SPES | Sustainability performances, evidence & scenarios

D5.1 Conceptualizing “SPES” policy mix(es) for just twin transitions: Policy mapping on Science, Technology, and Innovation initiatives in Europe and other countries

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Disclaimer

This Report 5.1 for the project SPES has been prepared by the University of Florence (UniFi), as part of Task 5.1 "Policy mapping" / Work Package 5. This task has allowed SPES research partners to map European policies and national policies (both in European Member States and in selected partner countries) that focus on directing R&I efforts and productivity-enhancement for the sustainability transition. It includes the identification of policies, the collection of available information and data and their systematization for wider research and policymaking purposes.

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Abstract

The recent policy debates have increasingly centred around the green and digital transitions, aiming to address the dual challenges of environmental sustainability and technological advancement. The green transition focuses on sustainable practices and climate change mitigation, and the digital transition aims to harness technology for societal benefit, albeit with associated risks such as inequality and security concerns. The European Green Deal represents a strategic initiative to integrate these transitions, targeting a climate-neutral EU by 2050 and coupling economic growth with environmental stewardship.

This report examines policies related to science, technology, and innovation (STI) from the EC-OECD STIP Compass dataset. The focus is on the European Union and its member states but extends to non-European countries where possible. It highlights the emergence of diverse policy mixes that blend innovation with environmental and social sustainability goals, reflecting varying national commitments to sustainability transitions. The analysis leverages the Science, Technology, and Innovation Policy (STIP) Compass database, co-managed by the European Commission and the OECD, which documents STIP interventions aimed at achieving a net-zero transition.

Utilizing the SPES framework, which aligns the 2030 Agenda's goals with Sustainable Human Development (SHD) principles, the report adopts an integrated approach to assess these policies. It emphasizes the importance of balancing human activities with social inclusion and environmental preservation, advocating for multi-sectoral cooperation and ecological awareness.

1. Introduction

Green and digital transitions are at the center of the recent policy debates. The green transition aims for a sustainable shift in how we produce and consume, focusing on climate change mitigation and preserving biodiversity all while ensuring an equitable process. The digital transition, meanwhile, is transforming societies and economies, promising increased prosperity and solutions to societal issues, but also bringing risks like social disruptions, inequality, and security threats (European Commission, 2022; Muench et al., 2022), increasing human insecurity.

The von der Leyen Commission introduced the European Green Deal as a strategy to transform the EU into a sustainable and equitable society with a modern, efficient economy targeting zero net greenhouse gas emissions by 2050 and decoupling economic growth from resource use (European Commission, 2019, 2020). Initially, the Green Deal and digital transformation were seen as separate objectives. However, the Green Deal Communication later recognized digital technologies as essential for achieving the EU's sustainability goals. The twin transition, which combines environmental sustainability with digitalization goals, is a key element of the European Green Deal and Digital Strategy, aiming to make Europe the world's first climate-neutral continent by 2050 and to ensure that digital transformation benefits all sectors of its economy. By integrating these two transitions, the EU seeks to drive innovation, competitiveness, and social inclusiveness, while ensuring that the digital transformation supports its environmental and climate objectives. Moreover, the EU has been a pioneering force in articulating and promoting the idea of a just twin transition by integrating the principle of fairness and the imperative to ensure that no one is left behind in these transformative processes (Verdolini, 2023).

This report aims to provide an overview of the landscape of policies addressing science, technology and innovation (STI policies), and the policies promoting the net zero transition. We focus both on the European Union and on its individual member countries, and, subject to the availability of data, we also extend the observation to non-European countries. By comparing the choices of policies made by various European countries, we will observe the emergence of policy mixes (combinations of different policies) - some more focused on the promotion of innovation, others oriented towards the blending of innovation support objectives with environmental and/or social sustainability objectives. Therefore, it is relevant to analyze these policy combinations at the country level, capturing the different countries' potential commitments towards sustainability transitions formulated in different policy mixes.

To conduct our policy mapping exercise, we refer to the Science, Technology, and Innovation Policy (STIP) Compass, which is a joint initiative of the European Commission and the Organization for Economic Co-operation and Development (OECD).[1] The STIP Compass is a database that includes STIP policies and interventions aimed at net zero transition implemented by various OECD countries. Despite several limitations that are described below, to the best of our knowledge it represents the most extensive source of data and information on the policies we are interested in.

To analyze these policies, we use the framework developed in the SPES project (Biggeri et al., 2023). The SPES framework, which bridges the 2030 Agenda's 5 Ps (People, Prosperity, Planet, Partnership, Peace) with Sustainable Human Development (SHD) pillars—productivity, equity, sustainability, empowerment, and human security—is applied to analyze the policies through an integrated

[1] https://stip.oecd.org/stip/

approach. The SHD emphasizes the interdependence of sustainable development and human well-being, advocating for a balance between human activities, social inclusion, and environmental preservation. Biggeri et al. (2023) extend this frame by integrating the Quintuple Helix model, promoting collaboration among government, business, academia, civil society, and the natural environment to drive innovation and transformative change toward sustainable human development. This approach highlights the importance of multi-sectoral cooperation and ecological awareness in achieving comprehensive sustainability and development goals.

The report develops as follows. In Section 2, we review the highlights of the EU's vision of science, research and innovation. Section 3 presents the SPES framework in brief. Section 4 describes the data and methodology. Section 5 illustrates the result of the analysis of the STIP Compass database on national-level science, technology and innovation policies implemented across the world. Section 6 concludes.

2. The EU's vision on science, research and innovation

The Science, Research and Innovation Performance (SRIP) of the EU represents one of the most outstanding voices of the European Commission and the Directorate-General for Research and Innovation on the topic. Between 2016 and 2022, the SRIP reports consistently highlighted the need for a systemic and strategic approach to science, research and innovation, integrating economic, social, and environmental dimensions to foster a resilient, competitive, and sustainable Europe.

In its first edition (EC and DG R&I, 2016), the SRIP report focused on overcoming the productivity challenge to enable the EU to achieve sustainable economic growth and create high-quality jobs. The report identified underinvestment in R&D, education, and ICT as critical issues. It highlighted the need for better incentives for businesses to innovate (Open Innovation), an improvement in the quality of the science base (Open Science), and a more global outlook (Open to the World).

Subsequently (EC and DG R&I, 2018), the messages were refined to emphasize the impact of Research and Innovation (R&I) on economic and social prosperity, highlighting the risks and opportunities. The European Commission acknowledged the weak productivity growth despite the return of economic growth – a particularly problematic trend when compared to that of the US – and the increasing job and wage polarization due to the new technologies. The report called for a new approach to analyzing innovation performance, moving beyond traditional science and technology metrics to include factors such as intangible assets and transformational entrepreneurship.

A crucial turning point happened when the vision expanded due to the EU Green (EC and DG R&I, 2020). This emphasized the critical role of science, research and innovation in shaping the future, particularly in overcoming the dual challenges of green and digital transitions. It set out principles including co-creation, diffusion, uptake, transformation, and directionality, with science, research and innovation leading the way. The report provides guidelines for policy to support people, the planet, and prosperity and embraces a transformative innovation policy as part of the European Green Deal. Considering the possibility of upcoming challenges, as learned from handling the COVID-19 pandemic, the European Commission emphasizes that public funding in research and innovation

are crucial strategic investments for attaining enduring goals beneficial to society and businesses alike. Aiming at fostering a comprehensive new health and well-being economy, encompassing physical, mental, skill-based, social, environmental, and economic dimensions (European Commission, 2020a; 2020b).

The latest publication (EC and DG R&I, 2022) deals with creating a sustainable future in uncertain times, reflecting the post-pandemic and sensitive geopolitical scenarios. It emphasized the need to build back better, regain competitiveness, prepare for unforeseen events ("think the unthinkable"), leverage businesses, institutions, and people connect actors while addressing disparities, and ensure research and innovation-friendly conditions.

3. The SPES framework in brief

In line with the most recent approach of the European Commission, the goal of the SPES project is to integrate the traditional concept of economic productivity and innovation with broader sustainable considerations. This integration implies that productivity should not be merely profit-oriented but should also enhance various aspects of human well-being (ex. environmental and social). Research and innovation processes must have a transformative approach to trigger changes in economic, social, and human-nature interactions (Schot et al., 2018; Biggeri and Ferrannini, 2020).

The approach of the project is applied in nature, as we believe that an operational definition that can be measured and assessed critically is essential to contribute to scholarly discussions on sustainability and to guide policy formulation towards enduring and ecologically responsible practices. Following Biggeri et al. (2023), in a parallel to Sen's (1980) query "Equality of what?", the SPES project probes the question "Productivity of what?", encapsulating the diverse methodologies for defining and gauging productivity, acknowledging the interplay and the balancing act between different practices, and evaluating their respective strengths and limitations. As Sen (1990) remarked, humans are central to progress, serving both as its arbiters and recipients, as well as, its driving force. This multifaceted role often leads to a blur between goals and means in strategy and governance, occasionally prioritizing the act of production and prosperity over the value of human life itself, thereby mistaking the conduit of progress for its goal. Following Biggeri et al. (2023, p.29), productivity is:

“The efficient use of economic, human and natural resources for the provision of goods and services, expanding human capabilities and increasing the standards of living for all”

The SPES framework integrates the 5 Ps of the 2030 Agenda (People, Prosperity, Planet, Partnership, Peace) with the pillars of Sustainable Human Development which include: productivity, equity, sustainability, empowerment, and – as a new addition – human security. This integration highlights the interplay between sustainable development and human well-being, recognizing that insecurities arise from unsustainable growth, leading to social and environmental issues.

This view has obvious implications for science, technology and innovation policies. We see the latter as instruments to combine the 5Ps, defined as (Biggeri et al., 2023):

People: centered on social inclusion and equity, aiming to ensure health, education, gender equality, and justice for all, particularly addressing poverty and hunger.

Prosperity: promoting economic development that is both equitable and sustainable, ensuring growth benefits everyone, particularly the vulnerable while protecting the well-being of future generations.

Planet: focused on protecting the environment through sustainable resource management, biodiversity conservation, and climate change mitigation to maintain the Earth's resilience within its natural limits.

Partnership: recognizing the importance of collaborative efforts across government, private sector, civil society, and international bodies for knowledge-sharing and capacity-building to achieve the SDGs.

Peace: understanding that peace, justice, and robust institutions are the foundation for sustainable development, targeting the roots of conflict and promoting good governance and human rights.

In our vision, the adjective 'just' must characterize not only policies for the twin transition, but also all science, research and innovation policies. Indeed, even if it is claimed that science, research and innovation are essential for the twin transition, not all research, knowledge, technology, and innovation positively contribute to SHD. Both public and private science, research and innovation have often worsened existing environmental and social problems in the pursuit of economic growth. To promote development consistent with the principles of SHD and enhance present and future human capabilities, policies must provide the right type of directionality to the economic agents (Schot et al., 2018; Biggeri et al., 2023).

Currently, EU policies fully embrace transformative research and innovation principles, steering sustainable development by promoting innovation across different domains. Initiatives like the European Innovation Ecosystems, Digital Innovation Hubs, LIFE Programme, European Urban Initiative, and the EU Programme for Employment and Social Innovation facilitate the flow of knowledge, adoption of digital technologies, market-based solutions for sustainability, integrated urban solutions, and social policy innovation, respectively. These policies foster a blend of radical and incremental innovations to transform production processes, behaviors, and organizational models, but also provide a strategic direction for sustainable transformation. They encourage collective action, engaging several stakeholders across governance levels and countries, and aim to disseminate knowledge and upscale sustainable solutions throughout European economies and societies (Ferrannini et al., 2023). However, these principles do not necessarily characterize the policies of all member countries or other countries worldwide. We map the characteristics of the existing science, technology and innovation policies in the next sections.

4. Data and methodology

To conduct our policy mapping exercise, we refer to the EC-OECD STIP (science, technology and innovation policies) Compass database. This database gathers both qualitative and quantitative data on national science, technology, and innovation policies and strategies. It includes a rich set of information that is provided by country representatives based on periodic interviews. The STIP Compass has a wide coverage, as it collects information on approximately 60 countries worldwide. The level of information in the dataset is high: besides basic information on the various policy lines (e.g., date of implementation, title of the intervention, type of instrument used) the dataset also includes a brief description of the content of the policy. However, the dataset is not without limitations. Firstly, the coverage is not total.

