy objectives, targets and tools moving towards the same integrated vision of sustainable development;*

- *We recommend to ensure multilevel governance of R&I policy through the reconciliation of bottom-up and top-down policy approaches and the mobilisation of international R&I cooperation and investment;*

- *We recommend to ensure open and inclusive spaces for dialogue, participation and public scrutiny in order to nurture social creativity, active citizenship and collective empowerment, helping actors to navigate conflictual views and to generate trust in co-creation processes;*

- *We recommend to ensure transparency and compliance with ethical guidelines in all R&I initiatives.*

Risks underlying R&I policy

- *We recommend to devote continuous and strong attention to anticipate, avoid and deal with several risks concerning, among others, trade-offs, low predictability and heterogeneity of long-run effects, ethical concerns, power and control of knowledge, rent-seeking behaviours.*

Metrics and indicators

- *We recommend to adopt an expanded indicator framework to measure the contribution of research and innovation to sustainable development;*

- *We recommend to enable the structured engagement among sustainable development experts, measurement specialists, statistical offices and policy-makers in charge of designing, implementing and monitoring R&I policy at different levels, in order to set new feasible and appropriate indicators, methodologies and standards;*

- *We recommend to identify tailored international and national targets to concretely foster R&I initiatives for sustainable development and keep all actors accountable for their efforts.*

All in all, in this report we argue that reconciling the objectives of economic, social and environmental sustainability requires the enhancement a new integrated vision and narrative underlying Research and Innovation policies in the European Union. Indeed, it is nowadays clear that not only do economic growth, productivity increase and R&I performances matter, but also their quality and directionality matter, especially to tackle the structural vulnerabilities of our societies made evident by the pandemic. Depending on the capacity to make economic growth, social inclusiveness and planetary boundaries compatible, they may lead to an increased ability to expand human capabilities, respond to collective needs and tackle societal challenges, or, vice versa, to the exacerbation of exclusionary and environmentally-detrimental trends.

This requires an expanded framing for R&I with new missions, objectives, stakeholders, resources and processes to empower individuals, communities and societies with innovative solutions, expanded knowledge and information, raised awareness and enhanced capacities to pursue sustainable human development.

1 Introduction

1.1 COVID-19 and sustainable development challenges

Nowadays, our global, national and local societies are at a crossroads. On the one side, the most dramatic global public health emergency of our time and its subsequent economic, social and human crisis is coupled with the productivity puzzle characterising many mature economies, increasing multidimensional inequalities at individual and place level, along with 'hyperglobalisation', pervasive financialisation, new forms of exploitation and extraction of limited resources, widespread and increasing nationalisms, increasing demographic pressures in urban areas, and – above all – the passing of the ecological limits of our planet[1] (Stiglitz et al., 2009; Stiglitz, 2012; Sachs, 2015; Fleurbaey et al., 2018; Martin et al., 2018; OECD, 2018; Rodrik, 2018). On the other side, the improvement of life conditions (especially in urban areas), the expansion of technological and social innovations around the world and the promising science and technology developments (both in industrial and social sectors), are accompanied by the rise of a new and young global activism and by committed multi-level efforts by individuals, communities, stakeholders and organisations to implement the 2030 Agenda for Sustainable Development (Fleurbaey et al., 2018; UN, 2015; EC, 2019a).

In this situation, **the COVID-19 pandemic has been making evident the vulnerabilities of our societies.** In the past few months, almost the whole world has been suddenly and simultaneously questioning – probably for the very first time in recent history – the capacity of our healthcare, food, housing, production, education, mobility, care and solidarity systems (among others) to meet people's needs.[2]

All in all, we live in times of deep structural transformations towards **new ways of structuring our economies and production systems, a new social dynamics and more sustainable and inclusive forms of development** (Bianchi et al., 2020; Ferrannini et al., 2020; UN, 2020).

In this regard, the **sustainable development paradigm** has today gained a broad global consensus on which the world is building supranational, national and sub-national strategies on the "5Ps" areas of critical importance: **People, Planet, Prosperity, Peace, and Partnership.**

This is apparent not only in the **UN Agenda 2030 for Sustainable Development** and in the consequent **national and local strategies for sustainable development**, but also in the **efforts devoted by the European Commission under the Juncker presidency (2014-2019) as well as in the new political guidelines and priorities currently pursued under the von der Leyen presidency (2019-2024)**. The former

[1] According to the Global Footprint Network, the Earth Overshoot Day was the earliest ever in 2019.
[2] The differential impacts of COVID-19 in terms of class, generations, social groups, territories and countries is undeniable and it has only begun to reveal itself (Harvey, 2020; OECD, 2020; Piketty, 2020; Stiglitz, 2020), with particular concerns for the most vulnerable social groups, regions and economies that were already at risk (Ferrannini et al., 2020).

include the EU Sustainable Development Strategy and the related monitoring system, along with its implementation actions, such as the European Pillar of Social Rights, the Investment Plan for Europe, the Horizon 2020 programme, the Circular economy action plan, the EU plastics strategy, the COP21 Paris Climate Agreement, the EU action plan for nature, people and the economy, the UN Habitat New Urban Agenda and the Urban Agenda for the EU, the Sendai Framework for Disaster Risk Reduction, the Global Solutions Summit and the EU bioeconomy strategy. The latter embrace striving to be the first climate-neutral continent, promoting social fairness and prosperity in our economies, empowering all people through new technologies, ensuring equality of opportunities and strengthening democracy, among others.

Already before the pandemic, the vision for "a Europe that strives for more when it comes to social fairness and prosperity" (von der Leyen, 2019) and the willingness to shift towards a new model of growth and sustainability were pushing at rethinking an **integrated approach for industrial and innovation policy** (Aiginger, 2014; Pianta et al., 2016; Bianchi and Labory, 2019; Arnold, 2020a; Aiginger and Rodrik, 2020; Bianchi et al., 2020; Di Tommaso et al., 2020; Ferrannini et al., 2020), **in order to holistically pursue these three dimensions of sustainability**. Today, the dramatically high human costs inflicted worldwide by the pandemic urge us to accelerate – as a sort of "revelatory shock" (Doughnut4EU, 2020) – these fundamental changes in our economic and social systems (Chang, 2020; Hepburn et al., 2020; Mazzucato, 2020; Piketty, 2020; Yunus and Biggeri, 2020), and particularly to **redefine the paradigm on the connection between production dynamics, wellbeing and sustainability** (Ferrannini et al., 2020). The recovery from the pandemic must not be missed as an extraordinary chance to shape a different future, thus "bouncing forward" – instead of "bouncing back" to Business-As-Usual – towards sustainability (Arnold, 2020b), ensuring planetary and human health, inclusiveness and shared prosperity.

1.2 The importance of analysing the nexus between Research & Innovation and sustainable development

In a similar vein, the pandemic seems offering an opportunity to proposing a new and different framing to structure government intervention properly to serve the public interest (Ferrannini et al., 2020), with unequivocal directionality towards responding to – and addressing the root causes of – the planetary and human emergencies and their multiple interconnected crises (Arnold, 2020b).

Within such inevitable revamping attention on the need for public action and government intervention, the importance of Research and Innovation (R&I) policies to simultaneously dealing with economic competitiveness as well as with public health, social inclusion and environmental protection is undeniable, especially when a broader vision and notion of development is embraced.

The general objective of this exploratory study is to analyse the nexus between the current debate on R&I policy and the notion and measurement of sustainable development in the uncertain scenario of our present and future times.

Through a state-of-the-art review of the up-to-date academic literature and policy debate on both sustainable development and R&I, **this study intends discussing to what extent and how R&I policy in the post-COVID scenario can represent a leverage for transformative change towards sustainable development**. In particular, it provides theoretical arguments and policy recommendations to foster a roadmap for a new approach on R&I policies at European level.

Indeed, in recent times and already before COVID-19, it was argued that **R&I policy undoubtedly plays a pivotal role for the pursuit of – and transition towards – sustainable development** (Chataway et al., 2017; Capriati, 2017; Mazzucato, 2018a; Schot and Steinmueller, 2018; UN, 2019). Current and future living conditions, multidimensional wellbeing and human capabilities are deeply influenced not only by new scientific discoveries or technological innovations, but also by social, cultural, financial, organisational and institutional innovations. Among others, new production processes and innovative business models, new governance mechanisms, new consumption patterns, new individual and collective behaviours and actions, new structures of living together in line with sustainability requirements would emerge (also) thanks to R&I investments and efforts (Bell et al., 2019).

In other words, within the global debate on **sustainable development as an integrated and indivisible concept** and in line with the so-called **triple bottom line approach to human wellbeing that combines economic development, environmental sustainability and social inclusion**, a new framing for R&I has been gaining momentum. Recognising the wider impact of research and innovation on broader societal aspects, an 'open and transformative approach to R&I' has been advanced (Weber et al., 2015; Schot and Steinmueller, 2018). This is conceived as an integrated strategy combining mission-oriented and disruptive innovation-friendly elements to tackle societal challenges. Such approach relies on a better coordination between supply of and demand for R&I in order to make our society and economy stronger, more resilient and more sustainable by drawing on the latest scientific discoveries, for the real benefit of the current and future citizens.

However, in this pandemic and post-pandemic scenario it is clear that transformative R&I policy and R&I agendas cannot be the same tomorrow as they were yesterday (Arnold, 2020b).

Indeed, one of the main issues the pandemic puts on centre stage concerns the **societal vision and directionality underlying the design and implementation of R&I policy**, especially at times requiring extraordinary interventions and measures to protect people, households, ecological systems and business and steer them towards a new development model (Ferrannini et al., 2020). For this reason, this report intends contributing to the debate by offering a robust ground for policy-makers at all levels to use **science, technology and innovation for empowering individuals and communities to meet social needs and promote sustainable and inclusive societies**.

The report is structured as follows. After this introduction, in section 2 we briefly review the evolution of the concept of sustainable development from its early environmentally-focused appearance in the global debate, to the more recent integrated perspective balancing the three dimensions of sustainability (i.e. economic, social and environmental), and it discusses about the datasets and indicators of sustainable development that are currently used in the debate. Then, in section 3 we explore the linkages between the recent academic and policy debate on R&I with the above discussed conceptualisation and measurement of sustainable development, focusing on the recent framing of R&I and STI for transformative change. Taking into account these arguments, in section 4 we present a new overarching vision and narrative for R&I policy in Europe in the current scenario, given in particular by the 2030 Agenda for Sustainable Development, the new strategies of the European Commission 2019-2024 and the post-COVID recovery. Finally, in section 5 we propose a set of policy recommendations to pursue this vision by better designing R&I policies for transformative change towards sustainable development both at national and European level. To conclude, in section 6 we summarise the role of R&I as a key driver for achieving a prosperous and sustainable Europe.

2 Reconciling Planet, People and Prosperity in the notion and measurement of sustainable development

Nowadays, there is a strong conceptual and practical case for embracing the **complex nature of development** in an integrated and systematic way. Over the years, different contributions to the literature have emphasised the importance of distinguishing between inputs and outputs of development processes (Torlockyj, 1975; Hicks and Streeten, 1979); the means and ends of development (Streeten, 1994; Haq, 1995); and the many complex linkages and interactions between different capabilities and freedoms and the participation of citizens as active actors of the transformative change (Sen, 1999; Clark, 2002; Biggeri and Ferrannini, 2014a, Clark et al., 2019). Moreover, awareness of environmental limits to growth spurred a variety of seminal contributions on sustainability and development (Tisdell, 1988; Lélé, 1991; Beckerman, 1992; World Bank, 1992; Anand and Sen, 2000) and went on to define subsequent work on environmental conservation and planetary boundaries (Goldin, 2014; Rockström and Klum, 2015; Newsham and Bhagwat, 2016; Raworth, 2012).

In other words, over the years the **multidimensionality of human well-being and development** have gained a prominent consensus in the academic and policy spheres, along with the acknowledgment and recognition that **unsustainable production and consumption patterns undermine** – if not even wipe out – **our human capabilities and the ecological, health, social, and cultural systems**.

