IN FAVOR OF
PURE SCIENCE

A Report by the
Aspen Institute Science & Society Program in Collaboration Among the
13 International Partners and 1 International Initiative of the Aspen Institute

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In Favor of Pure Science

When a catastrophe like a pandemic occurs, most people, understandably, desire practical and immediate solutions. People seek a vaccine that could save lives and end the spiral of recession and poverty that is trapping all countries in the world—consequences that do not distinguish between wealthy and non-wealthy countries.

Important to note is that a vaccine is not just a technical device. Vaccines, like other drugs, are made possible by the advancement of pure, or basic, research. That is to say, by research aimed at discovering the fundamental laws of matter, whether animate or inanimate.

Now, many people seem to believe in science and in scientists. In some circles, anti-vaxxers have gone quiet. But beware: this trend may not last. Vaccines derive from pure science, particularly from genetics. Big investments in vaccine development are welcome, but they are just a temporary solution—until the next pandemic appears. In order to have a safer world, one must first understand the structure of life. Moreover, it is crucial to have this knowledge before dramatic events occur.

Today, it is evident that had knowledge of cell biology and genetics been more complete, the time to create a vaccine for COVID-19 would have been dramatically shorter.

Advancement in pure science is good in itself, as it corresponds to one of the fundamental roots of civilization, of all civilizations: to understand who we are and the physical and the biological world in which we live. Advancement in pure science is also valuable because it allows for our material progress: better lives and longer lifespans. Without thermodynamics, relativity physics, quantum physics, evolutionary theory, and theoretical chemistry—to name just a few scientific fields—humans would live poorer and less interesting lives.

The sad fact is that almost everywhere in the world, the support for pure science is steadily declining, as stated by the latest *UNESCO Science Report: toward 2030* (https://en.unesco.org/unescosciencereport). More and more public funding goes toward applied science, or toward technological applications of pure science already established. At the same time, pressure on making profits on a short-term basis is displacing the funding for pure science by large private enterprises. There are no more examples in the world like Bell Labs, where no fewer than 13 researchers won or shared a Nobel Prize.

We have to look back to history. "Women and men can know; then they can be free": this statement is one of the basic foundations on which the modern world was built. The birth of modern science did not just mean a change in knowledge of the natural world, but also a change in knowledge of the moral world, and even a change in the way humans perceived themselves. Indeed, scientific inquiry assigned a key role to individual liberty in the inquiry into nature and the pursuit of truth. The ideas of individual liberty and of political institutions based on the principle of the limitation of sovereign power (constitutionalism) found their counterparts in the idea of freedom to research: such freedom regards every human being and every scientific community as free to express theoretical and experimental results, without censorship by any external authority, whether political or moral in nature. The idea of rights that we cherish flowed from the scientific revolution and modern science no less than from constitutionalism and the market economy.

Today, any sound narrative about democracy must include a universal "right to science" as a fundamental principle.

More than 50 years ago, the Aspen Institute launched a program called "Public Understanding of Science." The purpose was to understand which vision the American people had of pure science, and why people seemed skeptical of orienting public resources towards financing it. This program had an important role in making possible the flourishing of pure science in the United States in the following years.

At that time, there was only one Aspen Institute in the world. Today there are 14 Aspen Institute partners across the world (United States, Spain, France, Germany, Italy, Ukraine, Czech Republic, Romania, Japan, Mexico, India, New Zealand, United Kingdom, and Colombia), which are united by the same motto: "Timeless values, enlightened leadership." Aspen Institutes are made by a plurality of countries and cultures. No other private institution has this broad perspective.

Advancement in pure science is an important part of our vision of the good society. Pure science is a "public good" because every human being, every human society, benefits from it. It has no frontiers, no ethnical divisions. Its results are available to anybody. There is nothing that unifies humankind as ethnic knowledge does.

Our belief is that today, an important part of the Aspen mission throughout the world is to make a plea in favor of pure science: a plea for more public and private funding, a plea for more freedom of research, a plea for more globalized research, a plea for a more open access to pure science for minorities of all kinds.

The added value of a global action by the Aspen Institute International Partners in favor of pure science is that they do not represent any vested interest. Among their members are many eminent scientists, but they are not scientific societies. They represent learned people, concerned with the future of our societies and of our planet. They represent people who share the same humanistic values.

In the medium-to-long run, this project will have the objective to make the consciousness of the importance of putting pure science at the center of public and private policies a structural element of the "enlightened leadership" at the national and, ever more importantly, at the global level, for the general wellbeing of humanity.

Summary:
The Values of Pure Science

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A set of fundamental values results, more or less explicitly, from the reports of the 14 national Aspen Institute partners. Such a set is a good point of reference to understand the issues, strengths, and weaknesses of each country in view of the common goal: for public and private policy-makers to become more aware of how important, even urgent, it is to invest resolutely in basic or pure research. The reports clearly refer to values that are typical of the scientific endeavor, but which are often overlooked or even unacknowledged by public opinions. This lack of awareness is a cause for serious concern, since it may well lead to an overall decline of our civilization.

Hence the need, expressed almost unanimously, to enhance this awareness among the elite and public or private decision makers, and for them to share it as much as possible with every part of society. This need is in accordance with Aspen Institute Italia's proposal, "Aspen Global Initiatives in Favor of Pure Science," which the Aspen Institute forwarded to the fourteen countries. All the more so, because the notion of "pure science", as well as cognitive or epistemic values, also elicited, values that fully address the moral and civil sphere of modern liberal democracies and further enrich the already varied and complex interweaving of cognitive, economic and constitutional values identified by Aspen Institute Italia.

As some reports emphasize, this resonates with the Aspen Institute's long-standing tradition and its original commitment to think about and contribute to building a free and fair society.

It is therefore significant that, in the context of a specific reflection on pure science, all those consulted—the academics, scholars, researchers in the physical and social sciences, and the representatives of the world of economics, of politics and institutions—mention not only values such as curiosity, creativity, pure enjoyment, politics, and of institutions, the excitement of discovery, expertise, a love of knowledge in itself and not for its material rewards, but also aesthetic values such as elegance and beauty, and above all moral values such as trust; transparency; integrity; benevolence; competition among ideas and not among people; peace; tolerance; international cooperation.

The Mertonian norms—communism, universalism, disinterestedness, organized skepticism—are also mentioned, as ideal models both for research and for their educational function in shaping a renewed cultural base for a free, fair and equitable society (see Japan's report). Moreover, the panelists stress the importance, in actively promoting the public discourse on science, of alerting all interested parties to science's ethical implications, so as to make it more interesting as well as more challenging, and at same time closer to citizens' daily life. They strongly assert the fundamental right to science and to the freedom of research, as well as the constellation of rights linked to the purest forms of knowledge—above all, the right to a fulfilling development of our human personalities and capabilities in the most free and diverse ways through a lifelong education.

Trust in science. Trust, in particular, is a multifaceted value, and the reports included here consistently link its lack to many crucial problems. Trust is essential if science is to work (and for markets, states and civil society as well), but in other respects it underpins the delicate relations between science and society.