There are many countries, some of which are very relevant, for which the dataset does not include any information. In particular, the degree of coverage of the Global South countries is very low. Secondly, the dataset only covers policies implemented at the national level. While for some countries - where interventions are centralised - this is not a problem. However, there are other countries where innovation policy is conducted also at the regional level where the overview provided by the STIP Compass is necessarily partial. Thirdly, the database does not include detailed information on the policies' budget. What we do know is what types of interventions were implemented and - for some interventions - what size the intervention was in terms of the class of budget allocated by the policymaker to implement it. However, we do not know how much funding is actually allocated to the various lines of action. Despite these limitations, to the best of our knowledge, the dataset constitutes the most extensive and detailed source of information available on Science, Technology, and Innovation (STI) policies and thus provides an excellent opportunity to broaden our knowledge on this topic.

In particular, we analyze the data from the STIP survey of 2023, which contains information for the policy initiatives on innovation for 57 countries + the EU. This data contains information for old and new initiatives. Some initiatives started at the beginning of the 20th century and are still active. This is the case, for instance, of the Conférence interministérielle de la Politique Scientifique (CIMPS) in Belgium (Wallonia-Brussels Federation), which is an assembly composed of members of the federal, community and regional governments who are responsible for science policies. Others have been finished for many years. We focus our analysis on policies that are currently active, i.e., on the 3,118 policy initiatives (out of the 7,329 that are included in the database) that either do not have an explicit end date or whose end date is after the year 2023.

We classify these interventions following the approach developed in the SPES project and, in particular, using the project's five pillars: productivity, environment, empowerment and participation, equity and human security. If the observed policy responds to more than one objective (for example, support for productivity and environmental sustainability) it is classified as belonging to both scopes. To these five pillars we have added a sixth, relating to governance, in which we have included all interventions such as plans and strategies that cut across all pillars. The classification is as follows:

Productivity policies, as expected, constitute the lion's share of the STI policies included in the OECD database. These policies are aimed at financing innovation projects submitted by companies or research projects carried out by universities and companies.

Policies for environmental sustainability are related to the net zero transition. These policies are aimed at funding research and innovation projects on clean energy and the decarbonisation of the economic system with the aim to replace traditional carbon-intensive fuels with cleaner energies, such as solar or wind power. In addition to funding innovative ideas and solutions on how to support the green transition, STI policies also have a regulatory component, with the production of the rules of the game that on the one hand discourage the use of the most polluting technologies, and on the other produce incentives for the production and use of clean technologies.[2]

In the group we have labelled equity we find all the policies that are aimed at promoting equity and diversity in innovation processes. The pillar on participation and empowerment refers to those policies aimed at the inclusion of specific groups of individuals (e.g. PhD students, women entrepreneurs, young people) or organizations (e.g. spin-off companies) in research and innovation projects. Human security refers to issues of ethics (e.g., in the development and application of new digital technologies) and security (e.g., security in research).[3]

Moreover, as mentioned above, the interventions we have labelled governance refer to framework plans and strategies that cut across all pillars. Table A1 in the Appendix illustrates in detail the correspondence between the classification in the STIP Compass and the one used in this paper.

As a second step, we classified the interventions included in the OECD database according to the tripartition defined by Borrás and Edquist (2013) to add an interpretative layer to the policy analysis. We thus categorize policy instruments into three sets: economic and financial instruments (providing specific incentives or support), soft instruments (voluntary, non-coercive recommendations or agreements) and regulatory instruments (legal tools for regulation).

Financial instruments provide specific pecuniary incentives (or disincentives) to support or discourage specific social and economic activities. They can be in the form of grants, subsidies, tax incentives, or financial support for R&D and innovation activities.

Soft instruments are characterized by their voluntary and non-coercive nature. They rely on recommendations, normative appeals, or voluntary agreements to guide behaviors towards innovation-friendly practices. Examples of soft instruments include public-private partnerships, innovation networks and clusters, and information and awareness campaigns. Soft instruments play a critical role in shaping the innovation landscape.

Regulatory instruments involve the use of legal tools for the regulation of social and market interactions. They are obligatory, setting clear boundaries for what is permitted and what is not, often backed by sanctions for non-compliance. Examples of regulatory instruments include Intellectual Property Rights, standards and compliance and sector-specific regulations such as environmental or health regulations, which can stimulate innovation by requiring companies to develop new technologies or solutions that comply with these regulations.

While regulatory instruments ensure a conducive and safe environment for innovation, economic and financial instruments provide the necessary resources and incentives, and soft instruments facilitate collaboration and knowledge sharing. By carefully designing and implementing these instruments in a complementary manner, policymakers can effectively address the multifaceted challenges of fostering innovation and driving economic growth.

[2] Hence, in this report, we cannot distinguish between technologies used for biodiversity preservation and potential technologies favoring nature-based solutions.

[3] Therefore, in this report, we cannot consider other elements typical of human security based on protection, technologies empowering people and solidarity as described in SPES.

Finally, we also considered the beneficiaries of the interventions, which are classified in the STIP database as academia, business, civil society, and government (see Table A2 in Appendix).

After reclassifying the interventions included in the STIP Compass database, we calculated the incidence of the various types of interventions (e.g. policies supporting productivity) on the total number of STI policies in the country. Similarly, we calculate the incidence of individual policy instruments and different types of policy beneficiaries. In so doing, we compared the level of attention each national policymaker has towards the specific topic (productivity, in the example above), the specific instrument or the specific beneficiary.

To analyze the database, we first look at policy instruments and the type of beneficiaries they are aimed at. Secondly, we focus on policy goals. Looking at the STI policies implemented in various countries around the world, we identify the countries in which policymakers most support productivity / environmental sustainability / participation and empowerment / equity / human security. Building on this analysis, in a third step we identify the most common types of policy mixes (i.e. combinations of policies) on which national policymakers and the EU focus most. In so doing, we identify groups of countries that focus more on productivity support and groups of countries that combine productivity support with environmental and/or social sustainability support. Finally, we go beyond the definition of policy mix. Looking at the descriptions of the various interventions, we look at whether and to what extent interventions aimed at supporting productivity also directly incorporate objectives of environmental sustainability, social sustainability or both.

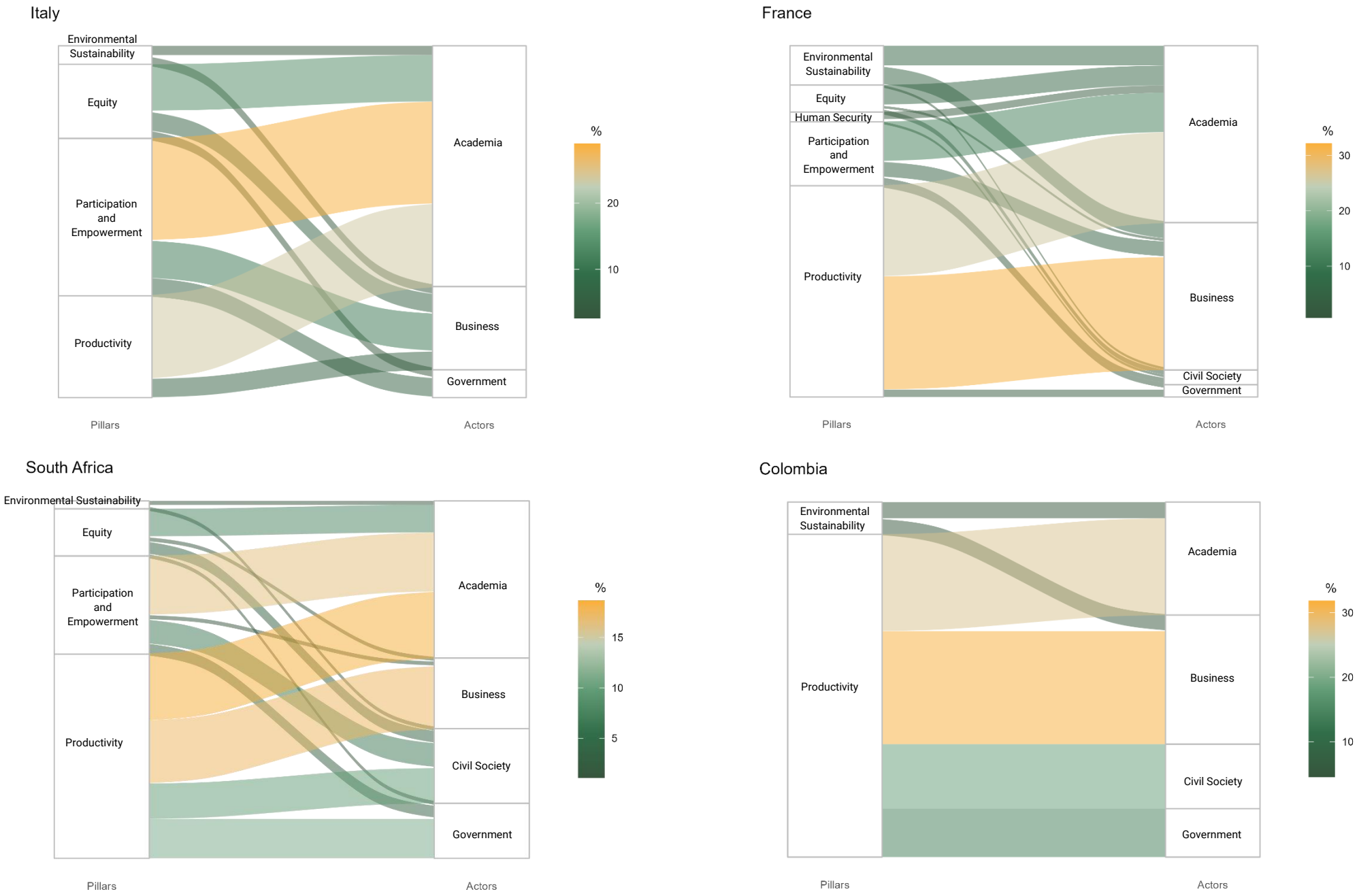
5. Main results

5.1. Policy instruments and target beneficiaries

Most of the policies using financial instruments are policies aimed at supporting productivity, and the bulk of this funding is directed at academia and business. This is true for most European countries. However, different countries also have very different intervention models, mainly because the institutional systems within which these policies are generated are different. Consider, for example, the figures below (Figure 1, first row). The figures consider only financial interventions implemented in the country and show which pillars are targeted and who are the beneficiaries of these incentives. The figure on the left shows Italy, where a large part of the financial interventions are also directed towards participation and empowerment policies aimed at academia, while the graph on the right shows France, where the majority of interventions are directed towards supporting productivity and benefits academia and business almost equally. The difference is easily explained by the institutional diversity of the two countries. In the Italian case, nearly all productivity support policies are designed and implemented at the regional level, whereas in France the national level is responsible for the bulk of productivity support policies.

Moving to the other countries, even more significant differences in intervention patterns are observed (Figure 1, second row). For example, on the left, the figure shows South Africa, where - despite the dominance of productivity policies - there is still a relatively wide variety of policy objectives and intervention beneficiaries. In the figure on the right - referring to Colombia - the range of STI policy objectives is relatively narrow. However, these policies are aimed at all types of beneficiaries.

Figure 1. STI policies: financial incentives by pillars and beneficiaries



Note: Authors' elaboration on EC-OECD STIP Compass data. The figure displays the percentage of financial initiatives themed by at least a pillar and directed to at least one actor for Italy nd France (top part), South Africa and Colombia (bottom part)

5.2. Policy objectives

Looking at the relative incidence of the different policies by country, it is not surprising that productivity policies cover the majority of STI policies in all European countries (Figure 2). Even in countries where the incidence is lower, such as Italy, it is still around 30% of the total number of implemented interventions. The highest percentages are observed in Serbia and Belgium, followed by France and Sweden. If we extend the analysis to all countries in the world for which information exists in the STIP Compass dataset, we note that productivity policies - at least in terms of the number of interventions – cover half or more of the interventions in countries such as Chile, Colombia, China or Kazakhstan.

In most countries, policies supporting productivity consist of granting various types of funding to companies or universities. However, in countries like Slovak Republic, Slovenia or Portugal, productivity policies are also based on many 'soft' interventions, aimed at networking, disseminating information, or supporting the functioning of innovation intermediaries.