Both arguments have been made apparent by **disrupting effects of the COVID-19 pandemic on our economies and societies**. There is wide consensus the pandemic is exacerbating several problems that were serious and evident well before it both in

developed and developing countries (Chang, 2020; Fleurbaey, 2020; Harvey, 2020; Mazzucato, 2020; Sen, 2020; WEF, 2020a; Yunus and Biggeri, 2020). Among others, increasing inequality within and across countries, multidimensional poverty conditions for millions of people, vulnerability of current socio-economic systems and planetary tipping points have coupled with atrophying in the capacity of state institutions (Acemoglu, 2020), making almost the whole world insufficiently prepared to a crisis that was waiting to happen (Rodrik, 2020). In this regard, just few months before the pandemic, the WEF Global Risk Report 2020 (WEF, 2020b) has warned that health systems around the world were at risk of becoming unfit for purpose, with vulnerabilities resulting from changing societal, environmental, demographic and technological patterns threatening to undo the dramatic gains in wellness and prosperity over the last century.[3]

The global health emergency and its subsequent economic, social and human crisis have made us realising not only how vulnerable we are, but also the close inter-linkages between – and the need for a simultaneous focus on – protecting the social foundations (including public health, social protection and well-being), on the one hand, and respecting environment sustainability and planetary boundaries, on the other (Doughnut4EU, 2020).

In other words, the COVID-19 pandemic seems to have given the last – hopefully decisive – boost to the combination of **theoretical advancements and measurement innovations to reconcile aspirations related to *People, Planet and Prosperity* within our economies and societies**.

Indeed, a broad notion of sustainable development has gradually emerged in the literature in the last decades (Purvis et al., 2019) and has recently gained momentum in the international debate.

2.1 The notion of sustainable development

Here, we briefly review how the debate between sustainability and development has broadened its scope from the fundamental concern over environmental and planet boundaries to simultaneously embrace people's multidimensional well-being, as well as attention to productivity, competitiveness and prosperity, notwithstanding the issues about compatibility and trade-offs among them.

[3] On the one side, the WEF Global Risk Report 2020 highlights that no country appeared to be fully prepared to handle an epidemic or pandemic, along with an increasing collective vulnerability to the societal and economic impacts of infectious disease crises. On the other side, pandemics were not listed among the top 10 global risks either in terms of likelihood or impact (they were 4th and 5th respectively in 2007 and 2008 in terms of impact). The rapide, massive and uncontrolled spread of infectious diseases ranked 10th in early 2020 in terms of impact and displayed a middle-low likelihood, showing low connections (calculated as "weighted degree") with other global risks.

PLANET

Concern for **environmental sustainability** – already stressed by Malthus in 1798 – boosted with the introduction of the first United Nations sanctioned Earth Day to promote awareness of environmental issues on 22 April 1970 along with Paul Ehrlich's 1968 book, *The Population Bomb*, and the Club of Rome's oft-cited report, *The Limits to Growth* (Meadows et al. 1972). Anyway, it was then the publication of *Our Common Future*, in 1987, by the World Commission for the Environment and Development (better known as the 'Brundtland' report) that puts the concept of 'sustainable development' on the international agenda and effectively mainstreamed **environmental concerns and awareness on environmental limits to growth**.

An important distinction within the notion of sustainability soon appeared in the debate (Neumayer, 2003):

- the **weak sustainability** approach assumes that natural capital and manufactured capital are essentially substitutable, that there are no essential differences between the kinds of well-being they produce, and thus simply the total value of the aggregate stock of capital should be at least maintained, or ideally added to, for the sake of future generations (Pelenc and Ballet, 2015, p. 37);

- the **strong sustainability** approach highlights that natural capital is characterised by irreversibly and threshold issues, is multifunctional, is required for the (re)production of manufactured capital, its depletion cannot be compensated for by investing in other forms of capital and the effects of its deterioration on human well-being is uncertain (Pelenc and Ballet, 2015). Therefore, certain elements of natural capital are "critical" due to their unique contribution to human existence and well-being (Ekins et al., 2003; Dedeurwaerdere, 2014).

Beside such relevant distinction, probably the strongest and most renowned argument in favour of giving priority to the protection of the environment has been so far the ethical need for **guaranteeing that future generations would continue to enjoy similar opportunities of leading worthwhile lives that are enjoyed by generations that precede them.**

PLANET AND PEOPLE

Concern for the social dimension of **people's inclusiveness, equality and wellbeing** was added to the notion of sustainability, based on the recognition that "this goal of sustainability would make little sense if the present life opportunities that are to be 'sustained' in the future were miserable and indigent" (Anand and Sen, 2000, p. 2030).

In this regard, the human development perspective, grounded on the **capability approach** (Sen, 1992, 1999 and 2009; Nussbaum, 2000, 2006 and 2011), was surely central in robustly challenging the development thinking distinguishing between the means and goals of the development processes and thus questioning the vision of development in itself, its institutions and its processes (Stewart and Deneulin, 2002; Stewart, 2013). This approach considers human well-being, participation and freedom to be central economic and social objective (Sen, 1999). Therefore, any **development process should be pursued or analysed by the point of view of people's capabilities to function, i.e. the opportunities and capacities people have to be and to do what they have reason to value** (Sen, 1999). In particular, the process of human development should create "a conducive environment for people, individually and collectively, to develop to their full potential and to have a reasonable chance of leading productive and creative lives that they value" (UNDP, 1990, p.1). This implies empowering individuals and communities as central agents, beneficiaries and adjudicators of human progress, through participation in co-design and co-creation processes making the most of people's potential, creativity and diversity to drive solutions for sustainable development.

The main policy implication of the capability approach is that **social and economic policies and arrangements in terms of institutions and processes should aim to expand people's capabilities** (Sen, 1999), i.e. their freedom to promote or achieve valuable beings and doings.

This perspective gained momentum also thanks to the **UNDP *Human Development Reports*** and **Human Development Index**, which since 1990s have been actively seeking to embrace a multi-dimensional vision of development, going beyond a utility and income framework, in order to expanding the richness of human life, rather than simply the richness of the economy in which human beings live.

Moreover, the defining moment in the historic transformation of the international development movement came with the advent of the **Millennium Development Goals** (MDGs) in September 2000 (UN, 2000). Despite several critics on a variety of grounds (concerning process, coverage, coherence, etc.) (Fukuda-Parr, 2012), the MDGs represented a historic agreement, i.e. the world's 'biggest promise' (Hulme, 2009) at the time. They consisted of 8 time-bound development goals supported by 18 targets and 60 indicators unanimously endorsed by all 189 United Nations member states – for tackling poverty and hunger, along with improving health and education, promoting gender equality and fostering environmental sustainability.

PLANET, PEOPLE AND PROSPERITY

Economic prosperity was further added and structurally embedded in the notion of sustainability through a gradual process, based on the evident shortcomings derived from "the separation of the 'economic' from the 'social' discourse inherent in orthodox policy recommendations (Mehrotra and Delamonica, 2007, p. 14). The central argument here is that **prosperity should no longer to be confused with the narrow and exclusive goal of economic growth, nor that economic expansion would automatically deliver benefits for all. Rather, a wider notion of societal shared prosperity – including, but not restricted to the economic well-being of people – should be embraced.**

The following main theoretical advancements have characterised this discussion.

Firstly, it emerged an increasing consensus that economic growth is an essential part, though not the entire structure, of human development and that the **quality of growth matters**, because historical evidence has shown there are different types of unsustainable growth, e.g. jobless growth, ruthless growth, voiceless growth, rootless growth, futureless growth, peace-less growth, healthless growth (UNDP, 1996; Fukuda-Parr, 2007; Ferrannini et al., 2020). Therefore, the **compatibility between shared prosperity, environmental sustainability and competitiveness** goes beyond being a moral case, towards an imperative when adopting a **holistic and longer-term perspective**. This implies promoting economically innovative and sustainable production and industrial systems, which acknowledge the benefits of an approach to prosperity that is inclusive, diverse and creative, to generate jobs and innovations whilst providing an equal distribution of opportunities for all and leave none behind (Arnold, 2019).

Secondly, the integration of the economic dimension of sustainability was evident in the four pillars of the s**ustainable human development perspective** (Haq, 1995):

a) **Equity for all**, in terms of political, economic, social and cultural opportunities, as well as distribution and cohesion;

b) **Participation and empowerment of citizens and communities**, conceived as being an active individual and collective agent of one's own future;

c) **Sustainability of our ecological and socio-economic systems**, promoting intergenerational equity of opportunities and contrasting the deployment and deterioration of natural, human and cultural capital.

d) **Productivity**, pursuing an efficient use of local resources within production systems.

As for the last pillar, the international debate highlights that a holistic view on the **business environment, composed by all factors of competitiveness and all**

drivers of productivity, accounts for both growth and human development. Thus, policy interventions should focus on those factors that can lead to improve productivity while reducing inequalities and addressing the environmental tipping points at the same time (WEF, 2019).

In a nutshell, **increasing competitiveness and productivity is necessary, especially for the provision of goods and services expanding human capabilities**, for increasing the standards of living – most notably of those left behind – and for **an efficient use of natural resources**. [4]

Thirdly, based on Jeffrey Sachs' thinking (2012 and 2015) and on a long lasting inclusive and participatory consultation process, the new **2030 Agenda for Sustainable Development** adopted on September 2015 by all 193-member states of the United Nations "embrace the so-called triple bottom line approach to human wellbeing" (Sachs, 2012, p. 2206). The **balance among the three dimensions of sustainable development** – the economic, social and environmental – is one of the hallmarks of the Sustainable Development Agenda and it paved the way for its 17 Sustainable Development Goals and 169 targets[5] to be "**integrated and indivisible, global in nature and universally applicable**" (UN, 2015, p. 13).

The integrated and indivisible nature of Agenda 2030 reflects the **deep interconnections and cross-cutting elements across the goals and targets, calling for an understanding of all inter-linkages, i.e. both positive interactions and potential hindrances / trade-offs between dimensions and goals** (Biggeri et al., 2019), along with coherence in design, implementation and monitoring. Such attention on the interconnections among the ecological, social and economic dynamics is apparent also in the **Doughnut of social and planetary boundaries** by Kate Raworth (2012 and 2017), whose approach has been widely influential among both policy-makers and activists as a compass to frame the current challenge of meeting the needs of all on life's essentials while ensuring that collectively we do not overshoot our pressure on Earth's life-supporting systems. In other words, the Doughnut framework invites policymakers to explore the range of economic systems that are compatible with achieving high levels of well-being and knowledge within planetary boundaries, ensuring an environmentally safe and socially just space in which humanity can thrive (Doughnut4EU, 2020). [6]

[4] The recent attention to – among others – the role of social entrepreneurship (Clarence and Noya, 2009; Defourny and Nyssens, 2010; Biggeri et al., 2019b) and the transition towards circular economy (Ghisellini et al., 2016; EC, 2020a; Urban Agenda for the EU, 2019) at individual, organizational and societal level appear to be particularly fit to make operational the four pillars of sustainable human development.

[5] For each Sustainable Development Goal, a set of aspirational targets was defined, requesting each government to set its own national targets (reconciling the the global ambition with national circumstances) and incorporating them into national planning processes, policies and strategies.

[6] Such vision is surely apparent also in the Pope Francis' Encyclical Letter *Laudato Si': On Care for our Common Home*, which has succeeded in creating common ground between followers of all faiths towards concern for our planet, and every living thing that dwells on it, especially the poorest and most vulnerable.

Some critics in the international debate are challenging the content, structure and coherence of the SDGs, e.g. regarding the weak attention to migration, terrorism, finance and democracy, as well as the weak enforcement mechanisms and accountability of governments (Vaggi, 2019). Nevertheless, the 2030 Agenda for Sustainable Development appears today the **most relevant single unified and strategic framework (with international validity) on sustainability that can appeal to different viewpoints and schools of thought**. [7]

All in all, the 2030 Agenda represents to date the last – but not final – step of a long lasting theory- and evidence-based process of reconciling aspirations related to *Planet, People and Prosperity*, acting as a **roadmap for a better future that inspires governance, action and cooperation among diverse multilevel actors and agents of change**.