In some countries, e.g. Germany, where trust in science and in the judgments of experts is higher than elsewhere in Europe, this was decisive in addressing the pandemic emergency with the necessary measures, and in effectively rebutting various expressions of skepticism. Anti-vax rebellions, conspiracy theories and fake news were much more difficult to stem where that trust declined or had already been lacking, and they generated huge human, social and economic damage.

The French proposal lists a triad of objectives—trust, education, simplification—functional to the construction of an entire ecosystem that can encourage public and private actors' propensity to invest in pure science. A similar approach to the issue of trust may be found in the British report, from which it appears that public debate, with ordinary people considered as crucial stakeholders, constitutes a good a starting point from which to build. A listing of other interested parties includes political decision makers, business, philanthropy, experts in science communication (whose roles, it is emphasized, are often underestimated).

In the web. Social networks and the digital giants are due some credit for remarkably positive changes, such as an easy and wide-spread access to culture, including science. Their overpowering presence means, however, that civil society is more vulnerable than it used to be. In the absence of trust in science and expertise, and when other forms of mediation (e.g. newspapers, magazines, educational systems) are challenged by new entrants, people are more exposed to the cognitive biases affecting all of us, even scientists when they move outside of their own specialized field.

We should pay attention to Japan's report where it says that

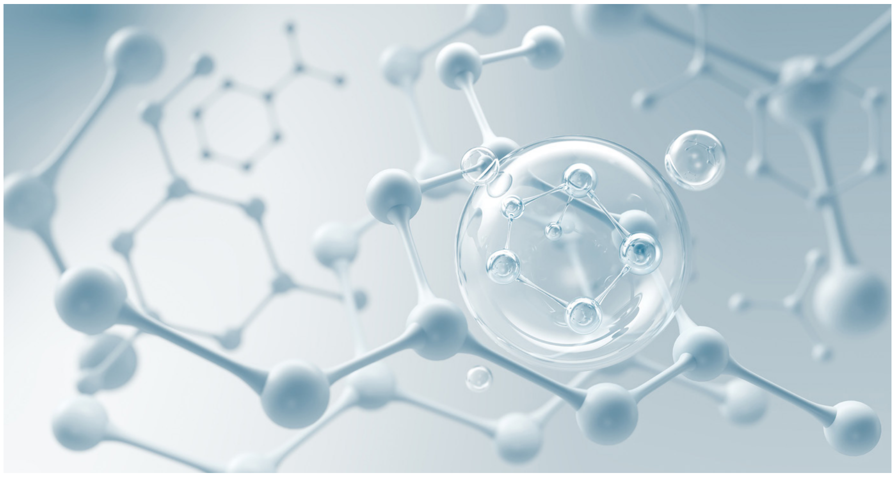
> The Internet will provide benefits to the people, but it may also damage the authenticity of modern society and modern science. Thirty years have passed since the Internet was introduced to society. We need always to pay attention to the merits and demerits of the influence of the Internet and its derivative services on pure science.

Scientific culture and cognitive sciences. Scientific culture and critical thinking are among the most important antidotes to these natural biases, which find fertile ground in the networks and their manipulative algorithms. Sharing the values of science and its methods worldwide could tone down forms of hatred, tribalism, conspiracies, demagogy, and polarization of opinions that a few reckless actors are able so easily to spread on the web to damage public debate, with the risk of tearing apart the very fabric of society. It should also be remembered that the values of science, the free market, and the division of powers have jointly established themselves in the modern age as constructs meant to shield humanity from those tribal instincts from which there arise most of the biases cognitive sciences are presently studying. Extraordinary progress is being made in understanding human nature and the development of civilization, from the origin of good manners to the free market and the definition of the fundamental norms of the constitutional states.

A society that trusts scientists and beliefs based on empirical evidence is therefore safer, both more efficient and more effective in dealing with collective problems without being sidetracked by prevailing misinformation. There is a general awareness of the importance of this point; it is all the more so in countries where the level of trust in science is lower.

Authoritativeness vs. Authority in science. Trust in science is a precious asset and needs cultivating with care. When pursuing it, we need to bear in mind aspects that are linked to the development of critical thinking. In particular, trust should not be pursued by appealing to the Authority of Science, distant from common sense and feeling, but to the authoritativeness and reliability of the procedures followed by scientific communities while collecting empirical evidence and weighing it precisely and rigorously. Some reports cite the peer-review system as at once democratic and meritocratic. This is right, but peer review seems impractical to use for the careful assessment of over 3 million papers a year in thousands of journals, approximately 20% of which are "predatory" and profitably exploit the "publish or perish" imperative. Recurring failures of peer-review, even in reputable journals, and the publication of irreproducible results have been eroding the public's trust.[1]

Relying on authoritativeness and reliability rather than Authority contributes to a less restrictive and more inclusive image of science, in line with the universe of values mentioned above. This is the aim on which the reports converge when they remind us that the authoritativeness and reliability of science is an integral part of its openness, constantly reassessed by newcomers—and, in this sense, of its quintessentially democratic nature. Sharing methods and procedures with the public avoids making science into an idol replacing other idols, keeps critical spirit alive, and reinforces a shared, common culture.



The British report insists on the importance of multidisciplinarity for the advancement of science; but it cautions that most systems of incentives (not only in the U.K.) do not, in fact, reward it, either in actual research or communication. This issue is connected with the motivations to embrace curiosity-driven or blue-sky research, essential today to spread the love for and trust in science.

Inclusiveness. As science is by definition inclusive, the recognition of the value of diversity is essential. The U.K. report—in addition to aiming at the construction of a truly varied and inclusive research ecosystem by encouraging diversity in ethnicity, gender and age—suggests that we should create a culture of science that is more accessible and gives people the opportunity to appreciate the variety of ways in which it is possible to contribute to the scientific enterprise. Lifelong learning, for example, should be encouraged and, according to the U.S. report, citizens who develop an interest in science after college should be encouraged by increasing flexibility about age.

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[1] See *The Economist* cover "How science goes wrong," October 19, 2013

In discussing inclusiveness, Spain highlights that we should avoid the "Matilda effect" (i.e., men getting credit for women's work), giving adequate recognition and visibility in the media and in textbooks to women's contributions. In this way they can act as role models and encourage girls to study STEM subjects (Science, Technology, Engineering and Mathematics).

The Aspen Institute New Zealand has an interesting point of view on inclusion, wondering how to involve in its initiatives the "mātauranga Māori," the traditional system of understanding the natural world, as the bearer of a different paradigm. "Pakehas are short-term in their thinking—Māori are not": fundamental research in the dynamics of interconnected ecosystems and applied research on the origins of zoonotic diseases have rediscovered the old Māori concept of human relationships with the natural world—if the environment is not in good health, people can't be in good health, either. "One Earth, one health," as Pakehas and, after them, the World Health Organization now call it. Science in a free society cannot fail to take into account the plurality of forms of knowledge, which in the definition of the common good goes hand in hand with other forms of pluralism—political, civil, and of lifestyle choices.