Policies supporting environmental sustainability are quite widespread in all European countries (Figure 3). In these countries, many policies aim at funding research and innovation projects implemented by universities and businesses on clean technologies and other environmental sustainability issues. Many different interventions are carried out at the EU level. Extending the observation to all countries in the world for which information exists in the OECD STIP dataset, we find that the US is among the countries that invest the most.

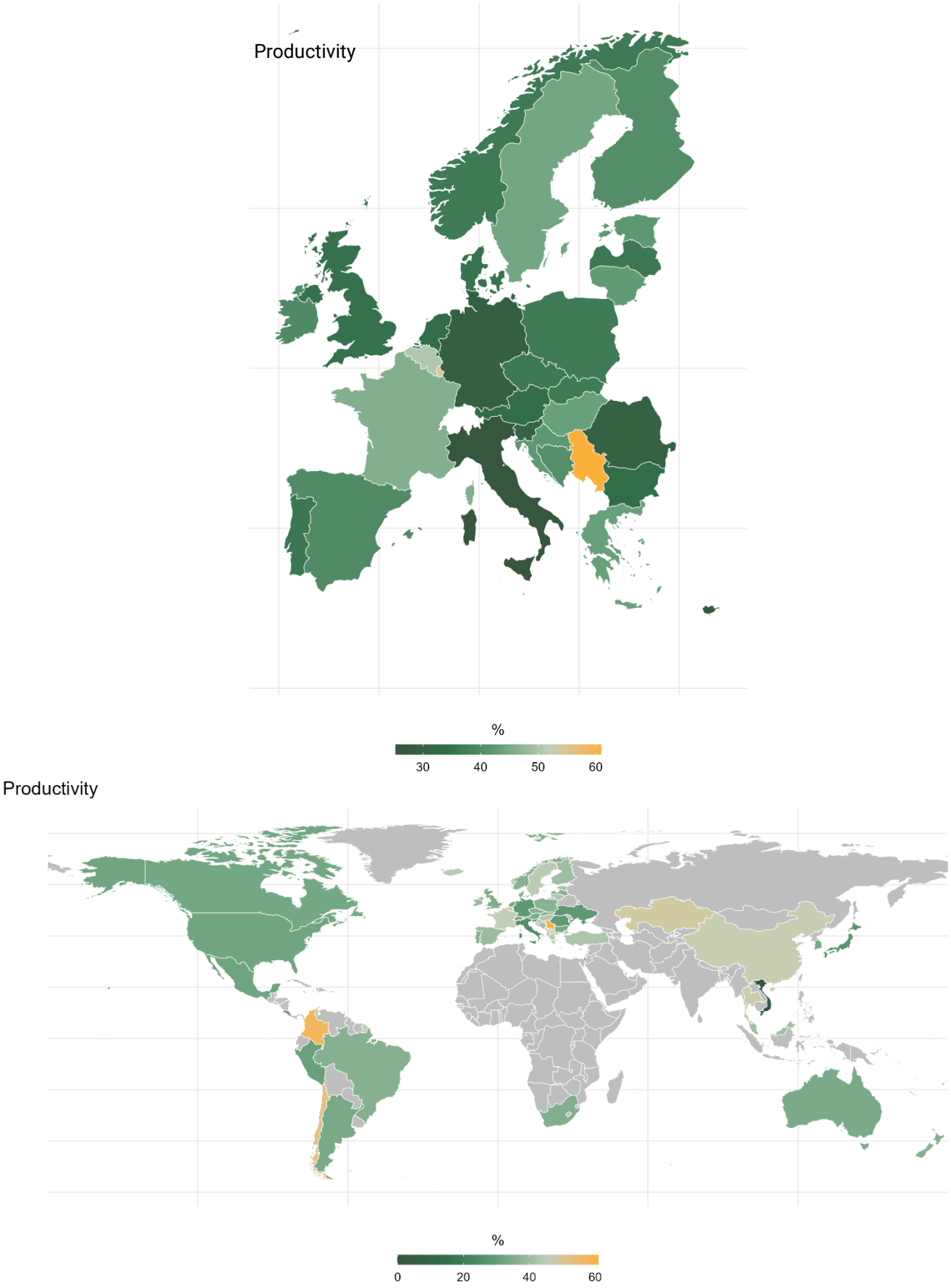
Policies aimed at environmental sustainability are primarily regulatory policies, which aim at defining the perimeter of new clean markets and activities, through prohibitions and incentives. However, in many countries, financial incentives - e.g. aimed at financing research projects in clean technologies - also play a substantial role. EU countries that fall into this category include, for example, Croatia, Portugal, the Czech Republic and Denmark.

Policies supporting participation and empowerment are quite widespread both in European countries and in the rest of the world (Figure 3), even if their incidence in productivity support policies is lower. The highest incidence is observed in the Czech Republic or Bosnia Herzegovina, where policies provide support for the participation of young people in training projects abroad or the consolidation of the university's presence in international research networks.

Interventions to support participation and empowerment are also implemented through a combination of financial incentives (e.g., mobility incentives for academics or women's innovative start-ups) and soft incentives (e.g., support for the formation of industry-academia networks). The first type of incentive is the predominant one in Sweden, Poland, and Slovenia, while Finland, Czech Republic, Italy, and Greece are examples of countries that make greater use of soft instruments (Figure 4).

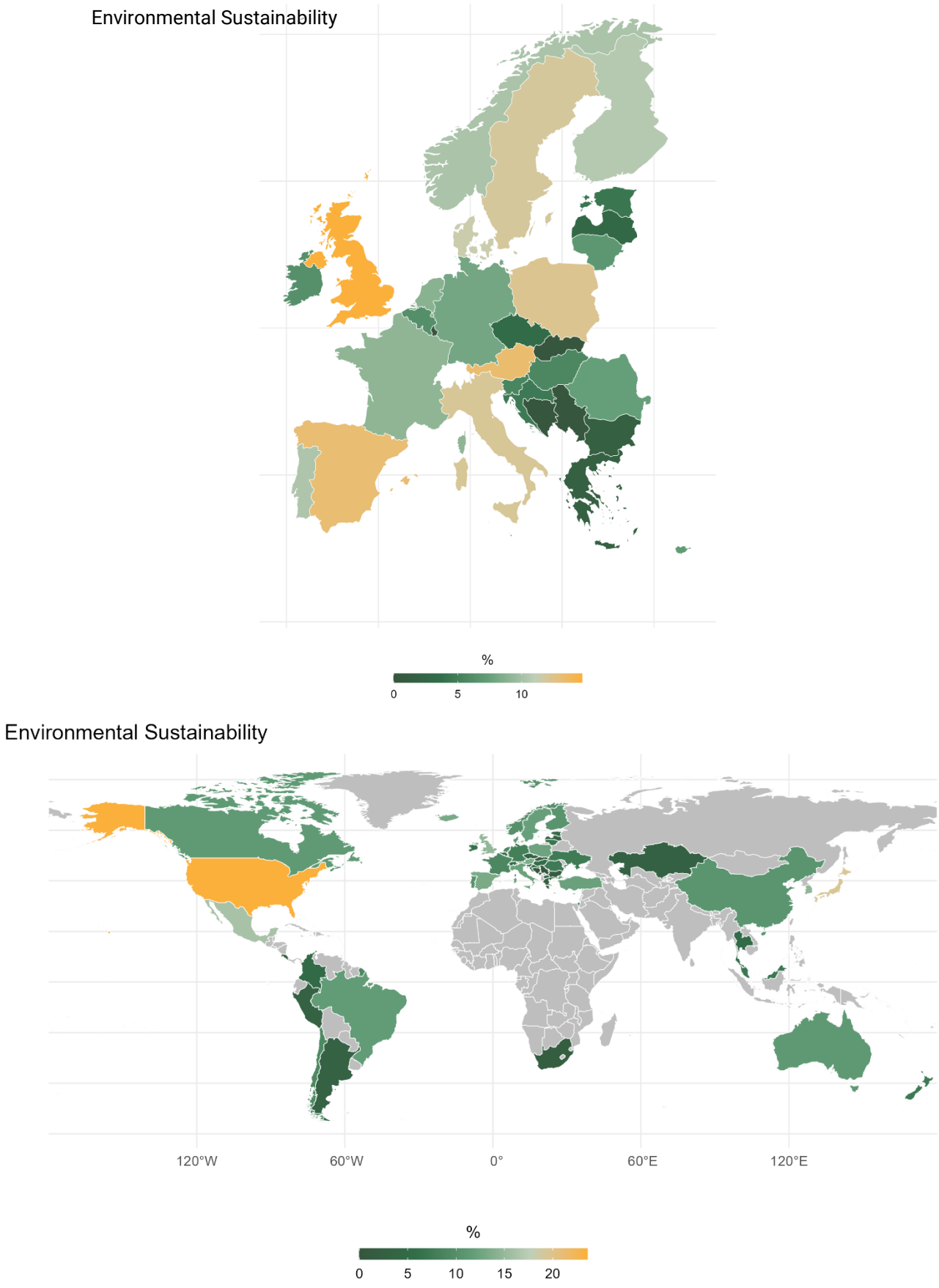
Not surprisingly, the incidence of policies promoting equity and human security on total STI policies is less significant. In the first group of policies (Figure 5), there are numerous interventions that ensure gender equality (e.g. in Ireland or Italy) in research or access for particular segments of citizens (e.g. Aboriginal people in Australia) to education, training or research. In the second group of policies (Figure 6), the interventions implemented by the US and the UK concerning the promotion of protocols for safety and ethics in research emerge. The combination of financial and soft instruments prevails also in the case of policies supporting equity and human security.

Figure 2. Countries with the highest percentage of interventions supporting productivity out of the total STI policies. European countries and worldwide



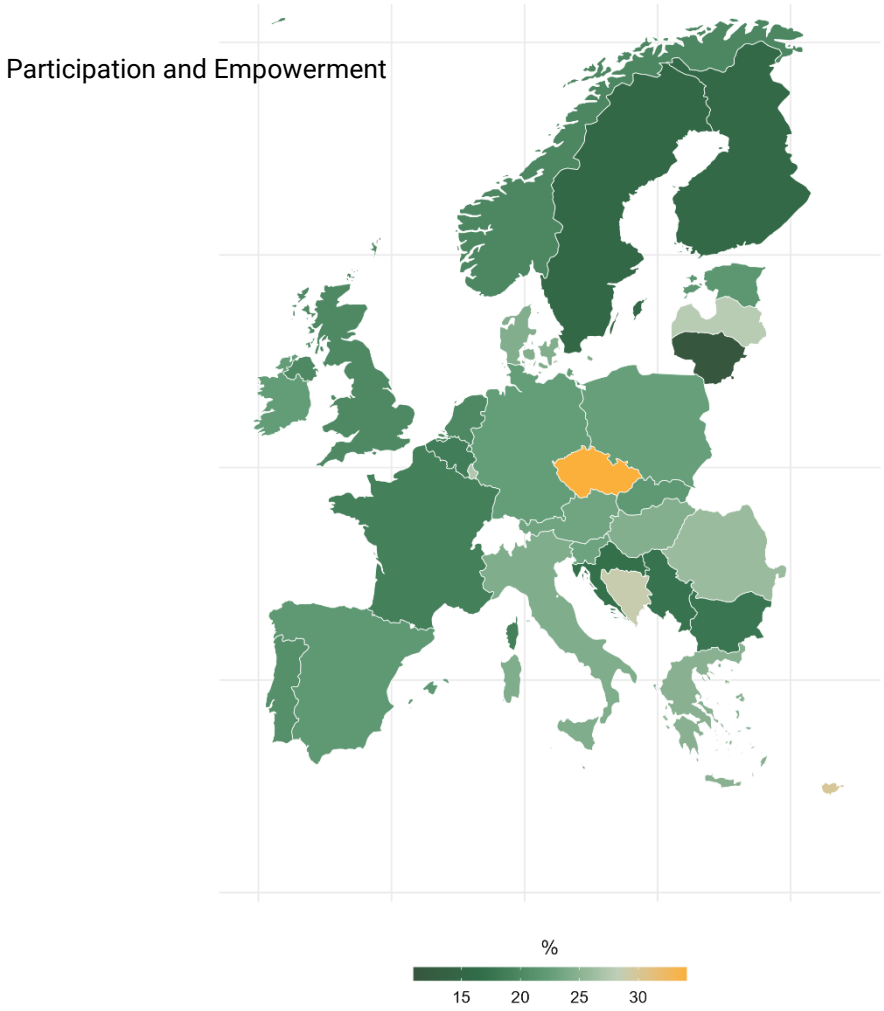
Note: Authors' elaboration on EC-OECD STIP Compass data. The figure shows the percentage of productivity-themed initiatives over the total (some initiatives have more the one theme, both in our and in the OECD classification)