2.2 The measurement of sustainable development

The measurement of sustainable development has surely been a long-lasting and key issue in the international debate involving scholars, policy makers and activists, which have joined efforts to **displace a strictly monetary or economic perspective in the measurement of development** thus threatening the hegemony of GDP in development accounting (Streeten, 1994; Haq, 1995; Sen, 2006; Stiglitz et al., 2009 and 2018). Such debate was decisively boosted by the renowned call to go 'beyond GDP' for the measurement of economic performance and social progress by the Stiglitz-Sen-Fitoussi Commission (Stiglitz et al., 2009).

According to Stiglitz et al. (2018), GDP has remained its key proxy both economic and general welfare, because it is commonly taken for granted. However, this metric displays several shortcomings as a measure of a country's success and it has failed to provide us the full picture in several occasions (last but not least, during the Great Recession) as it was used for purposes that it was not designed to address and it "seemed out of synch with the facts on the ground" (p. 20).

Several measures and indicators of sustainability have been developed and proposed, from some more environmentally oriented (e.g. on emissions, energy efficiency, ecological footprint, depletion of natural resources, ecological systems, biodiversity)[8] to other focused on human well-being (e.g. quality of life, social inclusion, political rights). Such discussion has received a new impulse, not only due to the call to go 'beyond GDP' (Stiglitz et al., 2009), but also more recently with the design of a **new global indicator framework for the Agenda 2030**,[9] in order to

[7] A similar perspective is surely underlying the new economic and industrial strategy for the EU – the European Green Deal – as well as the Harmonious Society vision in China, among others.
[8] One of the most well-known composite index on the environment is the Environmental Performance Index (EPI), which ranks 180 countries on 24 performance indicators across ten categories covering environmental health and ecosystem vitality.
[9] It includes 231 unique indicators to date (UNSD, 2020).

robustly embrace its integrated nature balancing the three dimensions of sustainability (Arnold, 2019; Biggeri et al., 2019).

Different sets of data and indicators of sustainable development – embracing its three dimensions in an integrated perspective – are thus available nowadays for measurement and policy-making purposes. In particular:

- Wide **integrated datasets** composed by several distinct indicators related to different dimensions and facets of sustainability, allowing to obtain a complete picture and in-depth understanding and assessment of each sustainability issue without losing the richness of information attached to specific targets and indicators (Biggeri et al., 2019).

- **Composite indicators**, whose pragmatic value is reflected in their capacity to shape policy debates and prevailing political discourses (Paruolo et al., 2013) by simplifying and effectively communicating complex multi-dimensional concepts and issues that facilitate the "generation of narratives supporting the subject of the advocacy" (Saltelli, 2007, p. 68).

Keeping into account this distinction, in APPENDIX 1 we briefly explore both the most relevant datasets and indicators (without any intention of exhaustiveness) that integrate the three dimensions of sustainability and are today informing the debate on the transformative change towards sustainable development.

All in all, this array of datasets and indicators has not only **allowed robust assessment** of performances, but also captured the imagination of politicians and the press, increasingly **guiding governments' planning, policy and allocation processes** to steer the multidimensional and integrated transformative change towards sustainable development. Anyway, **these indicators have not been mainstreamed** and have not fully "dethroned the GDP" so far, as the challenge is still "to make the dashboard small enough to be easily comprehensible, but large enough to summarise what we care about the most" (Stiglitz et al., 2018, p.13).

3 The linkage between R&I and sustainable development

As discussed in the previous sections, despite important improvements in life expectancy and wellbeing in many countries over the last decades, the **sustainability of our economies and societies** and the **fitness of current sociotechnical systems with grand challenges and societal goals** (Geels, 2020) have been questioned in environmental, social and economic terms, as made evident by the multidimensional consequences of the COVID-19 pandemic.

The academic and policy-making debate is increasingly calling for a transformative change to address social and environmental problems. More explicitly, it calls for **accelerated transformative changes**, because the "pace of change towards a more sustainable world seems to be frustratingly slow" (Silvestre and Tîrca, 2019, p. 326) in comparison with the depth, the magnitude and the urgency of the challenges that the

world is facing today. Therefore, further investments and initiatives from organisations, educational institutions, and governments are required to implement multidisciplinary approaches to resolve the pressing challenges (Almeida et al., 2013),[10] as well as to anticipate, react quickly and effectively to unexpected events of global magnitude, as it is now the case of COVID-19.

In this scenario, **Research & Innovation (R&I) policy is called to play a fundamental role to question the status quo and to pave the way for (and accelerate) this transformative change towards sustainability**.

3.1 A new framing on R&I

Keeping in mind these premises, the **evolution of the theoretical approaches underpinning R&I** deserves dedicated attention in our discussion. Schot and Steinmueller (2018) and Schot et al. (2018) discuss three main phases and framings of innovation policy, as reported in Table 1.

All in all, Lundin and Schwaag Serger (2018, p. 2) resume it very clearly: "**The theoretical approach to innovation policy is shifting from a predominantly market or system failure rationale to a system or transformative change approach**. Consequently, government efforts to promote innovation are moving from a more generic, reactive character – in which implicitly all innovation was seen as potentially contributing to economic growth and competitiveness and therefore 'good' – towards a more directional nature, with policymakers seeking to channel innovation efforts and support towards addressing societal challenges".

[10] According to the last Global Sustainable Development Report (UN, 2019, p. 112), these challenges can be categorised as *Simple*, *Complex*, *Complicated*, *Wicked*, or *Chaos*, because "the political scope for action largely depends on the interplay between the factual certainty that science can produce and socio-political factors that can be more difficult to delineate and demand negotiation".

#	TIMING	PREMISE	FAILURE TO BE ADDRESS	POLICY IMPLICATIONS
First R&I framing	After the Second World War	Science, technology and innovation are the basis for long-term economic growth (by sustaining improvement in factor productivity) and prosperity.	Market failures (e.g. Arrow, 1962) due to uncertain returns on investments in the long run and risks.	Promoting public and private R&D – regardless of its focus – through government investments and incentives and the commercialisation of scientific discovery through intellectual property rights.
Second R&I framing	During the 1980s	Interactive learning processes and strong absorptive capacities are necessary to bridge the gap between science, technological discovery and application or innovation.	System failures (e.g. Freeman, 1987, Lundvall, 1992, Etzkowitz and Leydesdorff, 2000 and Klein Woolthuis et. al., 2005) due to missing or malfunctioning links of cooperation and coordination and inappropriate framework conditions for the diffusion and application of science, knowledge and technology.	Building of national, regional and sectoral systems of innovation through public-private partnerships, university-industry linkages and the triple helix approach.
Third R&I framing	Last decade	Environmental and social goals can be seen as strategic and dynamic drivers of long-term growth and competitiveness in order to purse a structural change of our economies and societies.	Transformation failures (e.g. Weber & Rohracher 2012), highlighting that significant advances in technology have not truly resulted in disruptive innovation and systemic change to build more sustainable and inclusive societies for all.	Using of science, technology and innovation for meeting social needs (e.g. ending poverty and reducing inequality in all its forms everywhere) and tackling environmental challenges (e.g. climate change, energy transition and circular economy). Involving civil society and citizens not simply as consumers and adopters of innovation, but also as sources of new ideas and solutions, as well as drivers of organisational and business model changes and of new collaborative processes and partnerships for innovation, within a quadruple helix approach.

Table 1. Evolution of R&I framings (based on Schot and Steinmueller, 2018 and Schot et al., 2018)

According to Schot and Steinmueller (2018), the consolidation of the third framing does not imply lessening the importance of – or even abandoning – the previous rationales and policy practices: investment in knowledge infrastructure and R&D to overcome market failures continues to be fundamental, as well as strengthening interactions and learning process among all societal actors within national, sectoral, regional and transnational systems of innovation to overcome system failures. Rather, framing R&I policies for transformative change implies focus these efforts on

the **transformations/transitions of sociotechnical systems**[11] (Smith et al., 2005; Geels, 2020), including not only new innovations and new technologies, but also new models for partnership and governance, market creation, along with behavioural, organisational, infrastructural, regulatory and governance changes (Lombardi, 2010).[12]

Transformative nature and directionality are thus inextricable features of this new framing for R&I policies, which has been strongly enhanced in these pandemic times:

- *Transformative*, in the sense of **transforming in an integrated manner the economy, social relationships and the relationship between people and their natural environment** (Schot et al, 2018, p. 4);

- *Directionality*, in sense of **tackling the societal challenges and sustainability transitions for all the sociotechnical systems affecting present and future human capabilities**, e.g. concerning, among others energy, water, air, waste, climate, biodiversity, mobility, food, nutrition, healthcare, disability, ageing, social relations, communication, housing, building, justice and rule of law, production systems, consumption patterns, poverty, social exclusion, corruption, human rights, migration, violence, and so on.

Harnessing the role of innovation in addressing these societal challenges and driving transformative change explicitly implies that the **purpose underlying innovation policy can no longer be the non-directional promotion of innovation for growth and competitiveness** (Lundin and Schwaag Serger, 2018). Hence, as stated by Gjoksi (2011), innovation policy does not remain neutral but pursues a **normative direction** towards an integrated and balanced perspective on economic, environmental and social sustainability. Anyway, despite the current prominence of this direction towards sustainable development, many directionalities are always possible and a process of **societal appraisal and learning** is critical. Indeed, "the transformative change frame takes directionality as a starting point and engages actors with a process of opening up, engaging with all consequences, and setting collective priorities. Such a process involves the creation of visions about the sustainable future of the sectors, economies and societies and connecting these visions to specific development trajectories and technical options" (Schot and Steinmueller, 2018, p. 1562). This includes **knowledge and innovations to face unexpected crisis, as well as new radical alternatives to expand human capabilities** that may not be perceived yet as feasible or even desirable (Capriati, 2017; Schot et al., 2018, p. 5).

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[11] Sociotechnical systems can be defined as "multi-faceted combination of actors, networks, institutions, artefacts, infrastructure, markets and practices, along with cultural and symbolic views and representations" (Edmondson et al., 2019) that coherently intertwine "to fulfil societal functions" (Geels, 2004, p. 900).

[12] This is highlighted also in the European Commission High-Level Expert Group report on *The human-centred city: Opportunities for citizens through research and innovation* (EC, 2019b).

However, within this perspective R&I policies will not automatically bring about the necessary system transformation on their own. For this reason, arguing for greater directionality in innovation policy is often connected with a **mission- or challenge-oriented approach** (Mazzucato, 2018a and 2019). Indeed, the general directionality of a sociotechnical transition towards sustainability needs to be operationally translated in **new public missions, which sit between broad challenges and concrete projects** (Mazzucato, 2018), as it is now the case of the COVID-related research missions.

Specific arguments have been raised on **the nature, setting and governance of new public missions tackling societal challenges for sustainable development** (Mazzucato, 2018a and 2019):

- On the *nature*, missions should be, on the one side, broadly ambitious, inspirational and have a wide societal relevance to engage the public; and, on the other side, targeted, measurable, and time-bound – but not prescriptive on how to achieve success – in order to operationally commit cross-sectoral actors leaving room for freedom, creativity and curiosity to spur realistic research and innovation actions.

- On the *setting*, missions should be co-created through cross-disciplinary, cross-sectoral, and cross-actor processes and formulated in an open-ended way by encouraging societal partnership, experimentation and diversity, in order to gain widespread legitimacy and acceptance.

- On the *governance*, missions should be managed through an effective portfolio approach and flexible governance mechanisms that enable cross-sectoral, cross-institutional and multi-level coordination.

In other words, given a direction of transformative change, missions are intended to set clear and ambitious objectives to be pursued through a portfolio of R&I projects, initiatives and supportive measures, which may include interventions and tools typical of all the three framings.

3.2 The Agenda 2030 for sustainable development as an overarching vision and direction for transformative R&I

Wide attention has been recently devoted on discussing to what extent the **Agenda 2030 for sustainable development and its 17 SDGs can both provide a vision and direction for transformative R&I** and suggest targeted, measurable, and time-bound public missions.