We should not forget that in a broader perspective—as stated in the Japanese report—science in general is by its very nature an activity that both respects differences, and transcends political, linguistic, religious, social, and gendered borders. This feature is even more striking in the case of pure science, thus making its role all the more unifying and inclusive. Of course, one should keep in mind how universalism on the one hand, and the appreciation of pluralism and respect of particular identities on the other, may well carry conflicting values. These may, however, be reconciled in a broader perspective, one that aims at eliminating the prejudices hindering the development of individual and collective abilities. It is precisely its universalistic and transnational character that makes science potentially more inclusive than any other human activity.

Some reports convincingly suggest that we should think in terms of STEAM rather than STEM, to include the humanities and the moral and social sciences (the last of which, as the Aspen Institute New Zealand points out, do after all contain important components of basic science) among the knowledges that research, education and communication should deal with. And, in fact, the additional "A" stands for "Arts" in the broadest sense of the liberal arts: in short, education systems must be reassessed from the point of view of a critical thinking that benefits everyone, regardless of individual identities and inclinations, and that helps citizens everywhere to become free, knowing, and self-aware.

The report from Japan suggests that we should link STEAM to the "narrative" function of science communication for persuasive and rational purposes, positing that:

> whether [young people's] background is in humanities or sciences, it is important to foster the culture and abilities such as historical view, world view, nature view, imagination and creativity, reason and sensitivity, aesthetic sense, judgment of right and wrong, justice and conscience, tolerance and humility, acceptance of diversity, and passion.

A varied constellation of values. The constellation of values sketched above, for all its internal tensions, constitutes a rich armory of motivations in support of a renewed commitment, to be exercised at a global level, toward pure science and culture as the main drivers of human and economic development. These values must inspire the appeal that Aspen intends to launch globally.

Science policy in a free and open society must consider both the researchers' freedom, and the freedom of all other interested parties. Indeed, this accounts for the entire population, active and inactive, whose well-being—in terms of quality and duration of life—has grown enormously thanks to the extraordinary progress in basic physics and biology and their successive applications. But, as Karl Popper would object, research is an "unended quest" (the very title of his autobiography), and this is a concept that seems to escape the current funding system, focused as it is more than ever on applications, as if there were no longer any pure path-breaking discovery ahead. Although nobody really believes this, the OECD data on the trend of investments in research and development show that investors behave as if they did.

Critical thinking. The main message of the reports is that pure natural science and the human and moral sciences share a set of fundamental values, and that science must increasingly be part of the culture *tout court* of citizens and workers whose capabilities and skills should keep in step with the times they live in.

The core issue here is the development of critical thinking, and Aspen Institute Romania's report insists on its urgency:

> A community of workers lacking critical thinking skills represents a risk for democracy as well as competitiveness.

Two quotations taken from Japan's report offer an apt summary of the nature and roles of critical thinking in science:

> The important thing in science is not so much to obtain new facts, as to discover ways of thinking about them,

wrote Nobel laureate for physics William Henry Bragg; and, as Albert Einstein put it,

> The formulation of the problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skills.

(Here he seems to forget, however, that mathematical skills and the ability to conceive ingenious experiments are essential ingredients of creativity and critical thinking as well). One could add Bertrand Russell's opinion—as a philosopher, mathematician and Nobel laureate for literature—that the actual task of philosophy in our age is:

> To teach how to live without certainty, and yet without being paralyzed by hesitation.

This is a task not only for philosophy, but for a vast assortment of knowledges that ally cognitive psychology with economics, ethics, rational decision theory, computer science, data science, financial education, and—last but not least—probability. Each of these forms of knowledge provides efficient tools for one to learn to think for oneself and to master a critical thinking. This is, as the pandemic crisis subsides, more necessary than ever for good citizens and decision makers in the age of the Internet and pervasive digitalization processes.

Again, as stated in Japan's report:

> As we enter a major transition period to the new world after COVID-19, in which sustainability, diversity, and inclusiveness are emphasized as values of the 21st century, it is important to review the definition, purpose, scope, and methods of pure science, while maintaining its integrity and quality. To this end, it is important to focus on the roles and responsibilities of the humanities and social sciences, collaboration between the humanities and sciences, and support for such activities.

Pure and applied science: an operational approach

The reports highlights the bias in favor of funding applied science, even though there would be no application to develop and no mRNA vaccines for COVID-19 at "warp speed" without prior investments in pure research. And they underline that climate change, for example, is a global and central topic for pure research. In happier times, IBM let Benoît Mandelbrot and his team study a non-Euclidean geometry and produce delightful images that, on the short term, did very little to improve computing performance. Fractal geometry was later found useful in image compression and resolution, e.g. satellite maps of extreme weather events made more intense and frequent by global warming such as droughts, heat waves, and floods.

Perhaps one of the best-known examples of blue-sky research's unexpected outcome is the beam of pulsated coherent light that Einstein had imagined in 1917 and which was obtained on the cheap (USD 50,000) in 1960 in one of Hughes Aircraft's labs. The now ubiquitous laser, its inventor Theodore Maiman recalled, was greeted for decades as "a solution in search of a problem."

In their common effort to address the issue of a declining global funding for pure or basic research and in favour of applied research, most reports initially find the distinction difficult to express clearly enough. This weakness needs to be overcome if we are to communicate effectively with public opinion on how this trend is to be reversed. From this point of view, a communication failure reverberates on the entire cultural and scientific ecosystem. Even scientific communities crucial for decision-making, such as the economists, rarely set it at the core of their analyses and recommendations, despite their awareness of the close relationship between economic growth and investment in knowledge, and indeed their coining of the term "knowledge economy."

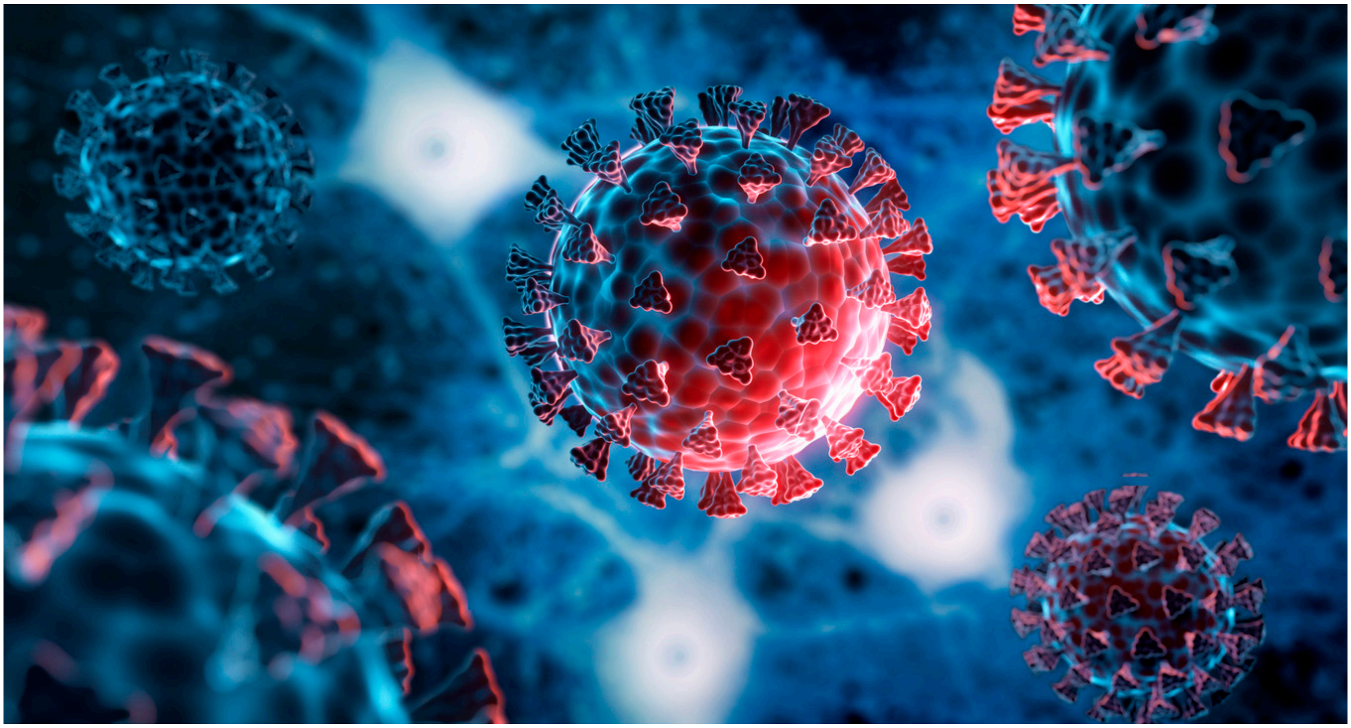
Our panelists also appear uncomfortable in having to admit that applied research is in fact strongly bonded with pure research, something that implies that applications will be built upon the latter.