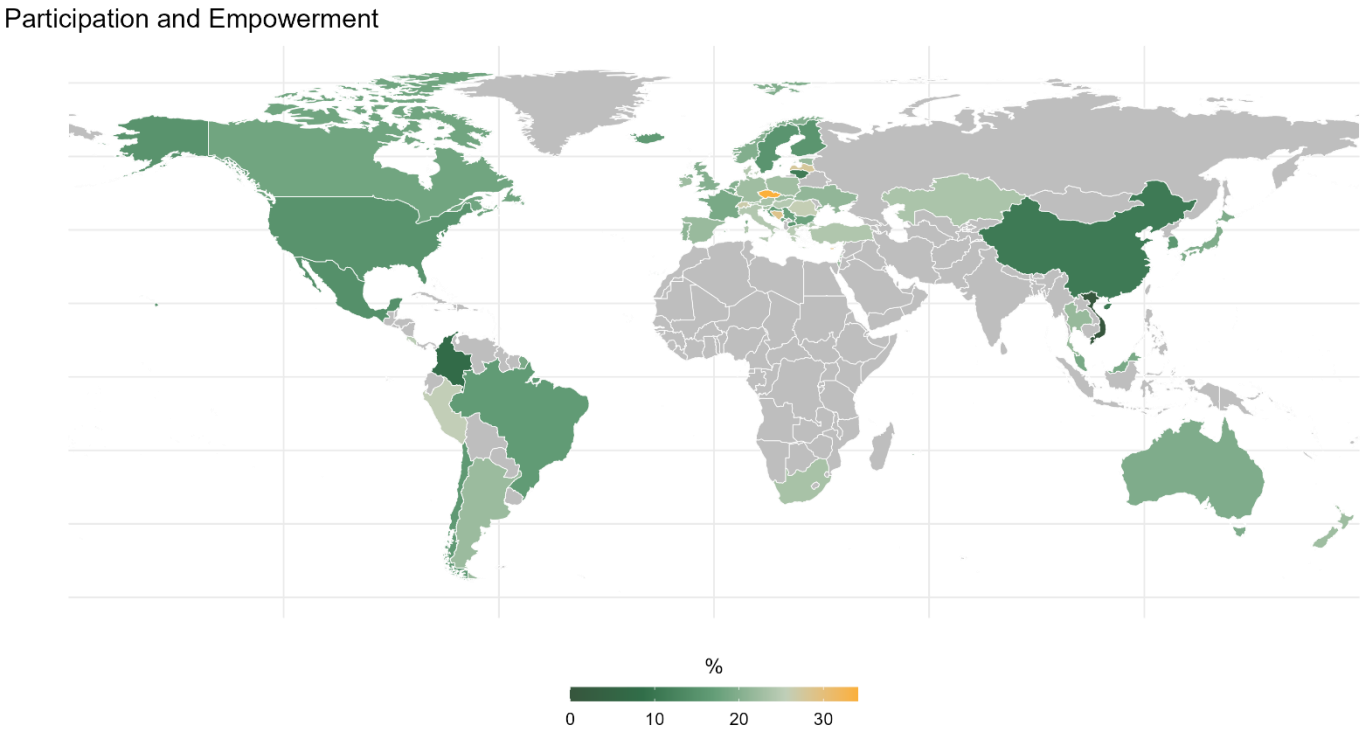
Figure 3. Countries with the highest percentage of interventions supporting environmental sustainability out of the total STI policies. European countries and worldwide



Note: Authors' elaboration on EC-OECD STIP Compass data. The figure shows the percentage of environmental sustainability-themed initiatives over the total (some initiatives have more the one theme, both in our and in the OECD classification)

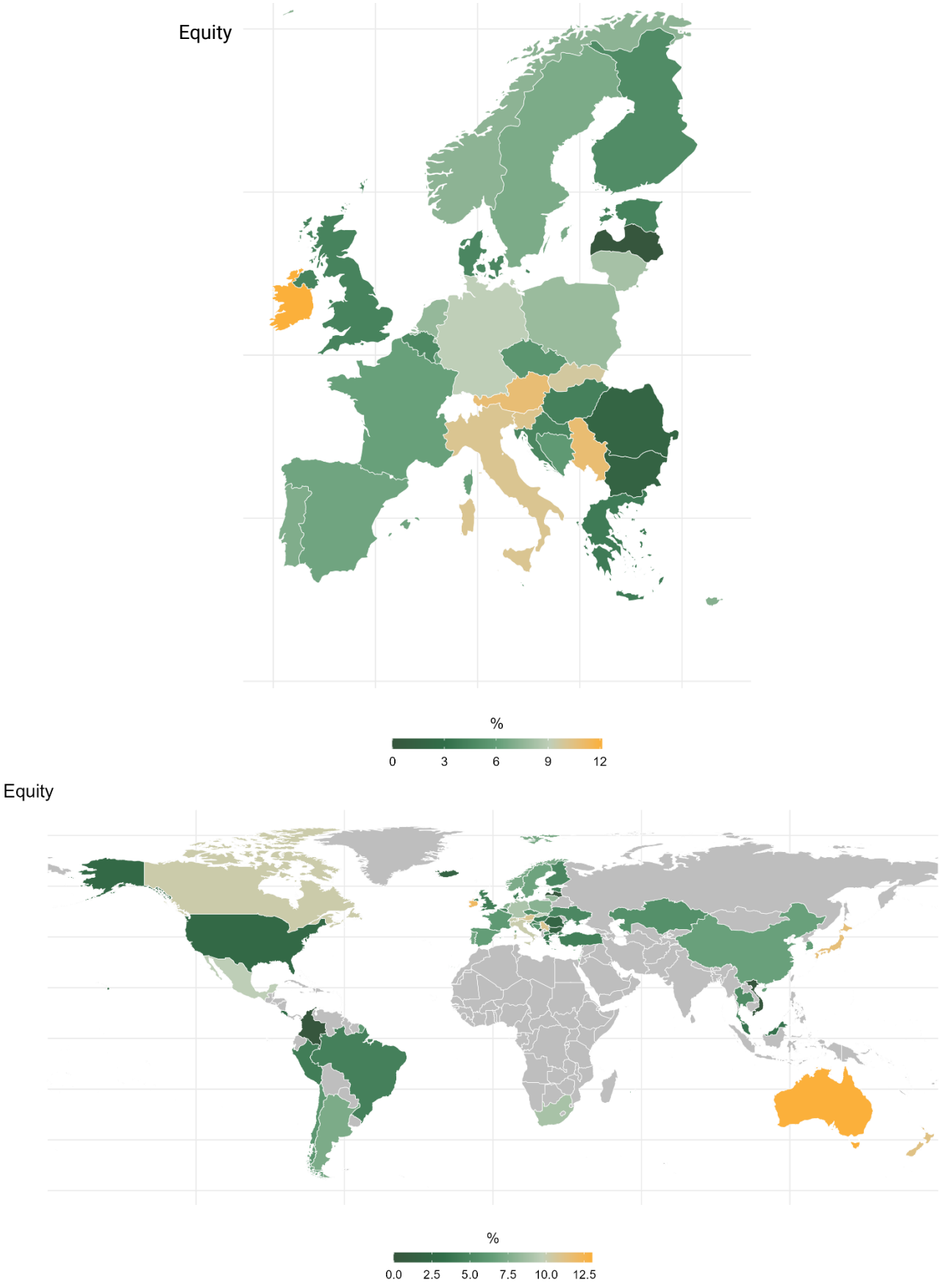
Figure 4. Countries with the highest percentage of interventions supporting participation and empowerment out of the total STI policies. European countries and worldwide





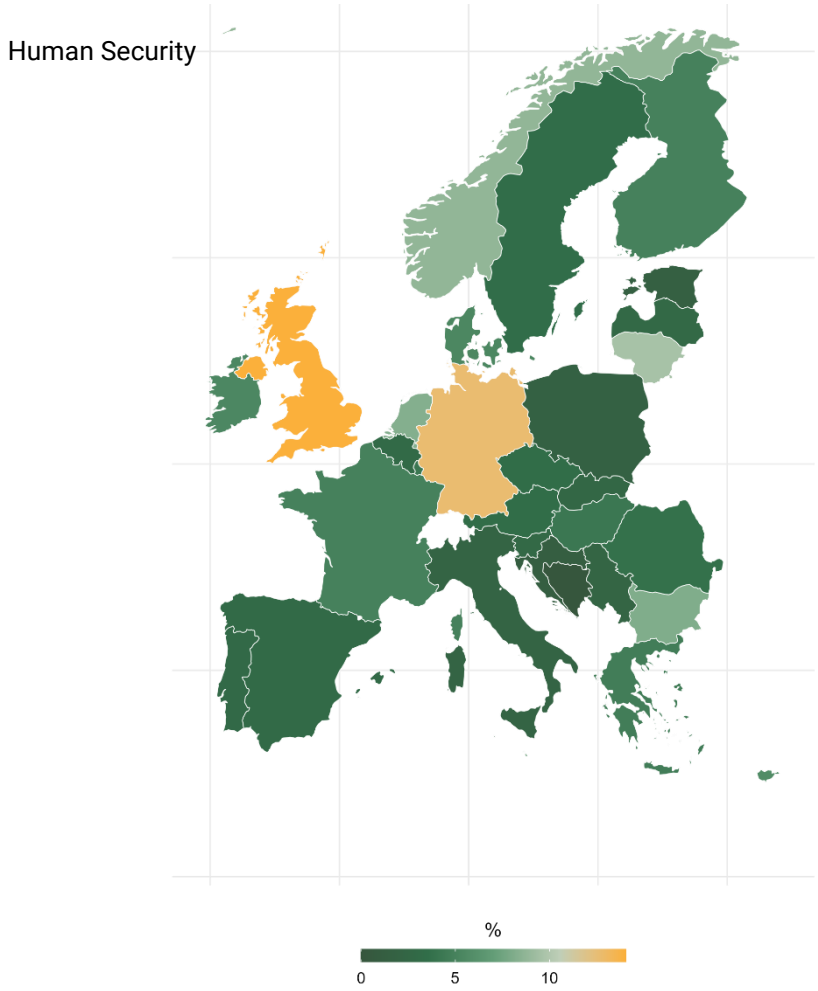
Note: Authors' elaboration on EC-OECD STIP Compass data. The figure shows the percentage of participation and empowerment-themed initiatives over the total (some initiatives have more the one theme, both in our and in the OECD classification)

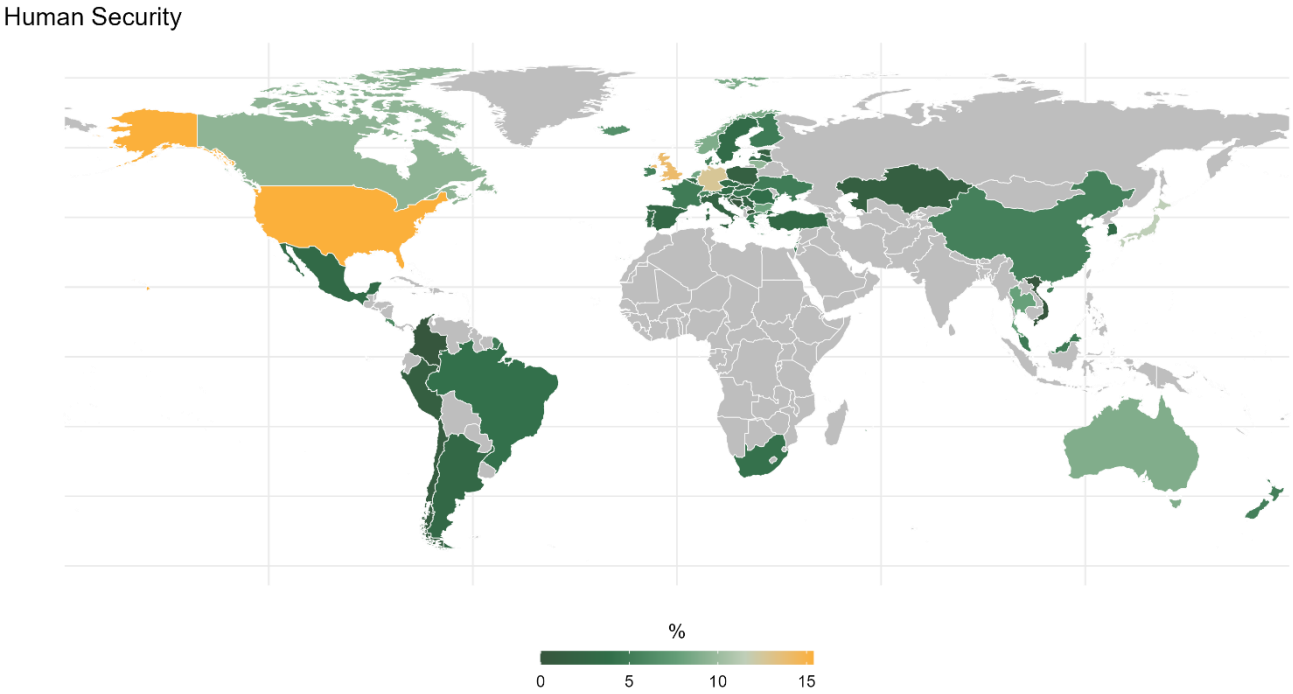
Figure 5. Countries with the highest percentage of interventions supporting equity out of the total STI policies. European countries and worldwide