First of all, it is clear that crosscutting policies such as **R&I will play a pivotal role in achieving the SDGs as they have the unique capacity to embrace the directionality given by the Agenda 2030, and to create synergies across policies to increase overall impact** (Bell et al., 2019, p. 2; UN, 2019; Borowiecki et al., 2019). The Agenda 2030 itself recognises that "scientific and technological

innovation [...] have great potential to accelerate human progress" (UN, 2015, para 15, p. 5), that our future economies should be – among others – dynamic and innovative and thus scientific, technological and innovative capacities are to be strengthened to move towards more sustainable patterns of consumption and production. Moreover, **technology is one among the five means of implementation** – along with finance, trade, capacity building and systems issues[13] – to enhance the depth, scale and speed of the transformative changes towards sustainable development.[14]

Secondly, besides having been directly included in SDG#9 "Industry, innovation and infrastructure" with dedicated targets, measures and time-bounds (e.g. 9.5 and 9.b),[15] the Agenda 2030 allows the **identification of more focused public missions for R&I policies, as they offer an integrated and systems approach, which targets the underlying connections and trade-offs among the SDGs**. Among others, these may concern:

- Technological upgrading and innovation to achieve higher levels of economic productivity (8.2);
- Agricultural research (2.a);
- R&D on communicable and non-communicable diseases (3.b);
- Research and technology on clean energy (7.a);
- Scientific knowledge, research and technology on ocean health and marine biodiversity (14.a).

In this regard, Schot et al. (2018), distinguish **three types of SDGs** that may support the identification of different missions for R&I policies:

- SDGs covering specific or a wider range of sociotechnical systems or application areas (e.g. SDG#3 "Good health and well-being", SDG#4 "Quality education", SDG#6 "Clean water and sanitation", SDG#7 "Affordable and clean energy", SDG#9 "Industry, innovation and infrastructure", SDG#11 "Sustainable cities and communities", SDG#14 "Life below water", SDG#15 on "Life on land");
- SDGs emphasising 'transversal directions' (e.g. SDG#1 "No poverty", SDG#2 "Zero hunger", SDG#5 "Gender equality", SDG#8 "Decent work and economic growth",

[13] i.e. policy and institutional coherence; multi-stakeholder partnerships; data, monitoring and accountability.
[14] The UN also launched a Technology Facilitation Mechanism to bring forward the development of Science, Technology and Innovation roadmaps for achieving the SDGs (UN, 2015).
[15] Target 9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending. Target 9.b Support domestic technology development, research and innovation in developing countries.

SDG#10 “Reduced inequalities”, SDG#12 “Responsible consumption and production”, SDG#13 “Climate action”);

- SDGs dealing with framework conditions necessary for realising transformation (SDG#16 “Peace, justice and strong institutions”, SDG#17 “Partnerships for the goals”).

All in all, according to Lundin and Schwaag Serger (2018), there is a perfect match and a mutual strategic relevance between R&I for transformative change and the Agenda 2030: the former needs to be implemented through highly a “innovative process, which goes beyond a business as usual scenario and current path-dependent systems” (p. 14), while the latter represents “a legitimate and comprehensive policy framework for conceptualising and experimenting with innovation-driven transformative changes in practice” (p. 5).

3.3 A new collective awareness on R&I processes

An important clarification is worthy at this stage. The emphasis on transformative nature, directionality and mission-oriented approach should not divert attention from reminding that **not all the research, knowledge, technology and innovation is good and positive to nurture a transformative change towards sustainable development**, an argument that is probably not raised enough within the Agenda 2030 itself. Innovation policies in their past and current format may have led and contributed to **exacerbate environmental externalities** – e.g. resource-intensive, wasteful and fossil fuel-based paradigm of mass production and mass consumption (Meadows et al., 2004; Bardi, 2011; Steffen et al., 2015) – and **social inequalities** – e.g. low quality jobs, exclusionary processes, polarisation of power (Kaplinsky, 2011) – associated with economic growth (Schot and Steinmueller, 2018). These effects may be direct and/or indirect, depending also on the reaction of other components of our societies (e.g. ecological systems, labour market) and related policies to innovation-led changes.

> To raise few examples: the direct impact of manufactured chemicals having caused ozone depletion; the direct impact of some drugs having diffusely caused unexpected diseases; the indirect impact of the combination of ICT tools (platforms, geolocalisation, online payment) having paved the way for new forms of potential exploitation and control of workers; the indirect impact of advanced video / mobile games having caused new forms of addiction with consequent potential problems of social exclusion and mental health disorders.

Therefore, it appears fundamental to stress the importance of **acquiring a collective awareness on the need of fostering at foremost those research and innovation processes with a foreseen positive and direct impact on human capabilities and the whole society, keeping under attention potential deviations from a sustainable development vision and potential distorted use and abuses**. In other words, this call for a re-orientation of our pedagogy, our behaviours and our awareness to be consistent with the desired transition to sustainability (Schot and Steinmueller, 2018).

This argument is also aligned with:

- the emerging practice of **responsible research and innovation**, built on the understanding that science and technology are not only technically but also socially and politically constituted, and thus pointing to shared responsibility and governance to take care of the future through collective stewardship of science and innovation in the present (Stilgoe et al., 2013; Rip, 2014);

- the most recent conceptualisations of **social innovation**, conceived as innovations that are social both in their ends (i.e. good for society) and in their means (i.e. enhance society's capacity to act) (Mulgan et al., 2011), thus potentially changing the dynamics of social relations, including power relations, referring to an ethical position of social justice (Moulaert et al., 2005) towards human development (Biggeri et al., 2017).

3.4 The current measurement of R&I for sustainable development

The consistency of our **metrics of R&I** with a transformative change towards sustainable development is surely another central issue to be explored. Indeed, the legitimacy of rationales and arguments for particular policies and actions is influenced also by the capacity to measure and communicate the impact of R&I on society – especially on sustainability for the sake of our discuss – that is anyway hard to capture and communicate because of its complex nature.

For this reason, without any intention of exhaustiveness, in APPENDIX 2 we briefly review the main indicators and datasets on R&I used to inform research, debate and policy-making and its recent linkages with sustainable development.

To put it briefly, **standard measures** like R&D expenditure as a proportion of GDP, researchers per million population and patent applications represent the most widely indicators framework of R&I, having embraced the new framing on transformative change towards sustainable development only to a limited extent. Therefore, an **open space for innovative proposals for measurement seems to be available**.

In this regard, two recent advancements are worth to mention.

Firstly, according to Montoya (2018), the UNESCO Institute for Statistics is developing a thematic set of indicators on Science, Technology and Innovation (STI), having selected the 40 targets that have the greatest relevance to STI covering (e.g. innovation, health, ecosystems, food security, habitat and education) in order to provide with more detailed monitoring of how STI contributes to their achievement.

Secondly, the European Commission has been designing and proposing a novel indicator framework named Key Impact Pathways (Bruno and Kadunc, 2019) for the post-2020 Programme, Horizon Europe. Key Impact Pathways are structured around three impact axes – i.e. scientific, societal and economic – and nine story lines that

capture and communicate the most typical changes expected to occur on a short, medium and longer term as a results of the Programme activities. The Key Impact Pathways towards societal impact focuses on the monitoring of how and to what extent the Programme contributes to addressing EU policy priorities (including meeting the Sustainable Development Goals) by assessing portfolio of projects that generate outputs which aim to contribute to tackle global challenges or to achieve future R&I missions. As stated by Bell et al. (2019), this could be steered through the development of ad hoc Sustainability Innovation Radar to identify and then deploy transformational solutions across the various governance levels in the EU.[16]

To conclude, we can argue that a **new transformative foundation for R&I policies towards sustainable development has been robustly set in the academic and policy debate** and is today globally diffused, having also been undoubtedly enhanced by the COVID-19 pandemic. Nevertheless, this is not fully mainstreamed yet into real policy-making and implementation practices and measurement efforts. Moreover, such framing for R&I policies is even more **complex, dynamic and uncertain** than previous ones, due to its **transformational nature and its multi-disciplinary and cross-sectorial requirements**.

It is thus fundamental to provide preliminary insights to design a roadmap for a new approach for transformative R&I policies towards sustainable development in Europe.

4 A new overarching vision and narrative for R&I policy in Europe

In this report we argue that reconciling the objectives of economic, social and environmental sustainability requires the enhancement a **new integrated vision and narrative underlying Research and Innovation policies in the European Union**. Indeed, it is nowadays clear that not only do economic growth, productivity increase and R&I performances matter, but also the quality and direction of growth, productivity and R&I matter, especially to **tackle the structural vulnerabilities of our societies made evident by the pandemic**. Depending on the capacity to make economic growth, social inclusiveness and planetary boundaries compatible (Raworth, 2017), they may lead to an increased ability to expand human capabilities, respond to collective needs and tackle societal challenges, or, vice versa, to the exacerbation of exclusionary and environmentally-detrimental trends.

In this regard, framing R&I policies for transformative change towards sustainable development offers the opportunity to **reconcile productivity enhancement and value-generation with inclusiveness, public health and environmental protection, in order to pursue shared prosperity and human flourishing.**

[16] The Key Impact Pathways could also be extended to the relevant governance levels of the EU's international cooperation in R&I.

Here, value-generation is referred for the society as a whole and for the common good, not only for few economic actors, clearly distinguishing it from value extraction and avoiding the related confusion between value, rents and profits (Mazzucato, 2018b). In addition, this framing calls for synergies between vital sub-systems (among others, health, food and nutrition, climate, energy, mobility), leaves behind silo thinking, mitigates trade-offs and guides success, by evidencing the benefits and impacts of truly integrated sociotechnical systems.

Therefore, if R&I policy is conceived as a collective leverage to drive the process of economic and societal transformation, the **identification of the vision and goals underlying R&I policy** become far more important – especially in the uncertain post-Covid19 scenario – than the subsequent discussion on targets and instruments.

Today, the **overarching vision and narrative for R&I policies in Europe are surely given by the commitment towards a prosperous and sustainable Europe by 2030** and by the political guidelines and first strategies issued by the new European Commission 2019-2024 (Arnold, 2020a).

To begin with, the *Reflection Paper towards a Sustainable Europe by 2030* (EC, 2019a) highlights that the **transition to a low-carbon, climate-neutral, resource-efficient and biodiverse economy in full compliance with SDGs needs to be for the benefit of all, leaving no one behind, ensuring equality and inclusiveness.** Four policy foundations for a sustainable future are thus identified: From linear to circular economy; Sustainability from farm to fork; Future-proof energy, buildings and mobility; Ensuring a socially fair transition. R&I is conceived as a horizontal enabler to raise awareness, broaden our knowledge, and hone our skills through a multi-actor and systemic approach that overcomes a silo perspective.

A similar perspective is embraced by the **political guidelines of the EC 2019-2024 under the presidency of Ursula von der Leyen**, who envisions "a transition to a healthy planet and a new digital world" by "bringing people together and upgrading the European social market economy to fit today's new ambitions" (von der Leyen, 2019, p. 4). The political guidelines focus on six **headline ambitions for Europe** over the next five years and well beyond: 1) A European Green Deal; 2) An economy that works for people; 3) A Europe fit for the digital age; 4) Protecting our European way of life; 5) A stronger Europe in the world; 6) A new push for European democracy. Among them, two are worthy to be highlighted here.

Firstly, the **European Green Deal** represents the new European growth strategy to transform the EU into a fair and prosperous society and put its economy on a more sustainable and inclusive path (EC, 2019c), based on the elements depicted in Figure 1. It aims at combining conservation and enhancement of EU's natural capital with protection of citizens' health and expansion of well-being, as well as justice and inclusiveness. It calls for active public participation and confidence in the transition and a new pact among citizens, authorities at all levels, civil society, industry and EU's institutions and consultative bodies.

The objectives and principles underlying the European Green Deal assign a pivotal importance to mobilising research and fostering innovation in order to advance knowledge, new technologies, sustainable solutions and disruptive innovation. In particular, building new innovative value chains would require increasing significantly the large-scale deployment and demonstration of new technologies and solutions. In this regard, the Horizon Europe programme will support the research and innovation efforts needed to leverage national public and private investments, pursuing four "Green Deal Missions" – dealing with adaptation to climate change, oceans, cities and soil – and embracing a systemic approach through experimentation, work across sectors and disciplines and involvement of local communities to combine societal pull and technology push.