Facts and values. The discomfort evident in the reports is due, to some extent, to the need to offer an accurate and honest description of the operational context (i.e. the current state of research and its funding in the various countries represented here, where in most cases various types of research are interconnected), while at the same time setting up effective recipes for the specific purpose of promoting an increase in funding for research in pure science.

It is necessary to make a non-trivial effort to reach a prescriptive and persuasive definition of choices and behaviors that deviate from the mainstream of public and private current decisions—even though these may be more attuned to gut feeling than to principles of rationality and reasonableness. This is precisely the challenge Aspen decided to face.

As regards the description of each country's research context, only the aspects that are more relevant to the considerations proposed here can be mentioned at this stage, leaving it to readers to consider the panelists' more detailed and in-depth analyses.

Means and ends. Some general philosophical reflections may be useful to navigate these concepts. For applied research, the most classic form of means and ends rationality is in place: applied research requires finding the means to reach a given end at the lowest cost and with maximum



efficiency and effectiveness. When the topic of pure science is introduced, however, a form of axiological rationality comes into play relative to the very definition of ends and values: pure science involves producing rational arguments to establish whether certain ends (rather than the means to achieve them) are good or not, and then turning the reasons for our decision one way or the other into reasons to guide our action. The 14 reports may be considered as a useful and varied intellectual exercise of this kind, and as such they collectively represent a solid basis for globally redirecting and re-motivating the elites' opinions.

Usefulness and other values. When the end of research is the pure love of knowledge, as expressed for example in the discovery of some fundamental law of nature, the set of reasons that support the end concerns above all the fact that that end is in itself a value to be defended together with other connected values (personal development, human flourishing, the pluralistic expression of capabilities, civil engagement, equality of starting conditions, elimination of discrimination, inclusiveness, etc.), rather than for the consequences that it may have.

However, it would be difficult not to acknowledge that in the long run pure science does lead to applications capable of solving social problems and facing emergencies on a planetary level. In other words (and this seems further to confirm the strength of the bias toward funding applications of applied science), even when it comes to justifying basic research, the main argument will often tend to be that a certain piece of pure research will produce beneficial results (e.g. studies on RNA regulation of the immune system and mRNA vaccines). This risks obscuring a decisive point: the fact that pure science implies investments with unpredictable or difficult-to-predict outcomes. It may (or it may not, for that matter) advance knowledge, but even when it does, such knowledge or may not translate into useful applications, at least in the foreseeable future. And when research involves exorbitant costs—think of the cost of building increasingly powerful colliders to study elementary particles, for example—persuading taxpayers and public decision makers can be even more difficult. In turn, this may well be the reason for that tendency, highlighted above, to foreground the good track record held by research in pure science in delivering the (applied) goods, even though this delivery (or its timing) are not fully guaranteed on every single occasion.

Here pure research in astronomy and cosmology suggests interesting counterexamples. Public opinion all over the world was quite satisfied with dear old Hubble space telescope's performance: media and millions of citizens spontaneously lobbied for its life to be extended when NASA decided to "switch it off" instead of planning an expensive and dangerous upgrade. But now even more citizens watch in awe what the huge and hugely expensive James Webb space telescope is revealing, since it reached its destination, about planets, stars and galaxies "far far away."

Many discoveries or applications (as shown by the sociologist of science Robert Merton, whose norms are quoted above) are serendipitous, i.e. human and financial resources are profusely invested in one area, and end up leading to completely unexpected results or discoveries in another. The history of scientific discoveries is studded with examples of this phenomenon.

Telling stories of serendipity and spreading them as much as possible may be an effective way to increase the appeal of pure research. For instance, one of the many stories about the past, when companies were doing pure research and their staff won Nobel prizes—and an entertaining one as well concerning the oft-mentioned Bell laboratories—is about the serendipitous discovery of the cosmic background radiation.

The intrinsic value of knowledge. It can be difficult, and perhaps even contradictory, to combine intrinsic values and fundamental rights with utilitarian reasons of usefulness and profits (albeit only in the long term and related to the overall well-being of humanity). But the two aspects really can and must coexist. They are not mutually exclusive and, if framed with good storytelling, they will reinforce one another. Understanding nature, high standards of scholarship, and education over and above training ultimately will have positive economic consequences for entire countries.

The current increase in investments in applications to the detriment of basic research and the prevalence (as confirmed by the reports) of an economic logic that requires fast results in terms of profits are jeopardizing the other essential values at stake.

The national Aspen Institutes are well aware that investing in pure science research involves a complex web of values. These values are not confined to the (however decisive) consideration that to go on failing to do so would likely involve the economic impoverishment of the developed world. Hence the enrichment that their reports bring to the list of values to be consolidated in our liberal-democratic societies. These values will be essential for us to define an effective and persuasive communication strategy geared at addressing decision-making elites.

This strategy can only start from a convincing definition of basic science, such as the one we find in the German report:

> The essence of basic research consists of the goal simply to advance knowledge. Pure science does not seek direct economic or social benefits, nor is its aim to apply its results to practical issues. Hence its practitioners focus strongly on curiosity as the leading motivator to pursue research in pure science. In this sense, pure science involves a creative, open approach to scientific theory, methods and results.

Pure research and education. Pure and disinterested research makes it possible to rethink an overall reform of the idea of culture, and therefore of educational systems. Putting curiosity and open-mindedness at the core of children's education from the earliest years of life, in line with the indications of cognitive scientists—and not filling their minds with scientific propositions too difficult for them to grasp at a young age—is fundamental whatever interests, scientific or humanistic, they will develop later on. Interest in science is one of the decisive vehicles for critical thinking. This implies the development of argumentative skills in all fields, in the discussion of the ends to be pursued, and in the definition of the different individual and social identities that are themselves constantly moving and evolving. As John Dewey wrote very pragmatically, alluding to the interplay of science, democracy, culture, and education:

> Not perfection as a final goal, but the ever-enduring process of perfecting, maturing, refining is the aim of living.