Note: Authors' elaboration on EC-OECD STIP Compass data. The figure shows the percentage of equity-themed initiatives over the total (some initiatives have more the one theme, both in our and in the OECD classification)

Figure 6. Countries with the highest percentage of interventions supporting human security out of the total STI policies. European countries and worldwide





Note: Authors' elaboration on EC-OECD STIP Compass data. The figure shows the percentage of human security-themed initiatives over the total (some initiatives have more the one theme, both in our and in the OECD classification)

5.3. Policy mixes

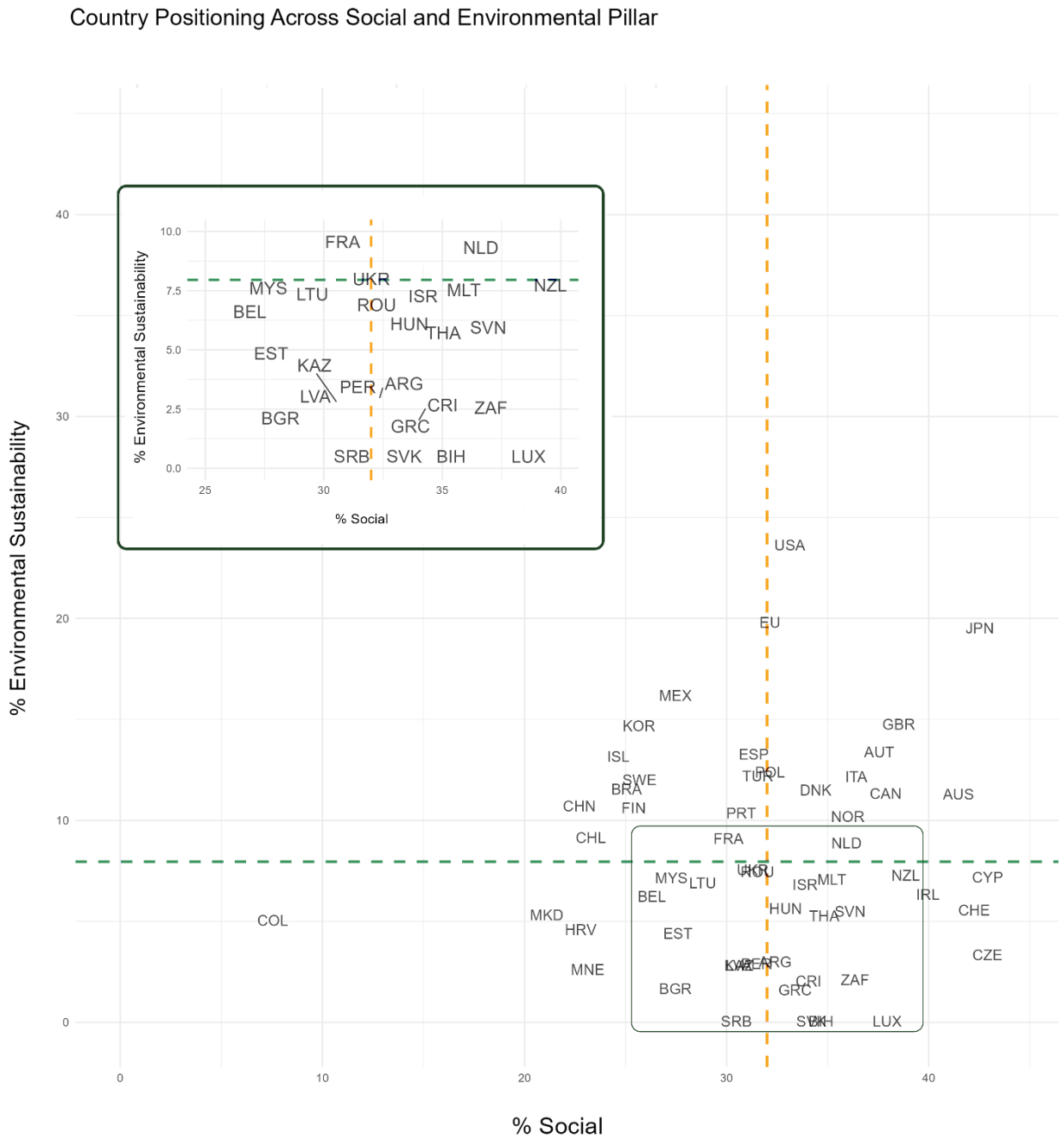
In this section, we try to identify some significant policy combinations (or policy mixes) that correspond to different types of policy strategies and see whether and to what extent they are implemented in different countries (Caloffi and Mariani, 2017). Such mixes are defined based on the **combinations of objectives** they pursue.

As a matter of fact, productivity support targets are present in all countries and, as seen above, they are not insignificant. What most distinguishes the various national policymakers is the extent to which they also direct their interventions towards environmental sustainability and social sustainability. Let us try to represent this in the graph below (Figure 7). On the x-axis we represent the percentage of interventions that have environmental sustainability objectives out of the total STI policies and on the y-axis we display the percentage of interventions that have social sustainability objectives (i.e. support participation and empowerment, equity, human security). The various countries (identified by their labels) are arranged in space based on these two magnitudes. Starting from the dotted lines, which correspond to the average value of both variables, four different quadrants can be identified, where four different groups of countries are placed. The fact that countries are scattered around the graph shows that the mix of policies used in different countries is quite dissimilar.

In the third quadrant, close to the origin, we find the countries that **focus above all on productivity** and which have relatively low shares (below the average) of interventions dedicated to both environmental sustainability and social sustainability. Among these, we find Colombia, the Republic of North Macedonia, Montenegro, Croatia, Serbia, and Bulgaria. In the second quadrant, we find countries that more decisively support the **productivity-environmental sustainability mix**. Among these, we find European countries such as Sweden, Spain, and Portugal as well as non-European countries such as, for example, Mexico or Korea. In the fourth quadrant, we find the countries whose policies support the **mix of productivity and social sustainability** (here especially understood as support for the participation of researchers in international networks, opportunities for women to access research, support for young researchers, promotion of ethics in research), including Luxembourg (which focuses less on environmental sustainability), the Czech Republic and Switzerland. The first quadrant is the one in which the portfolio of objectives pursued by the policies is the broadest. This is where countries whose STI policies include a **mix of productivity with environmental and social sustainability goals** lie. Among these, we find Austria, the UK, Australia and Canada.

The distribution of countries in the third and first quadrants is interesting, though not surprising. In fact, many of the older industrialised countries - located in the first quadrant - are in a position where, in addition to implementing productivity policies, they also focus on an array of other objectives - first and foremost those related to environmental and social sustainability. On the other hand, the countries located in the third quadrant are countries that have experienced relatively more recent industrialisation and are still strongly focused on promoting productivity objectives.

Figure 7. Countries with different STI policy mixes



Note: Authors' elaboration on EC-OECD STIP Compass data. The figure plot the linear correlation between the percentage of environmental sustainability and social (participation and empowerment + equity + human security) policies.

5.4. Beyond policy mixes

In this section, we look at a somewhat different aspect of the policy mix. The objective here is not to observe how the focus of different national governments is divided between different objectives, but to see if and to what extent national policies supporting productivity also incorporate other types of objectives, first and foremost that of environmental and/or social sustainability. Indeed, it is clear that the effect of policies pursuing productivity gains that are compatible with environmental sustainability can be very different from that of a policy mix that independently pursues innovation on one hand, and sustainability on the other. While in the first case, the policymaker is setting a clear conditionality and direction for the policies, stating that productivity must be directed towards sustainability goals, in the latter case the policymaker does not identify any direction for the policies, but at most sets objectives for tempering or mitigating the possible environmental or social damages of the innovation policies (Howlett and Rainer, 2007; Schot and Steinmueller, 2016).

Policies for the twin transition

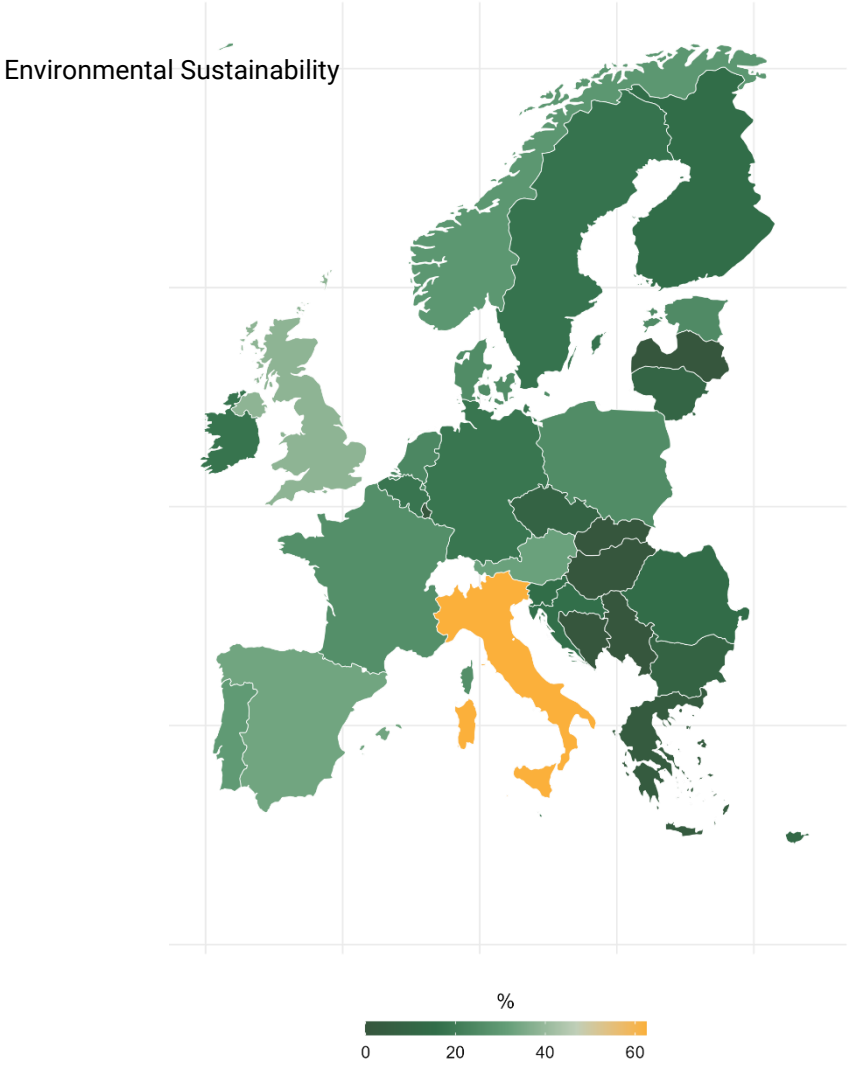
The twin transition is not just about making digital technology more sustainable but also about utilizing digital advancements to achieve environmental goals. It involves optimizing digital assets and infrastructure to reduce environmental impacts and harnessing the power of digital technologies to enhance organizational sustainability. Despite the potential for digitalization to carry a significant carbon cost, the twin transition aims to make a positive impact by "greening" technology and accelerating sustainability efforts across organizations.