Figure 1. The European Green Deal (EC, 2019c, p. 3)

In this regard, the **Annual Sustainable Growth Strategy 2020** (EC, 2019d, p. 1) recognises that "economic growth is not an end in itself. An economy must work for the people and the planet. Climate and environmental concerns, technological progress and demographic change are set to transform our societies profoundly. The European Union and its Member States must now respond to these structural shifts with a new growth model that will respect the limitations on our natural resources and ensure job creation and lasting prosperity for the future". In that sense, the Annual Sustainable Growth Strategy 2020 intends making the European Green deal operational, having identified environmental sustainability, productivity gains, fairness and macro-economic stability as the four dimensions of EU economic policy in the years to come (Figure 2). These four key dimensions will be crucial to put the SDGs at the centre of the Union's policymaking and action, and also to send a strong message about Europe's commitment towards sustainability.

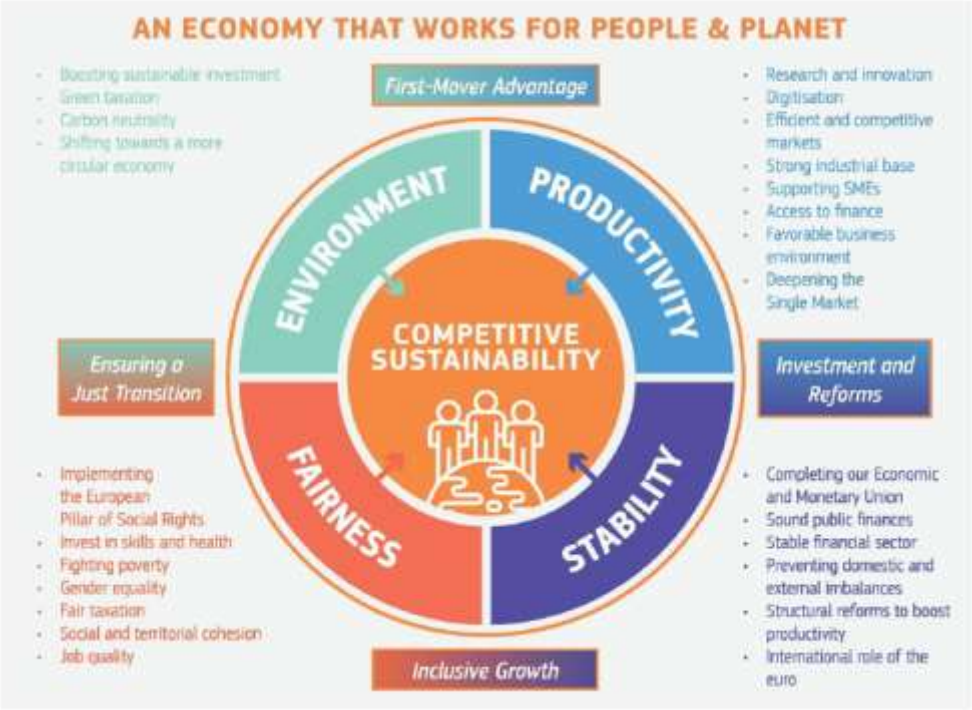

Figure 2. The Annual Sustainable Growth Strategy 2020 (EC, 2019d, p. 4)

Secondly, the European strategy for data (EC, 2020b) and the strategy Shaping Europe's digital future (EC, 2020c) represent the new strategies on digitalisation.

The **European strategy for data** is based on the premises that data is created by society and can serve to combat societal challenges keeping human beings at the centre, by empowering businesses, the public sector and citizens to make better decisions through the use of data and to seize the opportunity presented by data for the common good. Keeping into account several problems and risks – e.g. on data availability, imbalances in market power, data interoperability and quality, data governance, data infrastructures and technologies, individuals' empowerment to exercise their rights, data skills and data literacy, cybersecurity – the strategy is based on four pillars: A) A cross-sectoral governance framework for data access and use; B) Investments in data, capabilities and infrastructures for hosting, processing and using data, interoperability; C) Empowering individuals and SMEs; D) Creating a common European data spaces in strategic sectors and domains of public interest (EC, 2020b)

The strategy **Shaping Europe's digital future** starts from the recognition that digital solutions such as communications systems, artificial intelligence or quantum technologies can enrich our lives in many ways, but risks and costs associated to their diffusion and use may also hamper the inclusion and respect of every single human being. Therefore, the strategy focus on three key objectives to ensure a digital transformation that works for the benefit of people, with particular attention to i) Development, deployment and uptake of technology, ii) Level playing field for

companies to develop, market and use digital technologies to boost their productivity and competitiveness, and iii) Digital transformation enhancing democratic values and respect of fundamental rights (EC, 2020c).

Central to support the Green Deal and digital transformation is also **revitalising the European Research Area** to boost Europe's science lead, provide high quality and the circulation of knowledge, a critical mass of national and European investments and deliver innovative sustainable solutions across all systems. Such revitalisation would be grounded on essential principles of open science and open innovation, as well as on strengthened links with Education and Innovation as part of a broader knowledge policy. This will help creating a virtuous spiral of knowledge contributing to the wellbeing of Europe's society and to (re)create a relation of trust between the world of science/research and society (Gabriel, 2019).

Moreover, the **refocusing of EU's governance process** has also been started, **integrating the SDGs in the European Semester** for the coordination of EU's and its Member States' policies towards sustainable development. Firstly, the European Semester now embraces the broader economic and employment policy priorities put forward in the Annual Sustainable Growth Strategy 2020. Secondly, the 2020 country reports will feature: a reinforced analysis and monitoring on the SDGs (including a new dedicated section focusing on environmental sustainability to complement the analysis on economic and social challenges); a new annex setting out the individual Member States' SDG performance; an analysis of progress made on the SDGs in their national reform programmes. These reforms will support Member States' actions by identifying synergies and trade-offs between environmental, social and economic policies at national level, and will ensure the coordination of economic and employment policies on economic challenges that are a matter of common concern (EU, 2019d).

In this regard, the proposal of **transforming the existing European Semester process into a Sustainable Development Cycle** raised by the Independent Commission on Sustainable Equality (2018) is worth to mention. It calls for a multi-annual exercise aiming at implementing sound fiscal policy on an equal footing with sustainable development policies, composed by:

- A new and legally enshrined **Sustainable Development Pact** to encompass the existing Stability and Growth Pact in an alternate form (to exclude public investment) next to several other binding objectives related to the key elements of the threefold sustainable development path;

- A "**sustainability scoreboard**" to inform the policy coordination and surveillance process;

- A **Multi-annual Sustainable Framework** to set the overarching objectives of the process in order to ensure coherence and synergies with other EU policy tools;

- A **Sustainable Semester Process**, as an annual surveillance mechanism that which will monitor the respect of Sustainable Development Pact.

Last but not least, in the **EC proposal for a response to the COVID-19 outbreak and a major recovery plan** (EC, 2020d) R&I clearly plays an essential role.[17] Not only R&I efforts will be devoted in the health field in the areas of virology, vaccine development, treatments and diagnostics, and strengthen the EU's autonomy and leadership in value chains; but also, R&I will be directed at boosting the resilience of our production sectors, the competitiveness of our economies and the shift towards a clean, circular, competitive and climate neutral economy, in line with the Green Deal.

The rational behind this approach is **seizing the opportunity to make our societal and economic recovery truly transformative, sustainable and inclusive** by combining i) massive investments in solutions that address this crisis, ii) accelerating the digital and ecological transformation of our societies, and iii) contributing to regional cohesion and social inclusion, as the asymmetrical impact of the crisis across sectors, regions and segments of the population, including the youth, can exacerbate regional disparities and inequalities (EC, 2020e).

All in all, in the context of the response to COVID-19 and in view of potential future crises, public investments in R&I should be prioritised as "key strategic investments to achieve long-term societal and corporate sustainable objectives" (EC, 2020d, p. 4), towards a new economy for health and well-being in a broad sense, i.e. physical, mental, skills, social, environmental and economic aspects (EC, 2020f).

5 Roadmap and policy recommendations for a new approach

Taking into account the new overarching vision and narrative for R&I policy at EU level, **a roadmap for a new approach on R&I policies for transforming the EU's economy for a sustainable future** is proposed here (Figure 3). This builds on both the theoretical arguments discussed in the previous sections and the insights advanced in recent reports on sustainability transitions and role of science, innovation and technology (EEA, 2019 and UN 2019, among others).

This roadmap is composed by a **set of policy recommendations about** 1) R&I mission, 2) societal challenges and R&I fields, 3) vectors of action, 4) principles, 5) enabling conditions, 6) risks and 7) metrics.

[17] The STIP initiative by the EU and OECD is monitoring (through the STIP Covid-19 Watch) the types of S&I policy measures and arrangements countries are using to respond to the COVID-19 crisis, in order to provide a cross-country information service that S&I policy makers can use when designing their own policies.

Figure 3. R&I for transforming the EU's economy for a sustainable future (Authors)

Here, we report our main policy recommendations for each of these elements, briefly outlining their scope and a suggestion to make them operational. These recommendations should be conceived as preliminary suggestions for policy makers in the R&I policy domain to be considered when planning future policy avenues, in particular for institutions at EU, national and subnational level (starting from the European Commission DG Research and Innovation itself) to adapt their goals, targets and tools and enhance R&I contribution to sustainable development.

POLICY RECOMMENDATION 1: Mission for R&I policy

The combination of EU efforts towards a Sustainable Europe by 2030 with the new strategies designed and approved by the EC 2019-2024 on the European Green Deal, on digitalisation and data and on the post-COVID recovery points to an **enhanced mission for R&I policy** (Bell et al., 2019) as follows:

→ **PR1.1: Accelerate the transition towards a sustainable, fair and prosperous future for people and planet by achieving the desired scientific, technological and societal impact.** This should be based on evidence and the involvement of citizens and innovation ecosystem stakeholders and to be implemented in an ethically robust, effective and efficient manner.

POLICY RECOMMENDATION 2: Societal challenges and R&I fields

The evolution of the framing for R&I policy from supporting economic growth all-around (regardless of its quality and direction) to focusing on transformative change towards sustainable development implies devoting efforts on selected **priorities**. At this stage, it

is possible to identify – primarily based on the SDGs framework,[18] the European Green Deal and the post-COVID scenario, but without any intention of prescription and exhaustiveness – some preliminary **societal challenges**. In particular, to foster sustainability transitions for all the sociotechnical systems affecting capabilities and ecological systems, R&I may focus on energy, water, air, soil, waste, climate, biodiversity, mobility, food, nutrition, human and animal health, ageing, disability, social relations, communication, housing, building, justice and rule of law, production systems, consumption patterns, education and skills, poverty, social exclusion, corruption, human rights, migration, violence, among others.[19]

→ **PR2.1: Facilitate collective appraisal, participatory democracy and co-creation mechanisms** for the selection of the main societal challenges, opening up for many priorities and keeping the policy space adaptive and timely responsive to changing conditions.

→ **PR2.2: Avoid a silos-based approach** in terms of standard R&I fields (e.g. Natural sciences, Engineering and technology, Medical and health services, Agricultural and veterinary sciences, Social sciences, Humanities and the arts, etc.), by combining investments in different fields to open up for new knowledge and new solutions.

POLICY RECOMMENDATION 3: Vectors for action

R&I policies for the sustainability transition of sociotechnical systems should be structured into three interrelated vectors of action:

The "innovation vector", conceived as the search for new solutions, new technologies, new materials, etc. (including rediscovering past (and often environmental-friendly) practices and solutions) to tackle societal challenges and expand human capabilities today and in the future;

The "process vector", conceived as providing knowledge, information and data (e.g. standard and innovative statistics, real time and big data) for evidence-based policy-making, for advancing flows management processes, cyber-physical systems and value chains control mechanisms, and for improving conditions for individual and collective actions towards sustainability;
The "behaviours and values vector", conceived as increasing the individual and collective awareness on our role and the effects of our behaviours on sustainability transitions,

[18] For instance, six entry points for knowledge-based transformations towards sustainable development are identified in the last Global Sustainable Development Report (UN, 2019), which relate to human well-being; sustainable and just economies; sustainable food systems and nutrition patterns; energy decarbonization and universal access to energy; sustainable urban and peri-urban development; and the global environmental commons.
[19] These challenges are particularly and widely relevant for urban areas – whose share of world's population is expected to rise to just over 80 % by 2050 (EC, 2019b) – pointing to the need to create sustainable, smart, inclusive, resilient and safe urban systems, enhancing the innovation capacity of cities to address global urban challenges within a holistic perspective.

along with diffusing among all people, actors (public, private and social) and places innovative solutions and processes.