Pure and/or applied. Interestingly, the French report compares the American and the French systems and highlights the undeniable contiguity between the different types of research. This is worth quoting in full (**bold** in the original):

> The difference between the two is primarily cultural. In the United States, there is no real difference between academic/fundamental research and industrial research, and this is reflected in the guidance provided by the Aspen Institute when the terms are used interchangeably. **The American system is based on the recognition that the former is never truly "pure" but is instead always imbued with an element of practice or application to reality.** Moreover, the Americans have understood that applied/industrial research can only progress by relying on very high-quality basic research. Thus, the major applied research campuses are above all major basic research centers.
>
> In France, on the other hand, there is a difference related to the very purpose of research: **the Academy of Sciences defines basic research as research that does not have an application in mind.** But this vision is very far from reality. In fact, there is a total continuity or absence of barriers between the two types of research.

> The issue is therefore not to discuss the distinction between basic and industrial research, but **to question the absence and feasibility of creating a favorable ecosystem that would simultaneously:** 1) motivate basic research in a more global and interconnected context that would allow practical applications to be created from basic research; and 2) an issue related to the means of strengthening research activities in France. In the United States, it is possible to mobilize industrial investors to fund academic research programs that are economically or strategically attractive to industry. In France, industrial investors do not understand how academic campuses operate. It is therefore necessary to reinforce the acculturation between the public and private sectors to encourage industrialists to invest in research. This is the main source of the research funding deficit in France.

As indicated earlier, we must recognize that research can rarely be defined as pure in all respects, and indeed that trying to do so may be self-defeating. Nevertheless, to motivate basic research in a more global and interconnected context as stated in point 1) above, the fact that no clear-cut dichotomy may be readily available for general use does not mean that some forms of research aren't in fact closer than others to the ideal type of basic or pure science, (i.e. they "have no application in view") and are the victims of the funding bias mentioned above. Such a bias can be eradicated by thinking about a research ecosystem where we find not a sharp distinction between pure and applied science to be used in any context, but gradients: at one extreme there would be clear examples of pure research, at the other equally clear examples of applied research, and in between a range of intermediate cases.

The Ananta Aspen Centre and CTIER, in India, make the same point, and argue that it is more productive to think of a "continuum" between pure and applied. However, it is equally necessary to acknowledge the "pure" elements as opposed to the "applied" ones and, therefore, that an ecosystem may be oriented in one direction rather than the other. In other words, it must be clear that studying the fundamental structure of protons or viral proteins is very different from trying to design, for example, more efficient metals for car batteries or better therapies.

Making this concept clear in simple and operational terms—while avoiding objections in the style of Hume's is/ought fallacy—is a prerequisite for Aspen's appeal and for an effective campaign to raise awareness and shift public opinion in favor of a decisive redirection of investments toward pure research.

Good and bad science. We should not forget that the use of a range rather than a clear-cut distinction (which is in any case needed to underpin operating within a range in the ways sketched above) implies a constant critical exercise to identify and promote different forms of investment in research, also in view of a realistic quantification for them. It will be useful to keep in mind the *Frascati Manual* (considered by all to be a reliable instrument, even by those who, like Ukraine, are preparing to implement it only at this stage) and—as indicated by Aspen Institute Japan—the differences between the Pasteur quadrant (basic research inspired by "use"), the Bohr quadrant (pure research with no application in sight) and Edison-style research (directly aimed at application). A useful summary table is attached, in which pure curiosity-driven research is cross-referenced with the researchers' degree of awareness of the type of research they are doing. The situations included range from the cases in which the curiosity-guided mission is stated only in an external explanation and there is little awareness of the mission itself, to cases where it is possible to acquire basic knowledge aimed at future applications, even though the plan for this is not clear at the outset. They also range from cases where research will establish the foundations for a specific and already planned purpose to cases where research is performed in the full awareness of a specific mission.

Pasteur used to say that the most important distinction isn't between pure and applied science, but between good and bad science. However—to summarize many considerations contained in the reports—if pure research were not adequately funded anymore, the whole research endeavor would deteriorate (and so would our civilization), because science would end up being mostly bad.

The global challenges, unprecedented for humanity, that the international community must meet now, above all environmental sustainability and in particular climate change (see the Japanese report), require a major re-assessment of basic scientific research:

> Basic science research is important as it allows one to deal with the unknown.

It is precisely when events are very hard, if not impossible, to forecast accurately, that pure science will reveal to humanity its full value.

Funding: good practices, problems, and proposals

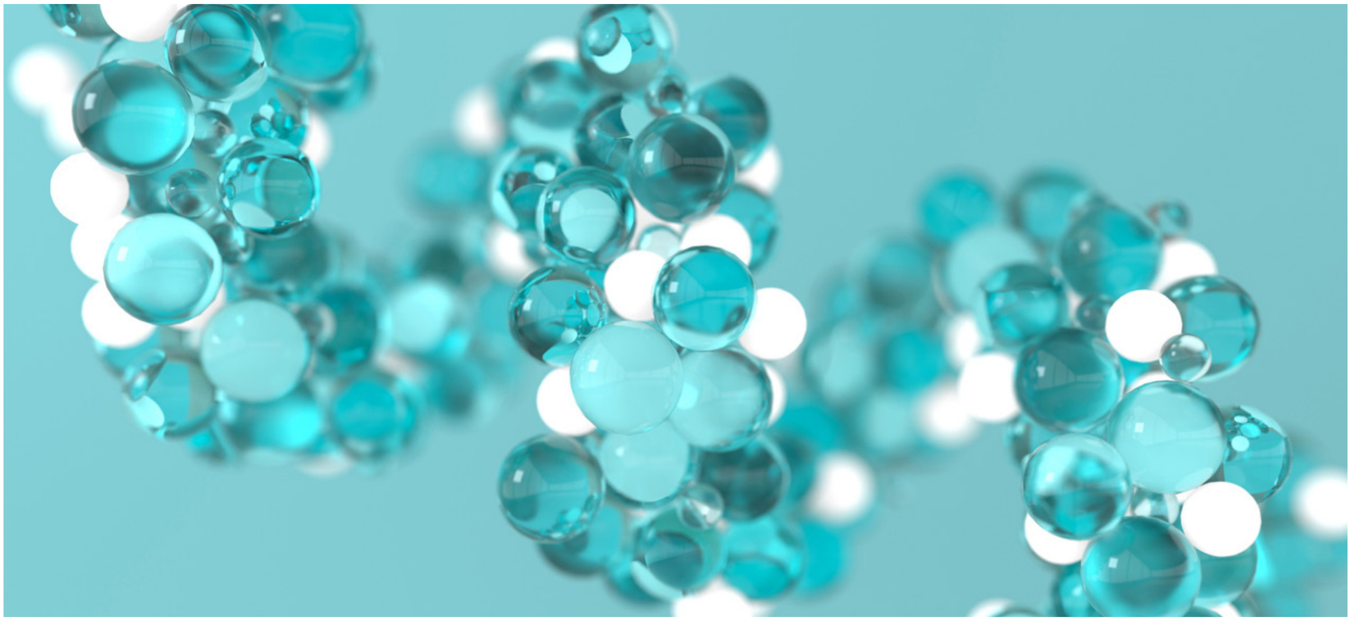
In comparing the reports, Germany's situation appears to be ideal from various points of view, and it seems entirely suitable to other countries as well. Germany is a leader in the production of pure science; according to the Science Barometer results, German people share a wide perception of the importance of science. There is ample freedom of research, i.e. research projects are mostly decided by the researchers themselves (even though in some cases their freedom is limited by a politicization of science, e.g. basic research in genetics ended up having to rely more and more on an international funding network). Actual funding dynamics need to be examined case by case as they differ from Land to Land and, even if the private sector does not provide the significant support that Aspen Institute Germany hopes for, there is no shortage of public subsidies. The pandemic crisis had a positive effect in boosting funding for pure research, and this is much less subordinate to applied research than in other countries. According to the report, in order to promote trust in the scientific enterprise, the ingredients of the German "recipe" are, as mentioned above, expertise, integrity and benevolence.