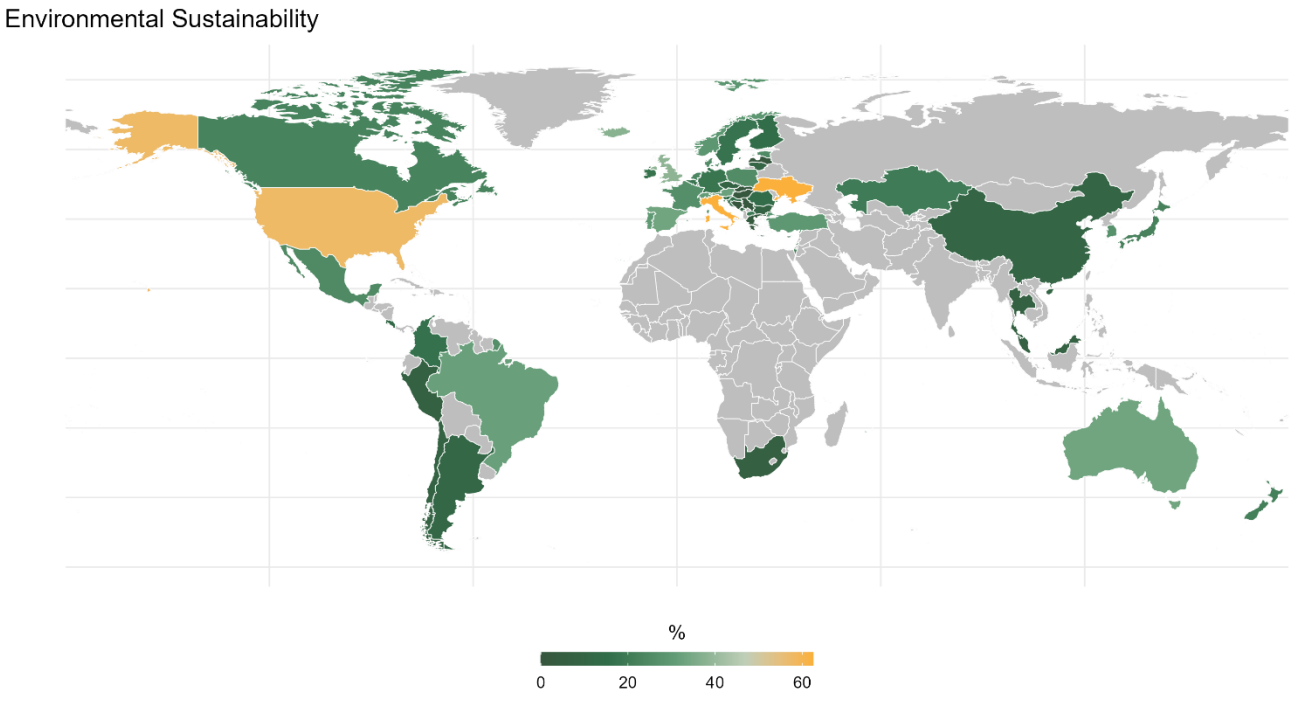
By looking at the STIP Compass dataset, we have identified the policies supporting the twin transition by looking at the interventions that **combine innovation with environmental sustainability goals**. These interventions aim to provide funding for research and/or innovation projects to specific categories of agents (mainly businesses and academia) to generate new ideas or new environmentally sustainable applications.

Among the countries whose national productivity support policies also include environmental sustainability objectives are several European countries, including Italy, Austria, Spain, Denmark and Portugal. In these countries, a non-negligible share of interventions aimed at supporting productivity are also inspired by environmental protection objectives. In Austria, for example, many research and innovation strategies identify environmental sustainability as one of the priority areas. This country funds several large-scale research and innovation projects focused on the identification of innovative solutions for higher energy efficiency, the reduction of energy consumption and the use of renewable energies in many sectors.

As discussed previously, most of the European Union's innovation policies integrate the two dimensions of productivity and environmental sustainability. Among non-European countries, the United States stands out, where many policies are aimed at funding entrepreneurial projects for creating and disseminating clean technologies, management, conservation, and sustainable use of natural resources, or research projects in the field of sustainable technologies. Turkey also emerges, because in recent years the national government has issued several strategic documents outlining future strategies for the energy market.

Figure 8. Policies that combine productivity support with environmental sustainability:





Note: Authors' elaboration on EC-OECD STIP Compass data. The figure shows the percentage of productivity and environmental sustainability (combined) initiatives over the total of productivity-themed (some initiatives have more the one theme, both in our and in the OECD classification)

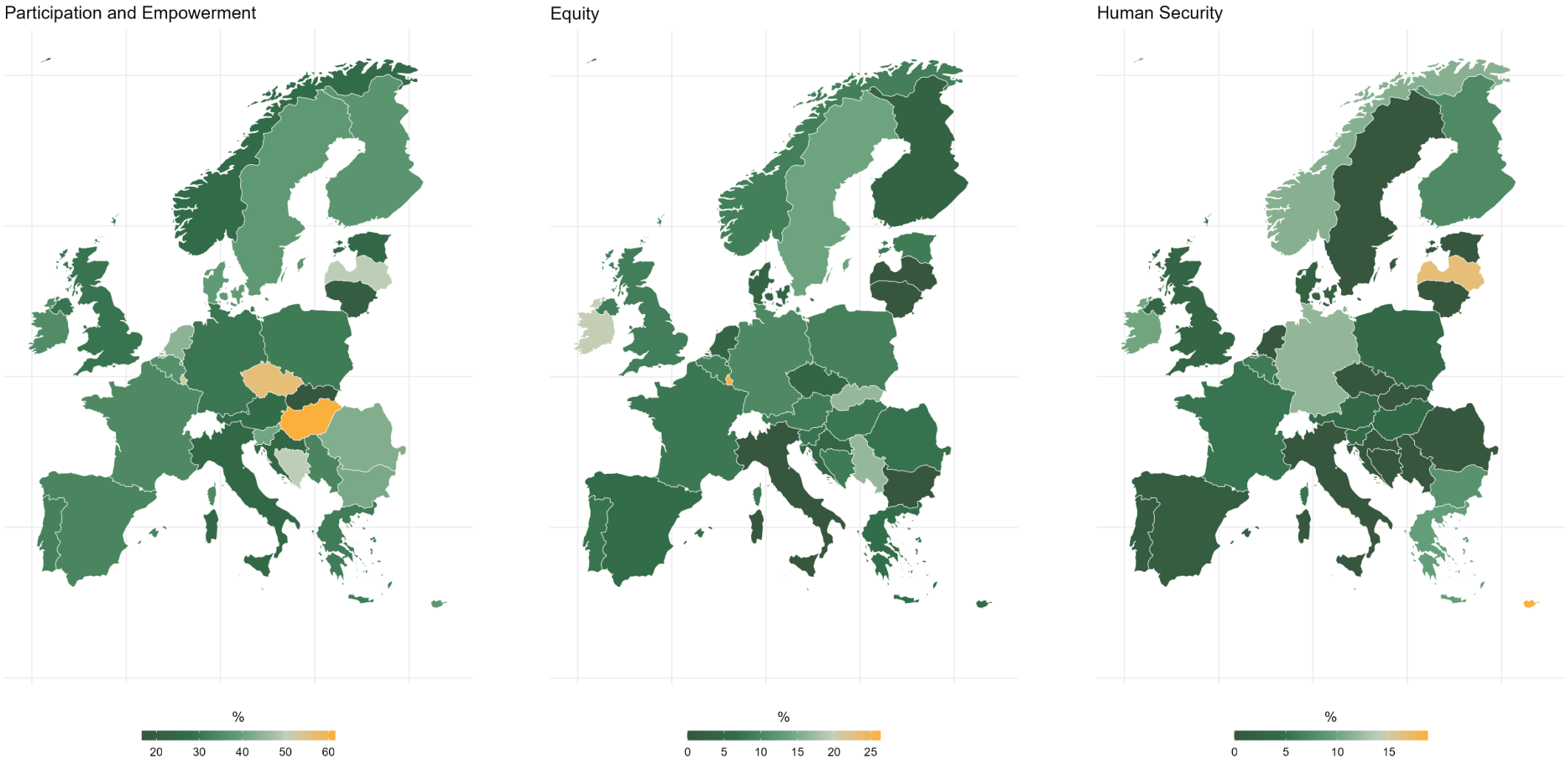
Policies for responsible research and innovation

In recent years, there has been much discussion on the topic of responsible research and innovation (European Commission, 2013, 2014; Owen and Pansera, 2019) and, more in general, on the fact that innovation policies should support innovation processes and outcomes that are aligned with the values, needs, and expectations of society. Following this approach, policies should promote the ethical acceptability, sustainability, and societal desirability of the innovation process and its marketable products. The range of interventions significantly varies mainly because the concept must be interpreted in a flexible and contextualised way (Pansera and Owen, 2018). Based on this idea, we identify a particular group of policies, consisting of interventions that seek to **combine productivity and social sustainability goals** - supporting citizen participation and empowerment, equity, and human security (i.e., policies for responsible research and innovation). These policies often use a mix of soft and financial instruments that target the research and innovation system. Policies for responsible research and innovation are mainly aimed at encouraging the participation of researchers of different kinds and positions, as well as citizens, in the implementation (sometimes even the design, of policies).

Among the countries whose national productivity support policies also include social sustainability objectives, many European countries are to be counted, including the Czech Republic, Germany, Hungary, Ireland, Norway and the Netherlands. In these countries, a not insignificant core of policies is aimed at funding research and innovation projects that have the explicit objective of addressing societal problems. The instruments used are varied. Countries such as Denmark or the Netherlands use open innovation instruments, such as innovation challenges, aimed at stimulating the participation of all kinds of agents (citizens and companies) in solving specific sustainable innovation problems. This is also true in the case of Germany, which finances many interventions aimed at innovation for all, i.e., the invention, production and adoption of technological and economic solutions for the transformation of the energy and social system and the adoption of technological innovations within the reach of all citizens and businesses. In Ireland, a large part of STI policies supports open and inclusive research, dealing with topics of societal relevance.

If we look in more detail at the various pillars related to social sustainability goals (Figure 9 below), we see that several European countries try to combine productivity policies with interventions that support participation and empowerment, equity and human security. Several countries (among others: the Czech Republic, Hungary, Latvia, Bosnia and Herzegovina, and the Netherlands) combine productivity with participation incentives. Other countries combine productivity with either of the other two objectives of social sustainability policies (Ireland, Slovak Republic, Serbia and Sweden for equity and Latvia, Germany and Norway for human security).