Vectors in practice

To raise one illustrative example on mobility: the "innovation vector" would concern advancing the technology for hybrid and electric cars; the "process vector" would concern advanced traffic management systems and smart mobility mechanisms; the "behaviours and values vector" would concern changing attitudes towards use of private cars.

→ PR3.1: Simultaneously pursue these three vectors for R&I within an overcharging strategy, in order to advance a "collective/systemic human intelligence" able to process knowledge, information and data and apply new solutions on the concomitant quest for social inclusiveness, environmental protection and economic prosperity.

POLICY RECOMMENDATION 4: Principles for R&I policy design and implementation

In line with the *Science, research and innovation performance of the EU 2020* (EC, 2020f), which analyses Europe's performance dynamics in science, research and innovation, and building on the recent literature, the following key principles should underline a roadmap for a new approach on R&I policies.

- ***Co-creation, multilevel approach and inclusivity***: A new policy space for a transformation emphasising 'co-leadership' and 'future engineering' in the EU emerges at the interface between transformative innovation policy and integrated sustainability policies for systemic transformation (Bell et al., 2019; Arnold, 2020a).

→ PR4.1: Involve a wide set of actors within our societies (not only dominant actors but also niche and marginal ones) to use collective intelligence for identification of evident and latent needs, knowledge brokering and social creativity, through co-creation, co-implementation, co-assessment, and citizen-oriented communication & dissemination.

- ***Complex thinking***: R&I reasoning, argumentation, and reflection should be based on complex thinking (Lipman, 2003) in all its three components: awareness of assumptions and implications, as well as of the reasons and evidence on which conclusions are based (critical capacity); imagining new ways of seeing and connecting the experience's elements (creative capacity); emotional and motivational dimensions for our peers, environment and common good (caring capacity) (Biggeri and Santi, 2012).

→ PR4.2: Continuously nurture the engagement of communities of inquiry, communities of practices, and communities of learners, opening-up to constructive dialogues within and among different generations.

- ***Directionality***: Missions, partnerships and collaborative R&I actions should all recognise the importance of the new directionality towards tackling grand societal challenges.

→ PR4.3: Link all R&I investments with specific, targeted and concrete goals for sustainable human development.

- ***Transformation and adaptation***: R&I policies should foster the renewal or transformation of the main sociotechnical systems affecting our people, planet and prosperity (including supply chains, consumption and use patterns, behaviours, infrastructures, regulatory approaches, new organisational and institutional models, partnerships, markets, policies etc.) (Schot and Steinmueller, 2018; Bell et al., 2019), framing R&I also outside the markets towards a broader "societal function" (Vollenbroek, 2002; Smith et al., 2010).

→ PR4.4: Make R&I policies and investments adaptive, in the sense of evolving over time according to changing conditions and being able to face future and unpredicted crisis (as apparent today in this pandemic times), in order to continue stemming unprecedented sustainability transformations (Arnold, 2020a).

- ***Evolutionary perspective and experimental learning***: The whole set of market (e.g. demand-pull control) and non-market determinants (e.g. institutional factors, knowledge capabilities) should be taken into account in understanding innovation dynamics for sustainability, embracing uncertainty and accepting failure as part of the learning and innovation process, and avoiding a deterministic and path dependent view, in order to understand how to promote both radical and incremental changes towards sustainable development.

→ PR4.5: Build temporary spaces for actors working together on a variety of concrete pathways, in order for them to design and experiment new solutions and processes, acknowledging the importance of new shared expectations and visions, new networks, of new markets to eventually challenge dominant practices in mainstream markets and institutions (Schot and Steinmueller, 2018).

- ***Diffusion and uptake***: innovations, knowledge and information, and awareness (i.e. the three vectors of action) that are required to spur a transformative change towards sustainability need to diffuse across actors, reaching – and being accessible and affordable by – all segments of our societies. Therefore, we need uptake of research and innovation outcomes by markets actors, public authorities, civil society organisations and citizens, turning research and innovation into applied sustainable solutions with a societal – and not only market – value for human flourishing.

→ PR4.6: Ensure the understanding, willingness for the uptake and absorption of new knowledge, novel solutions and management processes **not only by markets and citizens, but also and primarily by decision-makers who must be called – and**

kept accountable – to apply them in all policies guiding our societies towards sustainability transitions.

POLICY RECOMMENDATION 5: Enabling conditions

Conceiving R&I as the driver for sustainability transitions by escaping lock-in, deflecting path dependencies and transforming sociotechnical systems (Smith et al., 2010) pushes to identify a preliminary set of enabling conditions that would pave the way for a new institutional set-up for R&I policy at European level.

→ **PR5.1: Establish a clear, shared and long-term mandate** towards an integrated vision of sustainable development.

→ **PR5.2: Ensure a systemic and multi-disciplinary perspective in research and in policy design,** avoiding isolated and piecemeal approaches that have proven to be ineffective, while instead favouring the continuous combination of disciplines and knowledge caches and the pursuit and exploitation of inter-sectoral opportunities within missions to tackle societal challenges;

→ **PR5.3: Ensure that innovation policy for sustainability transitions is addressed in terms of policy mixes,** rather than individual instruments, as their comprehensiveness and cross-sectoral nature call for a **"whole-of-government" engagement and a "whole-of-society" transformation.**[20]

→ **PR5.4: Ensure policy coherence within the on-going evolution of R&I policy** that is currently based on the combination of "adding new goals and instruments (layering), adding new rationales and goals without changing instruments (drift), and adding instruments without altering rationales (conversion)" (Schot and Steinmueller, 2018, p. 1565). In other words, the coherence among the policy tools typical of each R&I framing (e.g. R&D policies, partnership-building and interactive learning policies and mission-oriented policies) should be continuously ensured to keep all pieces moving towards the same integrated vision of sustainable development.

→ **PR5.5: Ensure multilevel governance of R&I policy through the reconciliation of bottom-up and top-down policy approaches** (Crescenzi and Rodríguez-Pose, 2011; Biggeri and Ferrannini, 2014b) and the **mobilisation of international R&I cooperation and investment** (in particular via effective and tested platforms like Mission Innovation). This implies valorising the articulation of resources, capacities,

[20] In other words, the institutional "positioning" of innovation policy should be redefined, beyond a narrow sectoral, business and growth perspective "towards a horizontal and more inclusive and strategic policy mix for system innovation and transformative change" (Lundin and Schwaag Serger, 2018, p. 30). For instance: environmental issues cannot be solved with environmental policies alone if economic policies continue to promote fossil fuels, resource inefficiency or unsustainable production and consumption; social policies are not sufficient to accompany the fourth industrial revolution and support the labour force affected by digital transformation in productive sectors (EC, 2019a); education and training policies should link with R&I processes to prepare students, workers and citizens for future sociotechnical evolutions and prospects, building their capacities and skills to both drive transformations and ensure resilience in our societies.

knowledge endowments, ideas, and experimental innovations for human flourishing at each level, thus complementing horizontal with vertical networking.

→ **PR5.6: Ensure open and inclusive spaces for dialogue, participation and public scrutiny** in order to nurture social creativity, active citizenship and collective empowerment, helping actors to navigate conflictual views and to generate trust in co-creation processes (Biggeri and Ferrannini, 2014c; Schot et al., 2018).

→ **PR5.7: Ensure transparency and compliance with ethical guidelines** in all R&I initiatives and in all processes of co-creation, co-implementation, co-assessment, and citizen-oriented communication & dissemination;

POLICY RECOMMENDATION 6: Risks underlying R&I policy

The systemic, complex and uncertain nature of research and innovation processes for transformative change imply a wide rage of potential predictable and unpredictable risks to be taken into account, including, among others:

- **Trade-offs among sustainability dimensions**, with predominance of traditional economic concerns about costs, profits and deficits over social and environmental challenges;

- **Low predictability and heterogeneity of long-run effects** of innovations on human capabilities and ecological systems, due to potential deviations, misuses and abuses to pursue private interests instead of sustainability transitions for the common good;

- **Wide and deep ethical concerns** on the ownership, privacy, use and diffusion of data, potentially limiting not only the uptake and effects of increased information on societal issues, but also exacerbating exclusionary processes or disempowering social groups and actors;

- **Power and control of knowledge**, especially if research mechanisms and new technological tools do not properly follow ethical and transparency criteria or if production of knowledge is pursued to serve exclusively private and market interests instead of a wider societal function;

- **Rent-seeking behaviours** by the most powerful groups in decision-making processes about R&I investments, especially if co-creation processes are not fully inclusive and participatory for all the segments (and interests) of our societies;

- **Failure to address root causes of current societal challenges** when innovations accommodate changes but do not alter the fundamental characteristics of the sociotechnical systems (Fedele et al., 2019), so that they remain unsustainable and vulnerable;

- **Capture of disruptive innovation** by "business-as-usual" positions to preserve rents and powers in the status quo.

→ **PR6.1: Devote continuous and strong attention to anticipate, avoid and deal with each of these risks,** among others.

POLICY RECOMMENDATION 7: Metrics and indicators

Improving the measurement of the contribution of research and innovation to sustainable development is undoubtedly fundamental and urgent for evidence-based decision-making processes on R&I at all levels. As discussed in the previous section, there appears to be open space for designing a new expanded indicators framework complementing standard measures with innovative proposals. Based on the arguments raised in this report and on further reflections by Montoya (2018), our preliminary proposal is reported in Table 2.

Clearly, this **expanded indicator framework to measure the contribution of research and innovation to sustainable development** should be read as containing general – and not exhaustive – proposals, which are yet to be further and more robustly discussed, detailed and validated.

→ **PR7.1: Enable the structured engagement among sustainable development experts, measurement specialists, statistical offices and policy-makers** in charge of designing, implementing and monitoring R&I policy at different levels, in order to implement these proposals in practice by setting feasible and appropriate indicators, methodologies and standards.

→ **PR7.2: Identify tailored international and national targets** to concretely foster R&I initiatives for sustainable development and keep all actors accountable for their efforts.