Even in cases of good practice with regard to basic science such as we can observe in Germany, we should keep in mind that trust in industry-funded research tends to get weaker, and that private funding is often mistrusted due to the possibility of conflicts of interest. This requires a greater future effort on the part of the companies involved. Transparency and active communication concerning investments in pure science, whenever they do exist, are regarded as the main antidotes to public opinion's mistrust—common practically everywhere in the world—of the private sector's (entirely legitimate) interests. This is an old problem connected with a broader theme, dear to the Aspen Institute since the 1950s, and which resurfaces in the reports: that of the Public Understanding of Science.

Aspen Institute Italia too lists the merits of the German ecosystem and, as a positive example of a strong link between public research centers and business, it mentions the fact that private industry funds up to 50% of the Fraunhofer and Max Planck Institutes. Achieving such a goal, however, is not easy in countries such as Italy, where the industrial fabric consists mainly of small and medium-sized companies with relatively small budgets and a low propensity for the risk inherent in long-term investments.

Bureaucratic hurdles at the outset, the limited number of financial tools available, and hard-to-find non-public sources of funding are among the other reasons why companies tend not to invest in pure research. In fact, Italian companies may well be, in principle, willing to invest; but in order to survive and because of their size they are forced to seek a relatively rapid return on investment. Several proposals have attempted to overcome this predicament, facilitate access to more venture capital in order to make alternative forms of financing effective, promote and strengthen the role of banking foundations operating in the area, improve the administrative efficiency of public funding.

Moreover, the current Italian situation suffers seriously under an excessive burden of bureaucratic safeguards. Both tax exemptions for research investments and tax simplification are very sensitive issues. Some tools already exist, such as the "patent box" (a tax bonus on income generated by some intangible assets), which still needs to be improved, given its limited effectiveness to date.



According to the report, the "Tremonti law" of 2003 on tax breaks for reinvestment of profits, remains one of the best fiscal incentives. In addition to this and as a contribution to bureaucratic simplification, Aspen Institute Italia suggests a 1% levy on tax revenue to fund scientific research directly, which is twice as much as other levies for non-profit social activities. Were all these elements well organized and deployed, they would facilitate the flow of resources to research and development.

Countries where more work is needed come up with a number of stimulating proposals. It may seem counterintuitive or even paradoxical, but it actually makes sense that precisely in the most critical situations there emerge evidence, gaps to be identified and bridged, unusual ideas, possible ways forward. An extreme case is the current situation of Mexico: The Aspen Institute Mexico panelists are greatly concerned by the current crisis of research itself. This is the result not only of economic constraints, but now also of political direction in the current management of Conacyt, the national council for science and technology. The politicization of scientific research causes damage in other countries as well. In such a fraught situation, any initiative is welcome both in science communication, aiming at the promotion by any means of scientific literacy among the population; and in the public-private collaboration area, aimed at restoring initiatives interrupted under the present government, and reopening a dialogue with private partners.

The Czech Republic highlights the importance of improving access to secondary and tertiary education. This is not only on grounds of fairness, but also for a general improvement of the quality of life, as well as to cultivate relations with other countries in the European Union and world-wide. The country would by those means attract more international research projects which would tend to reward the nation's top performers, i.e. the teams of scientists in areas that have undergone a greater development in recent decades (such as particle physics, biochemistry, artificial intelligence) and, on the application/industrial side, automotive (Skoda is the largest private investor in R&D).

Aspen Institute Initiative for Colombia identifies three key factors on which to focus in order to bridge the gap with other countries: education, communication and funding. In particular, the report insists on how profitable it can be to stimulate science education in primary schools and to encourage the curiosity of children from a very early stage. The balance between public and private contributions is also crucial, both for funding and for the creation of a truly integrated system, based on clear guidelines and founded on the principle that the system cannot focus exclusively on narrowly defined applied research. There must also be exchanges on an equal footing with other countries. To achieve this goal, the only option is to be self-propelled in the creation of knowledge, thus avoiding the risk of being patronized and (above all) becoming competent and respected autonomous agents in the eyes of the international community.

Ukraine's report was drawn up shortly before the Russian invasion. It clearly exposes the need for a radical reform of education and research. Some early attempts were hindered, according to the report, by a conceptual problem: decision makers appeared not to understand the importance of these issues in relation to economic development. As to funding, the current situation is still very basic: there is no private funding at all for pure science, and public subsidies are still very low compared to needs. This is even after progress, especially since 2015, the year of Ukraine's association with the EU research and innovation funding programme "Horizon 2020." (This is the reason why the European model is viewed favorably by various reports as a useful lever to improve a country's position.)

Aspen Institute Italia's initial proposal also considers the strengths and weaknesses of the European system. Again, it does emphasize the merits of the German model:

> The direct financing model is especially developed in Germany and implemented through a stable research and development system, which is divided into the various phases of planning, financing, monitoring and control; application to individual

> projects is mainly entrusted to major research centers and universities. This model is often adopted in other European countries and appears well suited to encouraging the development of public-private partnerships.

But it also warns against fragmentation and a form of competition that may run against investments in pure research:

> The funds earmarked by individual [European Union] Member States for research and development projects have long been used for independent, non-homogeneous undertakings.
>
> Over time, each Member has outlined its own model for intervening in support of research based on its particular industrial policy requirements and conditioned by respective budgetary constraints/limitations.
>
> The sector is one that continues to generate strong competition among Members eager to attract researchers, research centers, facilities and funding.

And it concludes that:

> The effectiveness of the overall European system for funding research and development is undeniable, given the excellent results produced in a range of significant sectors.
>
> Nevertheless, it would appear essential in the current phase to outline two different and separate recommendations. On the one hand, increase and improve inter-country collaboration and coordination in order to avoid dangerous duplications and harmful competition and, on the other, simplify procedures for granting and disbursing benefits.
>
> Certainly, there should be a direct link between the various benefits assignable to a research project. Where, for example, an investment can take advantage of tax benefits based on verification by a competent authority, additional public financing could be granted automatically without further bureaucratic process.
>
> Similar non-repetitive procedures could be implemented in the case of monitoring both how funds are used and research results.