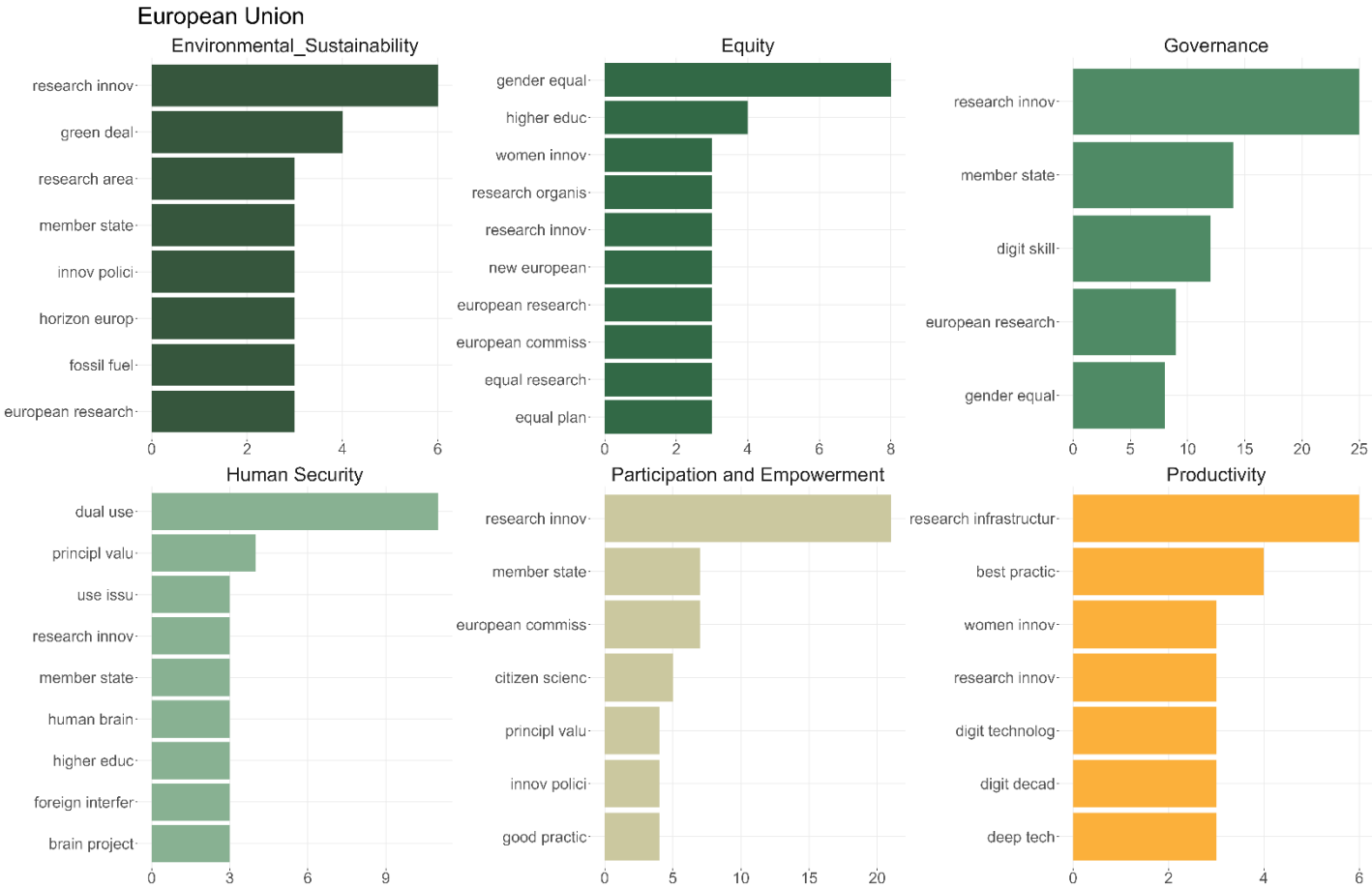
Figure 9. Policies that combine productivity support with social sustainability: Percentage of interventions by country. European countries



Note: Authors' elaboration on EC-OECD STIP Compass data. The figure shows the percentage of productivity and participation and empowerment (combined) initiatives, and productivity and equity (combined), and productivity and human security (combined) over the total of productivity-themed (some initiatives have more the one theme, both in our and in the OECD classification)

The responsible research and innovation approach embodies the STI strategies of the European Union, which has initiated the policy debate on these issues (European Commission, 2013, 2014). The goal of responsible research and innovation permeated the EU strategy of Horizon 2020 and embodies that of Horizon Europe. The interpenetration between productivity and social sustainability policies is quite clear if we look at the following histograms (Fig. 10), which shows the most frequently occurring bigrams (i.e., word pairs) that we found in the description of the interventions observed at the EU level. Looking at the bottom right histograms (highlighted in yellow), we can see that among the most recurrent keywords in the description of policies to support productivity (especially those using soft instruments) include several terms such as open science and women innovation. Not surprisingly, in the histograms relating to equity policies, we find terms such as gender equality and women's innovation. Citizen science recurs as a frequent bigram in policies supporting participation and empowerment. The most frequent bigram in human security policies is ensuring research integrity and managing dual-use research concerns. This includes forming strategic partnerships and funding projects to enhance cybersecurity.

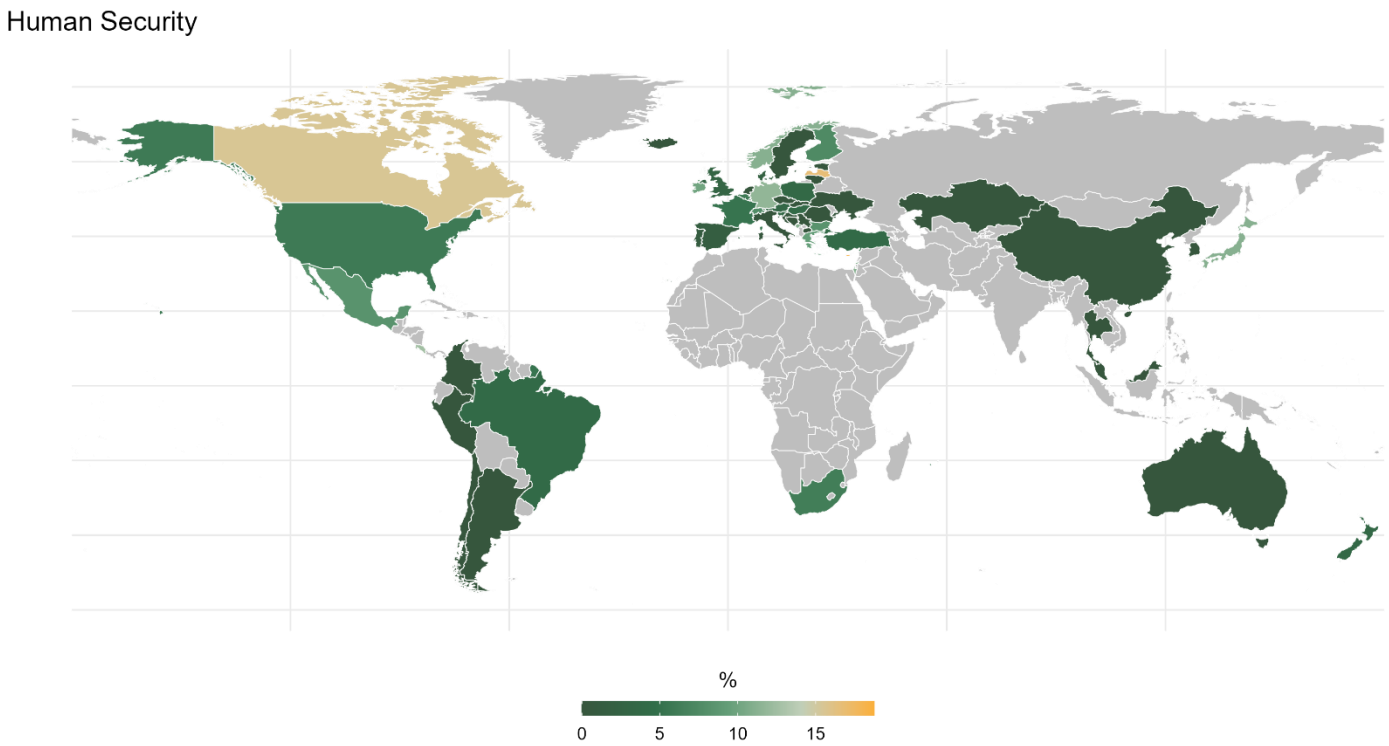
Figure 10: The most popular bigrams by topic. Number of word pairs appearing most frequently in policy descriptions. European Union interventions



Note: Authors' elaboration on EC-OECD STIP Compass data. The figure shows the occurrence of word pairs (bigrams) extracted from the description and objectives of the initiatives we classified as soft instruments.

Outside Europe - at least within the countries included in the OECD dataset - strategies supporting participation and empowerment are widespread. However, policies that support equity or human security are much less widespread. Concerning the latter, the figure below (Figure 11) shows that outside Europe, countries such as Canada and South Africa in the Global South emerge.

Figure 11. Policies that combine productivity support with human security: pct of interventions by country



Note: Authors' elaboration on EC-OECD STIP Compass data. The figure shows the percentage of productivity and human security(combined) initiatives over the total of productivity-themed (some initiatives have more the one theme, both in our and in the OECD classification)

Policies for a just twin transition

In recent years, just transition has entered research and innovation policies (Kivimaa and Kern, 2016; Schot and Steinmueller, 2018; Fagerberg, 2018). The idea of a "just transition" is centered on ensuring that the shift towards a sustainable, net-zero future is conducted in a fair and inclusive manner for all stakeholders involved (Eisenberg, 2019).

Just transition also means using the tools offered by new digital technologies to achieve sustainability goals, including net zero emissions. To emphasize this aspect, we speak here of just twin transition and identify the related policies in those interventions that **combine innovation objectives with those of environmental and social sustainability goals**.

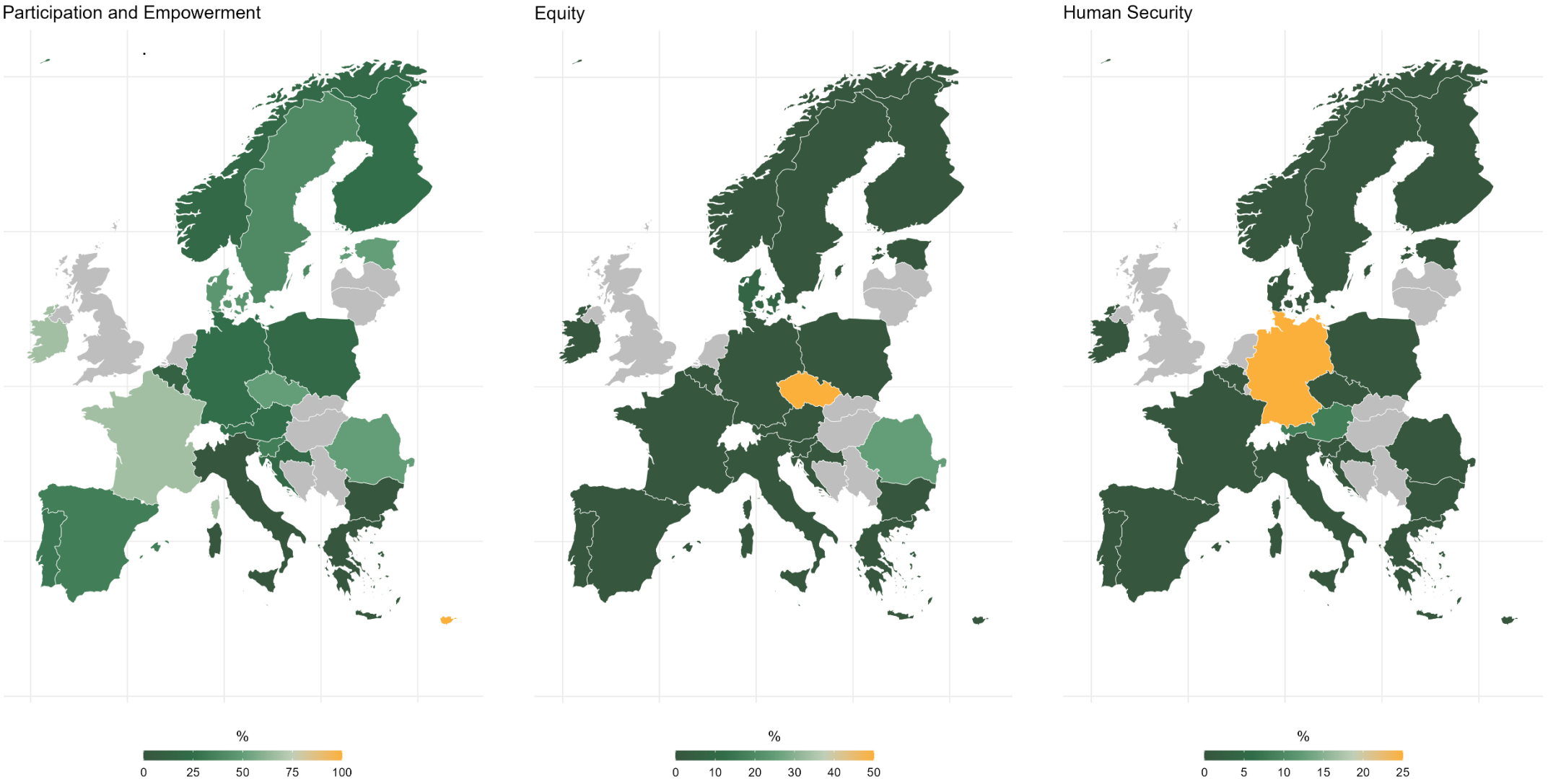
As can be seen from the figures below (Figure 12), in many European countries, policies that combine innovation and environmental sustainability objectives also pursue objectives supporting the participation and empowerment of citizens, businesses and research organizations. This is the case, for example, in France and Ireland, where policies that support productivity and environmental sustainability encourage the formation of collaborative networks or clusters between the various components of society to define research and innovation strategies for the future or have a focus on young people (PhD students for example).