PILLAR	ELEMENT	INDICATOR(S) AND RATIONALE(S)
Framework conditions	Shared vision	To measure the extent to which a societal vision towards sustainable development is shared by all actors and stakeholders at all levels.
	Governance	To measure the extent to which R&I for sustainable development plays a role in policy priorities (e.g. agenda setting, budget allocation) and the extent to which R&I indicators have been mainstreamed into policy monitoring and evaluation.
	Public attitude	To measure the public acceptance and support for R&I and its recognition as a key driver in efforts to address societal challenges.
	Educational infrastructure	To measure the extent to which the educational and training infrastructure (since primary to higher education and VET) provides students, workers and citizens with transversal skills, multi-disciplinary knowledge and complex thinking on future sociotechnical evolutions and prospects.
	Policy mix and coherence	To measure the extent to which R&I policy is synergically integrated and coherent with other policy fields towards the overarching vision of sustainable development (e.g. health policy, education policy, agriculture and food policy, energy policy) and vice-versa.
Inputs	Human capital	To measure the supply and engagement of R&I human capital (i.e. the total number of R&D personnel) not only by function, by sector of employment, field of R&D, but also primarily by key areas, e.g. by SDG. For instance, number of researchers working in the field of marine technology (combining INDICATOR 9.5.2 and INDICATOR 14.a. from the Global SDG indicators framework)

	Investments	To measure R&D investments – both appropriations and expenditures from all public and private sources –for sustainable development as key activity for knowledge creation, by creating a detailed "R&D budgeting / accounting" able to: i) simultaneously quantify and qualify the relative importance of some key areas (e.g. health, sustainable agriculture, clean energy) or SDGs within international, national and sub-national research efforts; ii) identifying to which SDGs each research investment / project is aiming at contributing to.
	Start-up and spin-offs	To measure the extent to which start-ups and spin-offs are positively contributing to develop and diffuse new solutions to tackle societal challenges.
Design process	Participation / Inclusivity	For instance, identifying to which SDG each start-up/spin-off is contributing to.
	Multi-disciplinarity	To measure the extent to which research and innovation design processes are participatory and inclusive, by assessing the involvement, role and empowerment of different actors / stakeholders / social groups / segments of our societies.
	Actors	To measure the extent to which R&I design processes are based on a multi-disciplinary combination of knowledge and insights transcending typical silos-based boundaries, by assessing the involvement, role and weighted importance of different disciplines.
	Networks and partnerships	To measure the prevalence of research and innovation activities for sustainable development within all sectors of our societies, by assessing the number of organizations (in the public, private or third sector) that have been innovative, innovation-active, non innovative for sustainable development.
	Collaborations	To measure the involvement in networks and partnerships in research initiatives and inventive activities for sustainable development.
Outputs	Innovation	To measure the propensity to collaborate – across institutions, disciplines, across sectors, across regions and countries – in scientific research and inventive activities for sustainable development through co-authorship of scientific publications and co-invention.
	Patents	To measure the consistency of innovations – e.g. among others, product, process, organizational, marketing, social innovation – with sustainable development principles, by assessing to which SDG / grand societal challenge each innovation is contributing to in positive way.
	Scientific publications	To measure the contribution of patents to sustainable development, by assessing to which SDG / grand societal challenge each patent application under the Patent Co-operation Treaty (PCT) is contributing to in positive way.
	International conferences	To measure the advancement and evolution of scientific specialization on grand societal challenges, by assessing the number of publications in top journals dealing with each SDG (e.g. thorough systematic measurement or keywords analysis).
Outcomes	Key impact pathways	To measure the advancement and evolution of scientific debate on grand societal challenges, by assessing the number of international conferences – and their participation performance – dealing with each SDG (e.g. thorough analysis of conference titles / thematic fields).
	Environmental impact / Planet	To measure the extent to which the Horizon Europe Programme contributes to addressing EU policy priorities (including meeting the Sustainable Development Goals) by assessing portfolio of projects that generate outputs which aim to contribute to tackle global challenges or to achieve future R&I missions (e.g. through the Sustainability Innovation Radar).
	Social impact / People	To measure the direct and indirect impact on the environment (at micro, local, national and international level) derived from research and innovation outputs, through both standard and innovative measures on environmental issues.
	Economic impact / Prosperity	To measure the direct and indirect impact on human capabilities and individual / collective empowerment (at micro, local, national and international level) derived from research and innovation outputs, through both standard and innovative measures on social issues and well-being.
	Take-over	To measure the direct and indirect impact on sustainable and inclusive growth (at local, national and international level) derived from research and innovation outputs, through both standard and innovative measures on economic performances.

Table 2. A new expanded indicators framework on R&I for sustainable development (Authors)

To conclude, we believe the proposed elements and policy recommendations of this roadmap (i.e. mission, societal challenges and R&I fields, vectors of action, principles, enabling conditions, risks, metrics) may be composed to create a **Theory of Change** on this new approach for R&I policies. This would allow disentangling the processes characterising the contribution of research and innovation to sustainability transitions, in order to advance the theoretical and measurement discussion on the new framing for R&I policies.

6 Conclusions

The overarching policy framework given by the 2030 Agenda for Sustainable Development, the new strategies of the European Commission 2019-2024 and the post-COVID recovery conceives **science, technology, research and innovation as a key driver for achieving a prosperous and sustainable Europe**.

Therefore, R&I policy lies at core of a transformative change towards sustainable development. Indeed, **R&I plays the key role to**

i. **Pursue a direction for transformation**;

ii. **Create, expand, advance and disseminate knowledge among all**;

iii. **Find, test and evaluate solutions (that can be scaled-up and replicated) to pursue human wellbeing, global public health, sustainability, social progress and societal prosperity today and in the future**.

This requires an expanded framing for R&I with new missions, objectives, stakeholders, resources and processes to empower individuals, communities and societies with innovative solutions, expanded knowledge and information, raised awareness and enhanced capacities to pursue sustainable human development.

In a COVID-19 and post-COVID world, a new approach on R&I policies that simultaneously addresses the social, environmental, and economic challenges of our present and future is an imperative, in order to boost the transformations of our sociotechnical systems towards sustainable and inclusive economies and societies.

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Acknowledgements

We would like to express our gratitude to the staff at the European Commission DG RTD Directorate A – Policy and Programming Centre for providing us with many helpful feedbacks on this report.
We are most grateful to Elisa Barbieri, Marco Bellandi, Patrizio Bianchi, Marco R. Di Tommaso, Mauro Lombardi and Paolo Nesi. We have benefited substantially from their invaluable comments and suggestions on the topic of this study.
We would also like to thank colleagues at ARCO (Action Research for CO-development), at the Department of Economics and Management of the University of Florence, at the Department of Economics and Management of the University of Ferrara and at c.MET05 (National University Centre on Applied Economic Studies). We developed many of the arguments employed in this study while working alongside them and taking advantage of their expertise and creativity.

About the Authors

Mario Biggeri is an Associate Professor of Development Economics at the University of Florence; Scientific Director of ARCO (Action Research for CO-development); Director of the Scientific and Ethical Committee of the Yunus Social Business Centre University of Florence; former Academic Director of the BA in Economic Development, International Socio-sanitary Cooperation and Conflict Management at the University of Florence; former Academic Director of the MSc. in Development Economics at the University of Florence; Fellow of the Human Development and Capability Association; Fellow and member of the Steering and Management Board of c.MET05 – National University Centre on Applied Economic Studies, Italy.
His research concentrates on political economy for sustainable human development; international cooperation programs; industrial policies; evolution of informal activities and clustering of SMEs; social economy and social enterprises; local development; collective action; research methods; impact evaluations; poverty measures; the well-being of children, persons with disabilities, and migrants.
He is co-author and co-editor of 21 books and has published extensively in several international academic journals.

Andrea Ferrannini is coordinator of the Strategic Unit on Local Development at ARCO (Action Research for CO-development); Coordinator of the Thematic Group on Participatory Methods of the Human Development and Capability Association; Fellow of c.MET05 – National University Centre on Applied Economic Studies, Italy; former lecturer of Development Economics at the University of Florence
His research activities focus on sustainable human development, industrial policies and social progress, international development cooperation, Sustainable Development Goals, local economic development and participatory methods.
He is co-author of 4 books and has published articles and chapters in academic journals and books.

8 APPENDIX 1: Selected datasets and indicators on sustainable development

Without any intention of exhaustiveness, we briefly review here the most relevant datasets and indicators – developed respectively by the UN, the World Bank, the World Economic Forum, selected independent actors, the OECD and the EU – that integrate the three dimensions of sustainability and are today informing the debate on the transformative change towards sustainable development.

CUSTODIAN ORGANISATION	DATASET / INDICATOR	DESCRIPTION	TIME SPAN	LEVELS	MAIN USE
UN Stats	Global SDG Indicators Database	Data on the 232 individual indicators adopted by the General Assembly (A/RES/71/313) based on the Work of the Statistical Commission pertaining to the 2030 Agenda, containing over one million observations.	Since 2000	- 243 countries Regions -Development groups	Secretary-General's annual report on the Progress Towards the SDGs
UN DESA	UN Data	Integration of 32 databases compiled by the UN statistical system and other international agencies, containing over 60 million data points.	Depending on database	- 232 countries Regions	Statistical Yearbook
UNDP	Human Development Index (HDI)	HDI is a summary measure for assessing long-term progress in three basic dimensions of human development: a long and healthy life, access to knowledge and a decent standard of living. The HDI is computed on 4 indicators drawn from the United Nations Population Division, UNESCO and the World Bank.	Since 1990	- 189 countries Regions - Developme nt groups	UNDP Human Development Report and HDI country profiles
UNDP	Inequality-adjusted Human Development Index (IHDI)	The IHDI takes into account inequality in all three dimensions of the HDI by discounting each dimension's average value according to its level of inequality.	Since 2010	- 150 countries Regions -Development groups	UNDP Human Development Report and HDI country profiles
UNDP and OPHI	Multidimensional Poverty Index (MPI)	The MPI identifies multiple overlapping deprivations suffered by individuals in 3 dimensions: health, education and standard of living. All the 10 indicators needed to construct the MPI for a country are taken from the same household survey.	Since 2010	- 101 developing countries	UNDP Human Development Report and HDI country profiles
UNDP	Human Development dashboards	Dashboard 1: Quality of human development (14 indicators on quality of health, education and standard of living). Dashboard 2: Life-course gender gap (12 indicators on gender gaps in choices and opportunities over the life course – childhood and youth, adulthood and older age). Dashboard 3: Women's empowerment (13 indicators on reproductive health and family planning, violence against girls and women, and socioeconomic empowerment). Dashboard 4: Environmental sustainability (11 indicators on environmental sustainability – levels of or changes in energy consumption, carbon-dioxide	Depending on database	Available countries	UNDP Human Development Report and HDI country profiles

		emissions, change in forest area, fresh water withdrawals, and natural resource depletion – and environmental threats - mortality rates attributed to household and ambient air pollution, and to unsafe water, sanitation and hygiene services, percentage of land that is degraded, and the International Union for Conservation of Nature Red List Index). Dashboard 5: Socioeconomic sustainability (11 indicators on economic sustainability – adjusted net savings, total debt service, gross capital formation, skilled labour force, diversity of exports, and expenditure on research and development – and social sustainability – old age dependency ratio projected to 2030, the ratio of the sum of education and health expenditure to military expenditure, changes in inequality of HDI distribution, and changes in gender and income inequality).			
World Bank	World Development Indicators	It represents the primary World Bank collection of 1,600 development indicators, compiled from officially recognized international sources. It includes a subset of indicators for the Sustainable Development Goals.	Since 1960	- 217 countries Regions -Development groups	World Bank Atlas of Sustainable Development Goals
WEF	The Global Competitiveness Index	The GCI is the product of an aggregation of 103 individual indicators, organized into 12 pillars: Institutions; Infrastructure; ICT adoption; Macroeconomic stability; Health; Skills; Product market; Labour market; Financial system; Market size; Business dynamism; and Innovation capability. Indicators on "Commitment to sustainability" and other environmental issues (e.g. energy and water) are included in Pillar 1 and 2, while selected social indicators are included in Pillar 6 and 7.	Since 2007	- 141 countries	The Global Competitiveness Report
WEF	Inclusive Development Index	In 2014-2015, a sustainability-adjusted GCI were computed to assess countries for their ability to generate this long-lasting prosperity for their citizens in a socially and environmentally sustainable way.	Since 2015	- 113 countries -Development groups	Inclusive Development Index report 2018
Bertelsmann Stiftung and Sustainable Development Solutions Network	Sustainable Development Index and Dashboards	The Sustainable Development Report is the first worldwide study to assess where each country stands with regard to achieving the SDGs. Its dataset consists of 86 global indicators (plus an additional 35 indicators for OECD member states) from a variety of official and unofficial sources that are publicly available.	Since 2016	- 162 countries Regions -Development groups	Sustainable Development Report
Social Progress Imperative	Social Progress Index	By aggregating these indicators, the SDG Index is computed to capture overall performance in sustainable development within a single composite index that can be used to make comparisons across countries and over time. The Social Progress Index is a comprehensive measure of actual life outcomes, independent of economic indicators and designed to complement,	Since 2014	- 149 countries	Social Progress Report