India looks to the U.S. model where universities compete for resources, be these National Institutes of Health (NIH) or National Science Foundation (NSF) or even Small Business Innovation Research (SBIR) grants, and the result of this competition is that partnerships with industry occur at the same time as support from government sources is also sought. In India, however, academic institutions do not compete for resources as would be desirable. The report suggests transferring research funding progressively from national laboratories to the higher education system. This would not be a popular move with the labs but, according to the panelists, it would improve the research system within a few years. Public and private universities and advanced studies institutes should compete for these grants fairly and on a peer-reviewed basis.

As Aspen Institute Italia points out, basic science should be understood as a public good on which to focus a constructive and non-polemical political debate. This would help channel investment into research and ensure sufficient resources for dealing with the problems humanity has to face and will be facing in the near future.

Communication and public understanding

It is not the first time in history that a lack of "Public Understanding of Science" is deplored. Diderot and d'Alembert's *Encyclopédie* and the Scots' *Encyclopædia Britannica* were written for woefully unenlightened gentlemen and rulers, but a century later a large fraction of the population could subscribe to encyclopedias for a few pennies a month or peruse them in public libraries. Petits-bourgeois could become self-taught amateur scientists—with hilarious consequences in Gustave Flaubert's novel *Bouvard et Pécuchet*. In most Western countries attending school became mandatory, even though since World War II the mandatory education available has been increasingly found lacking. And in 1985 the Bodmer report commissioned by the Royal Society was alarmed; in Britain there was a considerable public interest in science and yet, its authors warned, the relationship between scientists and public opinion was fraying:

> A basic thesis of this report is that better public understanding of science can be a major element in promoting national prosperity, in raising the quality of public and private decision-making, and in enriching the life of the individual.

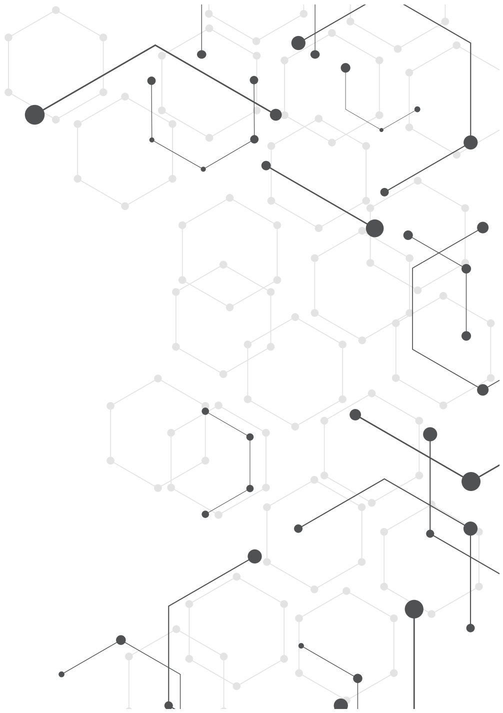
Their conclusion was peremptory (bold in the original):

> **our most direct and urgent message must be to the scientists themselves: Learn to communicate with the public, be willing to do so and consider it your duty to do so.**

The Aspen reports unanimously agree with this statement and link it to inclusivity, educational system reforms, improving elite and mass knowledge, funding requests, etc.

In recent decades the public understanding of science movement has fostered several initiatives: research institutions' growing effort to make their results visible—the U.S. government's order requiring immediate public access to U.S.-funded research papers by 2025, dedicated press departments and public relations services, more public involvement programs funded by national and international institutions, a proliferation of science journalism courses and masters, explicit statements that outreach is both the researchers' and their institutions' "third mission", new and often high-tech museums, some of which bring together arts and sciences.

All this must be taken up and strongly consolidated. Innovative tools for public understanding of science have been tested by the social sciences in recent decades, in a new and highly



multidisciplinary field of research. Awareness of all this reverberates in the variety of themes in the Aspen reports. They record the change of climate, identify the new global challenges that are arising and the new opportunities that are to be grasped, even as—unfortunately—pandemics and other global crises are expected to recur.

To summarize the complexity of the issues that climate scientists have dealt with since the late 1980s, even though never before so urgently or globally, a discerning extract from the *Routledge Handbook of Public Communication of Science and Technology* (edited by Massimiano Bucchi and Brian Trench, 2021) might be helpful:

> Researchers from many disciplines, but particularly the health sciences and statistics, were suddenly and in massive numbers required to explain complex, uncertain, and highly contingent realities to publics with insatiable appetites for crisis news. Thousand of scientists went from near-invisibility to high visibility in short order, with no time to prepare communication strategies. More or less spontaneously, they had to find a balance between providing assurance and guidance and acknowledging the limits of collective scientific knowledge about the possible trajectories of an unknown virus. After decades in which scientists increasingly worried that they were distrusted, public respect, confidence, even love, were heaped on those at the frontline on the war against COVID-19.
>
> The COVID-19 crisis has raised many familiar questions about science's standing in society but in unfamiliar forms. Science communication research has been thrown a new and unexpected set of challenges, for example, around long-standing questions about communicating science with policy-makers, and the claims of the latter to be 'following the science.' New questions have been raised too: When all of society was talking about the same science-related topic, what effect did it have in these conversations that they took place for long periods in conditions of weakened social interaction? What will be the long-term impact of such unprecedented public exposure of scientific experts on the public image and perception of science and scientists?

Although the reports do not address them directly, the same questions arise about "bad science," and whether honest science can self-correct in a timely and public manner.

As the pandemic has shown, misconduct and fraud in published results can be literally deadly. Although national offices for research integrity do exist in the U.S. and in several European countries, they are sorely understaffed and underfunded, and all they can do is recover public grants and ban dishonest researchers from participating in calls for proposals.

France is now one of the few countries with a legally binding definition of scientific integrity, mandatory reporting of misconduct, and mandatory sanctions.[2]

In Italy, universities and research institutes have adopted a code of conduct but they tend to ignore it, even when a scandal hits the press. A noteworthy exception to the rule is the National Council for Research (CNR). Its Research Ethics and Integrity Committee publishes updated guidelines on ethics and integrity and does investigate misconduct cases, probably because its reporting procedure for alleged misconduct "in activities carried out by CNR staff or carried out with CNR funds, or publications with authors affiliated to the CNR" is clear, simple, and protects both the whistle-blowers and the anonymity of the personnel involved.

Any attempt to boost trust in science, whether pure or applied, should take into account a possible backlash due to the popularity online, and even in journals such as *Science* or *Nature*, of a grass-root movement of “science sleuths” and whistle-blowers—the Davids against the Goliath of the establishment. They seldom manage to “clean the scientific record,” a fact anti-science and bad faith actors generalize as “all science is corrupt,” “climate change is a hoax,” “vaccines kill,” etc.

The Aspen appeal urges our societies to learn the lessons of the pandemic and turn them into a historic opportunity. Elite communicators—scientists, decision makers, journalists—were caught wrong-footed, totally unprepared for the “modern world” (as the Bodmer report put it in a slower age) of cell phones and social media, amplifying the 24/7 flow of news and fake news, and of fake therapies recommended by real scientists. This is a context the first proponents of the public understanding of science had not foreseen, but one that makes their appeal all the more topical and urgent.