There are relatively few countries whose policies combine innovation and environmental sustainability with equity objectives or the promotion of human security. Concerning policies promoting equity, the Czech Republic and Romania stand out, while Germany and Austria are the countries in which policies for human security are combined with those promoting the twin transition.

Participation and empowerment are objectives also pursued by twin transition policies implemented in other countries around the world.[4] However, even in the rest of the countries of the world monitored by the STIP Compass the other aspects of social sustainability considered here (equity and human security) have a much lower incidence.

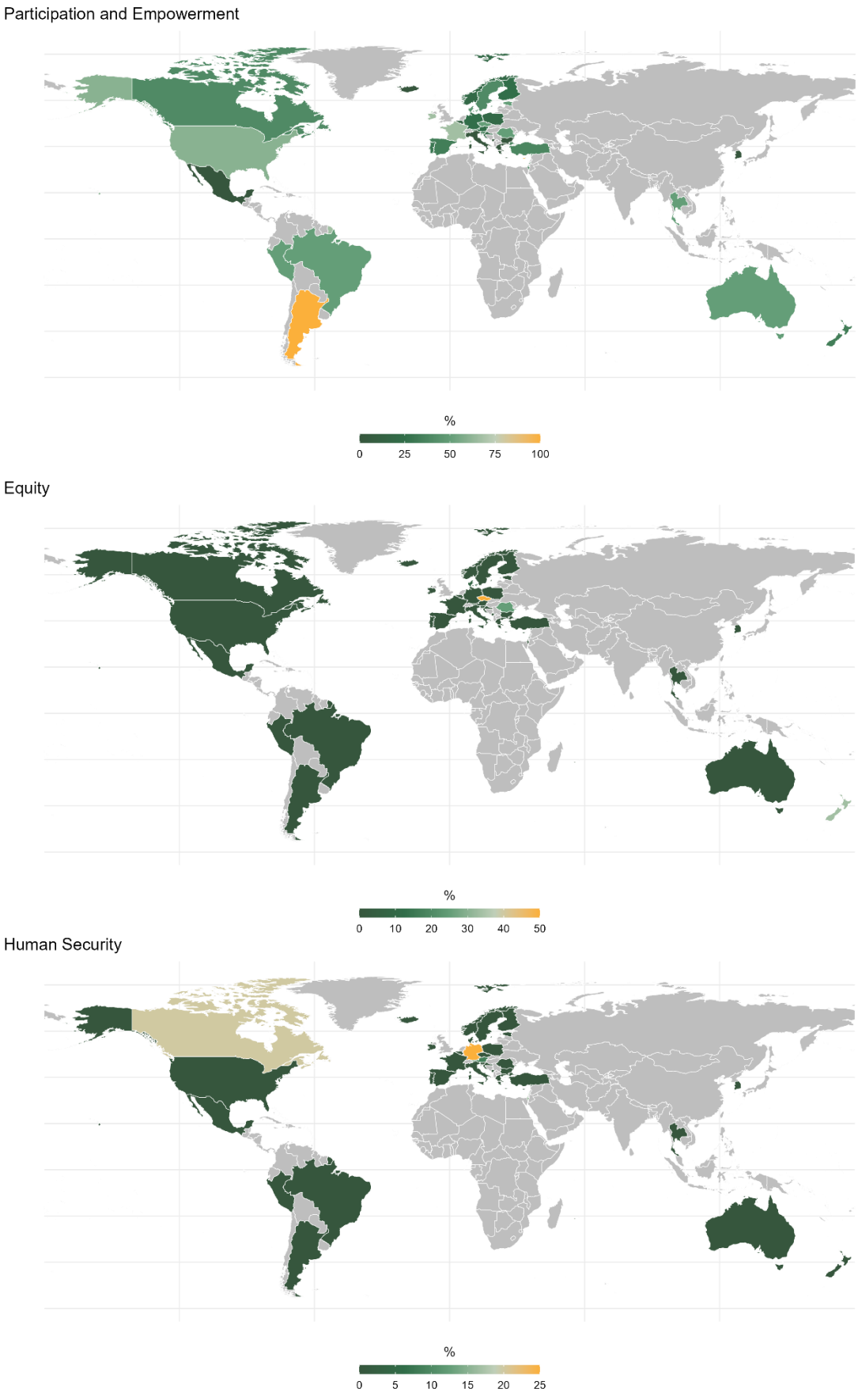
[4] The case of Argentina stands out, but the case is quite peculiar, since only one strategy included in the database fulfils both productivity-supporting and environmental sustainability objectives, and that strategy also pursues objectives supporting participation.

Figure 12. Percentage of policies that combine productivity support with environmental and social sustainability: Percentage of interventions by country. European countries



Note: Authors' elaboration on EC-OECD STIP Compass data. Here we first select initiatives that are both productivity and environmental and then we plot those that have also social features

Figure 13. Percentage of policies that combine productivity support with environmental and social sustainability: Percentage of interventions by country. World countries



Note: Authors' elaboration on EC-OECD STIP Compass data. Here we first select initiatives that are both productivity and environmental themed and then we plot those who have also social features.

6. Conclusions

Looking at the national policies for science, technology and innovation contained in the STIP Compass database, we notice, as expected, that productivity initiatives form a significant part of science, technology and innovation policies. This is particularly true in low and middle-income countries (e.g., Chile, Colombia, China and Kazakhstan), in which national policymakers focus on productivity to better compete and integrate into the global economy. In contrast, higher-income countries, most of them now de-industrialised countries, use a diverse policy mix, targeting productivity, environmental and social sustainability giving a new perspective to the concept of "sustainable productivity".

Several European countries place relatively more emphasis on environmental sustainability, funding research and innovation in clean technologies and other related areas. Many of these policies are also pursued at the EU level, where innovation policies have a strong focus on environmental sustainability.

In addition to innovation and environmental sustainability, national science, technology and innovation policies implemented in the EU Member States also support the participation and empowerment of citizens, businesses and research organizations. However, innovation policies that also pursue participation and empowerment are also diffused in extra-European countries. For example, we observed a relevant incidence in policies supporting youth participation in international training projects and strengthening the presence of universities in international research networks (e.g. Czech Republic and Bosnia and Herzegovina).

The incidence of science, technology and innovation policies focusing on equity and human security is relatively limited. Many of these policies refer to measures to ensure gender equality in research, access to education, training or research for certain groups of citizens, or the promotion of safety and ethics protocols in research. Even fewer countries have policies that combine innovation and environmental sustainability (the twin transition) with equity or together with the promotion of human security.

Our analysis does not take into account one element of the SPES framework. We leave out the natural environment, understood as a wide range of plants, animals and other natural resources, collectively referred to as 'natural capital', which underpins the functioning of the other four actors (science, business, civil society and government). The natural environment is a central foundation of human existence, making it an essential source of knowledge and innovation (Carayannis et al., 2012; König et al., 2021; Biggeri et al., 2023). The dynamic interplay, mutual growth and evolution between society and the natural world are presented as a key catalyst for societal change, fostering the generation of new knowledge and promoting advances in innovation, including eco-innovation and eco-entrepreneurship (Baccarne et al., 2016; Carayannis et al., 2022). The natural environment is not only an additional source of inspiration for knowledge and innovation but is of critical importance as it underpins the preservation, survival and flourishing of human life (Carayannis et al., 2012; König et al., 2021), also in terms of nature-based solutions (European Commission, 2023). However, even if it plays a key role, it is not (or not yet) a direct actor or target group of science, technology and innovation policies.

We cannot ignore the fact that, traditionally, part of the policies for science, technology and innovation have been linked to military objectives. The SPES framework, as outlined by Biggeri et al. (2023, p. 37), conceptualizes human security as encompassing the ability to achieve 'freedom from want, freedom from fear, and freedom to live with dignity'. We advocate a peace-oriented approach to human security, which is particularly relevant in the context of current geopolitical tensions and instability.

Supranational entities such as the EU can be crucial in compensating or substituting to guarantee a complete and multidimensional policy mix. Given budget constraints, political agenda and other specific needs a country can leave behind a goal. In the case of EU member states, this can be remedied at higher levels. The same applies to lower levels of government. The comparisons we make are at the level of national policies, but in many countries, the regional (or federal state) level of intervention can cover some of the objectives not covered at the national level.

Cooperation can take place not only between different levels of government but also between countries. In particular, it can be crucial from now on to design joint initiatives that integrate North-South, South-South and triangular STI cooperation for a just green transition (UNCTAD, 2023), through multi-level and conscious governance. However, as for the South-South collaboration, challenges such as limited incentives, investment and frameworks for cooperation can hinder progress. Developing countries might prefer to collaborate with more developed countries due to better research and other infrastructures. Despite the UN General Assembly's call for increased South-South cooperation to achieve the Sustainable Development Goals (SDGs) on 15 April 2019, collaboration remains limited. Initiatives such as the Science, Technology and Innovation Strategy for Africa (STISA-2024) are promising, but cooperation, particularly on climate change, is still minimal. In addition, smaller and lower-income countries face difficulties in attracting investment in green innovation due to unattractive markets. There is a push for donor countries to support regional green technology hubs to overcome these challenges. While developed countries drive innovation through competition and incentives, developing countries struggle to replicate these strategies effectively due to resource constraints (UNCTAD, 2023).

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Appendix

Table A1. Correspondence between the policies included in the STIP Compass database and the SPES project pillars.

Productivity	
Business innovation policy strategies Financial support to business R&D and innovation Non-financial support to business R&D and innovation Stimulating demand for innovation and market creation Entrepreneurship capabilities and culture Targeted support to SMEs and young innovative enterprises Foreign direct investment Access to finance for innovation	Innovation in firms and innovative enterpreneurship
Collaborative research and innovation Commercialisation of public research results Intellectual property rights in public research Cluster policies	Knowledge exchange and co-creation
Digital transformation of research-performing organisations Open and enhanced access to publications Open and enhanced access to research data Competitive research funding Research and technology infrastructures Cross-disciplinary research Third-party funding	Public research system
Digital transformation of firms Mission-oriented innovation policies	Research and innovation for society

Environmental Sustainability	
Net zero transitions policy debates Government capabilities for net zero transitions Net zero transitions in transport and mobility Net zero transitions in food and agriculture Cross-sectoral policies for net zero Net zero transitions in energy	Net zero transitions
Equity	
Equity, diversity and inclusion (EDI) International mobility of human resources	Human resources for reserarch and innovation
Inter-sectoral mobility	Knowledge exchange and co-creation
Governance	
STI plan or strategy Strategic policy intelligence Evaluation and impact assessment International STI governance policy Horizontal policy coordination	Governance
STI human resources strategies	Human resources for reserarch and innovation
Public research strategies Structural change in the public research system	Public research system
Research and innovation for society strategy	Research and innovation for society

Human Security	
Research security Research integrity and reproducibility High-risk high-reward research	Public research system
Ethics of emerging technologies	Research and innovation for society
Participation and Empowerment	
STEM skills Doctoral and postdoctoral researchers Research careers	Human resources for reserarch and innovation
Knowledge exchange and co-creation strategies	Knowledge exchange and co-creation
Non-competitive research funding Internationalisation in public research	Public research system
Research and innovation for developing countries Multi-stakeholder engagement Science, technology and innovation culture	Research and innovation for society

Note: On the left column, the list of interventions and on the right column the macro-classification used in the STIP database

Table A2. Correspondence between the target groups included in the STIP Compass database and the SPES project actors.

Academia	
Undergraduate and master students Postdocs and other early-career researchers PhD students Teachers Secondary education students Established researchers	Researchers, students and teachers
Higher education institutes Public research institutes Private research and development lab	Research and education organisations
Business	
Private investors Entrepreneurs Labour force in general	Economic actors
Firms of any age Nascent firms (0 to less than 1 year old) Young firms (1 to 5 years old) Established firms (more than 5 years old)	Firms by age
Firms of any size Micro-enterprises SMEs Large firms Multinational enterprises	Firms by size

Civil Society	
Women Disadvantaged and excluded groups Civil society	Social groups
Government	
National government Subnational government International entity Programme managers and other research support staff	Governmental entities
Incubators, accelerators, science parks or technoparks Technology transfer offices Industry associations Academic societies / academies Non-governmental organisations (NGOs)	Intermediaries

Note: On the left column, the list of target groups and on the right column the macro-classification used in the STIP database.