		rather than replace, economic measures. Three broad dimensions of social progress – Basic Human Needs, Foundations of Wellbeing, and Opportunity – are measured by a total of 51 social and environmental indicators. The diverse selection of indicators allows for granular analysis of the specific underpinnings of social progress in each country, while the broad categories of the index framework help to better understand global and regional trends. Moreover, strengths and weaknesses for each country are identified by comparing performances relative to 15 countries of similar GDP PPP per capita			
Legatum Institute	Legatum Prosperity Index	It measures national prosperity based on institutional, economic, and social wellbeing. The Index consists of 12 pillars of prosperity, built upon 65 actionable policy areas (elements), and is underpinned by 294 indicators.	Since 2007	- 167 countries	Annual report on Legatum Prosperity Index
Bertelsmann Stiftung	Sustainable Governance Indicators (SGI)	The SGI explores how governments target sustainable development. Sustainable governance is built on three pillars: Policy Performance (i.e. economic, social and environmental policies); Democracy (i.e. quality of democracy); Governance (i.e. executive capacity and executive accountability). Data is collected through a cross-national comparative survey combining 86 indicators (16 qualitative and 70 quantitative).	Since 2014	41 EU and OECD countries	SGI Report
OECD	Better Life Index	The BLI allows comparing well-being across countries, based on 11 topics that reflect what the OECD has identified as essential to well-being in terms of material living conditions (housing, income, jobs) and quality of life (community, education, environment, governance, health, life satisfaction, safety and work-life balance). Each topic is built on one to four specific indicators, for a total of 24 indicators.	Depending on single variable	OECD countries and other selected G20 countries	Better Life Index website
OECD	Regional social and environmental indicators	The database includes 42 indicators at subnational level (TL2 or TL3) on the following dimensions: Health access; Environment; Exclusion indicators; Housing; Internet broadband access; Safety; Voters turnout.	Since 1995	- Subnational level in OECD countries - OECD countries	
Eurostat	EU SDG Indicator set	The indicator set comprises around 100 indicators and is structured along the 17 SDGs. For each SDG, it focuses on aspects that are relevant from a EU perspective. It allows a statistical presentation of trends relating to the SDGs in the EU over the past five years and, when sufficient data are available, over the past 15 years.	Since 2010	- EU member countries - EU	Monitoring report on progress towards the SDGs in an EU context
Eurostat and Joint Research Centre	Social scoreboard	It monitors the implementation of the European Pillar of Social Rights by tracking performances across EU countries in 12 areas divided around three people-centred dimensions: Equal opportunities and access	Since 2005	- EU member countries - EU - Euro area	Monitoring report on the European Pillar of Social Rights

		to the labour market; Dynamic labour markets and fair working conditions; Public support / Social protection and inclusion. It relies on a total of 94 indicators.			
EC DG Regio and Social Progress Imperative	European Social Progress Index	The EU regional Social Progress Index aims to measure social progress for each region as a complement to traditional measures of economic progress. It follows the overall framework of the global Social Progress Index and is based on 50 indicators, primarily from Eurostat.	2016	Subnational level in all EU member countries	
Eurostat	Cohesion data	Dataset on aggregated information on finances, payments and achievements under the European Structural and Investment Funds (ESIF) 2014-2020. Data are available, by country, fund and by the following themes: Research & Innovation; ICT; Competitiveness of SMES; Low-Carbon Economy; Climate change Adaptation & Risk Prevention; Environment Protection & Resources Efficiency; Network Infrastructure in Transport and Energy; Sustainable & Quality Employment; Social Inclusion; Educational & Vocational Training; Efficient Pubic Administration.	2014-2020	- EU member countries - EU	

To conclude, it is worth highlighting the interesting three-tier classification for evaluating global SDG indicators: Tier I indicators are conceptually clear, have an internationally established methodology and standards, and are available for the majority of countries; Tier II indicators are conceptually clear, have an internationally established methodology and standards, but sufficient data for monitoring purposes is not widely produced; and Tier III indicators currently lack an internationally established methodology or standard, although appropriate methods or standards will be developed (IAEG-SDG, 2020). Besides the fact that this classification is frequently updated depending on methodological development and data availability at the international level, it is surely illustrative of the diffused efforts to continuously improving not simply – and fundamentally – the reliability and robustness of data and indicators, but also the statistical coverage of an ever wider array of societal challenges and issues.

9 APPENDIX 2: Selected datasets and indicators on R&I

Without any intention of exhaustiveness, we briefly review here i) the main indicators and datasets on R&I used to inform research, debate and policy-making (PART A), and ii) its recent linkages with sustainable development (PART B).

PART A

CUSTODIAN ORGANIZATION	TYPE	INDICATORS
UNESCO Institute for Statistics [21]	Human resources	R&D personnel available by • function (i.e. Researchers, Technicians and equivalent staff, Other supporting staff); • by sector of employment (i.e. Business enterprises, Government, Higher education, Private no-profit); • sex [22], age, formal qualification, seniority/grade level; • field of R&D (e.g. Natural sciences, Engineering and technology, Medical and health services, Agricultural and veterinary sciences, Social sciences, Humanities and the arts, etc.).
	Financial resources	Gross Domestic Expenditure on R&D (GERD) computed as percentage of GDP, per capita and per researcher, and also available by • sector of performance (i.e. Business enterprises, Government, Higher education, Private non-profit); • source of funds (i.e. Business enterprises, Government, Higher education, private no-profit, Rest of the world); • field of R&D (e.g. Natural sciences, Engineering and technology, Medical and health services, Agricultural and veterinary sciences, Social sciences, Humanities and the arts, etc.); • type of costs (e.g. Current vs. Capital, or Labour, Land and buildings, Machinery and equipment, Capitalised computer software, Other intellectual property products); • type of R&D activity (i.e. Basic, Applied, Experimental, Not specified).
	Innovation in manufacturing	Data mostly available by size class and by manufacturing industry in terms of • type of innovation (i.e. Product, Product-only, Process, Process-only, Product and process innovation); • firms (i.e. Innovative, innovation-active, non innovative firms); • activities (i.e. Innovation activities, Abandoned or on-going innovation activities only); • Sources of information, Cooperation, and Hampering factors; • Organizational innovation and Marketing innovation.
World Bank / WDI	Indicators on R&I	• Scientific and technical journal articles; • Standard indicators on R&D expenditure and human resources.
WEF / Global Competitiveness Index	Indicators on "Innovation Capability"	• International co-inventions and Multi-stakeholder collaboration; • Scientific publications and Patent applications; • R&D expenditures; • Research institutions prominence.
Bertelsmann Stiftung / Sustainable Governance Indicators	Indicators on Research, Innovation and Infrastructure	• Public and non-public R&D expenditure, number of researchers, ratio between license receipts to payments concerning intellectual property, number of patent applications under the PCT; • Scoring based on the question "to what extent does research and innovation policy support technological innovations that foster the creation and introduction of new products".
OECD / Directorate for Science, Technology and Innovation	Internationally comparable databases on the links between	• Key indicators on R&D expenditure (by country and by industry) and personnel; • Data on Government appropriations or outlays for RD (GBAORD) by socio-economic objective, using the NABS 2007 classification i.e. Exploration and exploitation of the Earth; Environment; Exploration

[21] Data available for most countries in the world over the period 2012-2018.
[22] A detailed focus on Women in Science is also provided by UNESCO.

	industry, technology, competitiveness and globalisation	and exploitation of space; Transport, telecommunication and other infrastructures; Energy; Industrial production and technology; Health; Agriculture; Education; Culture, recreation, religion and mass media; Political and social systems, structures and processes; General advancement of knowledge (RD financed from General University Funds vs other sources); Defence. • Data on patent applications (by country and technology fields) to the European Patent Office (EPO), the US Patent and Trademark Office (USPTO), patent applications filed under the Patent Co-operation Treaty (PCT) that designate the EPO, as well as Triadic Patent families; • Indicators of international co-operation in patents (co-inventions, cross-border ownership of patents); • Statistics on ICT value added in business sector value added, R&D expenditure in selected ICT industries, ICT employment in business sector employment, ICT-related patents; • Innovation indicators, such as Innovation activity intensity across industries, Innovative firms, Firms receiving public support; • Careers and mobility of doctorate holders, in collaboration with the UNESCO Institute for Statistics and Eurostat.
Eurostat	Statistics in the fields of science, technology and innovation[23]	• R&D statistics on expenditure and personnel (by performing and funding sectors, types of costs or economic activities); • Government appropriations or outlays for RD (GBAORD) as a % of total general government expenditure, by NABS 2007 socio-economic objective, by funding mode; • Data on projects and related organisations funded by the European Union under all framework programmes for research and innovation (since FP1 to Horizon 2020); • Innovation statistics about enterprises that have product and business process innovations, their strategies, knowledge management and innovation activities, as well as about the innovation environment (i.e. enabling or hampering factors); • Data on high-tech industries and products, high-tech trade as well as knowledge-intensive services; • Statistics on the current stock of Human resources in science and technology and on the current and future supply / flows of highly skilled persons; • Data on intellectual property rights, including patent applications to EPO by priority year, ownership of inventions, European and international co-patenting, trademarks and community designs.
	Cohesion data Research & Innovation	Information available by fund and by country on Planned investments; Implemented investments; Project stories; Achievements.

It is worth mentioning the *STIP Compass* initiative by the European Commission and the OECD, which collects together in one place quantitative and qualitative data on national trends in science, technology and innovation policy. In this portal, data about STI policies (e.g. on Themes, Target Groups, Policy instruments, Responsible organisations, Budget ranges, as well as key trends and benchmarks and on related publications for each country) are made available for policy research and advice supporting government officials, analysts and scholars.

[23] Eurostat data are most often provided both at national and regional level.

Indicators on conducive environments for innovation have been also appearing and consolidating in the debate for matters of analysis, benchmarking and policy evaluation, such as the *Innovation Input Sub-Index of the Global Innovation Index* and *Innovation Cities Index*, among others.

PART B

CUSTODIAN ORGANIZATION	TYPE	INDICATORS
UN / Global SDG Indicators Database	Official indicators concerning R&I[24]	• INDICATOR 9.5.1 *Research and development expenditure as a proportion of GDP* (Tier I) ;[25] • INDICATOR 9.5.2 *Researchers (in full-time equivalent) per million inhabitants* (Tier I); • INDICATOR 3.b.2 *Total net official development assistance to medical research and basic health sectors* (Tier I); • INDICATOR 7.a.1 *International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems* (Tier I); • INDICATOR 12.a.1 *Amount of support to developing countries on research and development for sustainable consumption and production and environmentally sound technologies* (Tier III); • INDICATOR 14.a.1 *Proportion of total research budget allocated to research in the field of marine technology* (Tier II).
Bertelsmann Stiftung and SDSN / Sustainable Development Index and Dashboards	Indicators on R&I	• R&D expenditure and for the number of scientific and technical journal articles for all countries; • R&D researchers, Triadic Patent Families filed and Women in science and engineering for OECD countries only.
Eurostat	EU SDG Indicator set	• Government support to agricultural research and development (SDG#2 "Zero hunger"); • Gross domestic expenditure on R&D by sector (SDG#9 "Industry, innovation and infrastructure"); • Employment in high- and medium-high technology manufacturing and knowledge-intensive services (SDG#9 "Industry, innovation and infrastructure"); • R&D personnel by sector (SDG#9 "Industry, innovation and infrastructure"); • Patent applications to the European Patent Office (SDG#9 "Industry, innovation and infrastructure").

Finally, it is also important to highlight that other indicators that have embraced a sustainable development perspective (presented in section 2) – such as the Social Progress Index by Social Progress Imperative, the Better Life Index by OECD, the Inclusive Development Index by WEF and the Multidimensional Poverty Index by UNDP and OPHI –

[24] The three-tier classification by the IAEG-SDGs distinguishes among Tier I (conceptually clear, internationally established methodology and standards, and worldwide availability), Tier II (conceptually clear, internationally established methodology and standards, but not widely produced) and Tier III (still lacking an internationally established methodology or standard).
[25] Also used by the UNDP Human Development Report Office for its analysis on socio-economic sustainability.

account for R&I inputs, processes and outcomes to a lesser extent or only indirectly on underlying conditions, e.g. through information on access to ICT and knowledge.

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The objective of this exploratory study is to analyse the nexus between the current debate on R&I policy and the notion and measurement of sustainable development in the uncertain scenario of our present and future times.

Through a state-of-the-art review of the up-to-date academic literature and policy debate on both sustainable development and R&I, this study intends discussing to what extent and how R&I policy in the post-COVID scenario can represent a leverage for transformative change towards sustainable development. In particular, it provides theoretical arguments and policy recommendations to foster a roadmap for a new approach on R&I policies at European level.

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