The Aspen Institute U.S. suggests an intriguing idea for science communication, namely, in order to reach and engage more stakeholders and non-obvious audiences. Why not try to share the passion for science through all forms of art, using an inspirational approach, and involve media that already reach and influence their users: "television, radio, movies, new apps, and the social web. Experts in public understanding of science have already been recommending this “wide-field approach” for a couple of decades, and indeed well-known scientists have cooperated with screenwriters, filmmakers, and Hollywood stars. However, this is not enough. To buttress a trust in science, and more specifically to increase appreciation of basic science, it is important to have role models—and to exploit the so-called “wow factors” that will appeal to non-scientists.

There are, of course, caveats. Fictional scientists tend to be romantic stereotypes, innocent bumbling nerds, ignored doomsayers, or fiendish villains. As to “wow factors,” successful

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[2] See item 16, law n. 2020-1694 and application decree n. 2021-1536

advocacy for the largest-ever collider needed in Europe to find the Higgs boson—the ultimate "God particle" for which "tantalizing" clues were being collected at Fermilab in Chicago—backfired when CERN published its plans for an even bigger machine. In the new narrative, there is no well-defined chase and no race to win.

In Spain, the biennial FECyT survey on the social perception of science and technology reports positive data: nearly half the population appears to regard a scientific career appealing for young people. But there are negative data as well: two-thirds consider a career in science inadequately remunerated or valued. These opinions are very likely affected by a romantic idea of the lone heroic researcher dedicating their entire life to science (think e.g. of Nobel laureate for medicine Ramón y Cajal). A different perception may result from a dialogue with civil society organized by the Centre for Genomic Regulation in Barcelona in the fall of 2021, an experience that elicited the following comment:

> The pandemic crisis has made basic research more relevant in the eyes of citizens, as a base on which to build medium and long-term discoveries. Basic and applied research, in their fundamental and oriented versions, are hard for both practitioners and citizens to tell apart. For the latter, basic research is envisaged as previous research. Also, basic research is conceived to be guided by its importance to society.
>
> Scientists are strongly trusted in this and other respects. As the recent 516 Special Eurobarometer shows, they are considered by Spanish respondents rather more intelligent, reliable, collaborative, and honest than the European average, but it is 20 points higher in considering that scientists know best what is good for people. However, this must be taken with a pinch of salt, since it may be chalked up to a poorer knowledge of the issues involved: citizen's engagement with science and technology (watching documentaries, reading related magazines or books, visiting museums etc.) is consistently lower than in other countries.

Climate change is often mentioned as having similar traits, for instance in Japan's report:

> The issue of climate change, which is now a major problem even in the international political arena, is a typical example of how people around the world have shared a sense of crisis and moved international politics through the promotion of international cooperation and communication with politics and society in pure science's simple activities since the 1960s (accumulation of observation data, modeling, etc., across various atmospheric and oceanic fields). It is important to keep telling this narrative to people. It is a clear example of the importance of pure science and evidence-based policy making.

Before concluding, it is worth adding some further considerations about the U.S. proposal to involve more of show business' actors and authors. Movie scripts often involve the Frankenstein effect: they are chastening tales of *hubris* as the results of the scientist's quest endanger society—think of Steven Spielberg's Jurassic Park or David Cronenberg's *The Fly* and *Rabid*.

Similarly, movies dealing with climate change, even when scientifically accurate, tend to look like catastrophe movies, and are perceived as exaggerated and untrustworthy. There was no lack of films that accurately described all the effects—epidemic, political, economic, and social—of the pandemic and yet, according to the *Routledge Handbook:*

> political leaders and their science advisers seemed to be caught off-guard and struggled to align epidemiology, health care management, democratic rights and public communication.

The difficulty scientists encounter to be listened to by politicians and society, whether they have a positive message or not, and to report scientific and factual evidence in a context in which entertainment, politics, and society mix uncritically on the same plane, is also ripe for fiction. The film *Don't Look Up* is an example of an effective, wise, and humorous unmasking of today's media dynamics.

As for humor, entertainment, and a passion for science, Japan's report reminds us of the Ig Nobel Prize, awarded since 1991 at Harvard to "improbable research"—of which so far quite a large amount has been performed in Japan. The prize:

> possesses and appreciates a primitive but essential spirit of pure science. It serves the function of providing intellectual entertainment as well as the educational function of pure science. Pure science that cannot or should not be justified from the perspective of usefulness is what society seeks as top-level intellectual entertainment that satisfies the intellectual appetite, a fundamental human desire. [...] we must analyze the reasons for strong results in the Ig Nobel Prize, and the increase in the number of Nobel Prize award recipients in the 21st century (not that all of them are related to pure science) and draw lessons from them.

For an ecosystem of pure research (key points)

The many indications of these reports can be summarized in an appeal to public opinion's elites, a "Manifesto for pure research" (or "for an ecosystem of pure research") in a few key points:

Definition. Provide a convincing definition of pure science, as distinct from applied science, to overcome the plurality of views and our culture's frequent misapprehensions. Extend the German definition and, as suggested by the French and Indian reports, outline an ecosystem of the different types of research in a continuum that shows the degree of pure research whenever it interacts with the applied, so as to supply a background for the subsequent key points.

Values. Deploy the vast array of fundamental values that emerge from an accurate assessment of what science is and how it works.

Education. Use again the German definition of pure science as blue-sky research, adding "curiosity" to the crucial ingredients suggested by the Italian report: creativity and critical thinking (the main traits of which should be made explicit, using updated knowledge about the brain and cognitive abilities). Include social sciences as the Aspen Institute New Zealand proposes (e.g. big data analytics), and indeed all the Arts and Humanities, starting with the historical studies (e.g. the history of the sciences), the philosophy of science, ethics, etc. Underline that education in the fundamental elements of the scientific method and thought should start in primary school, with playful and creative approaches that will trigger an interest in naturally active and curious minds. Open a discussion on the need for a better formation, career progression, and status for teachers.

Culture. Show that investing in pure science is consistent with the idea of a new humanist culture that will involve a reassessment of the links between the so-called "two cultures." This is to be based on critical thinking as the unifying feature of all knowledge, and it will focus on aspects of knowledge acquisition that, while they may not be immediately and directly relevant to individuals' positions in the job market, will contribute to their own and, crucially, the whole society's overall wellbeing and continuing development.

Multidisciplinary dimensions of knowledge. Encourage and disseminate the idea that the sciences have no strict disciplinary boundaries, and that problems exist before individual disciplines are called to solve them (great examples from the cooperation of physics and medical/biomedical research, e.g. in spectroscopy or in the physics of soft matter, etc.). The key is knowing how to define problems accurately and ask pertinent questions. Open a discussion on how to mitigate the well-known career difficulties of many multidisciplinary researchers.

Economy. Create an index to identify accurately the trend of public and private investments, set precise goals for them, and exert constant pressure until they are reached. Use this index to propose a minimum amount per year (perhaps more effective than a percentage of GDP) below which investments are to be regarded as insufficient. We can also imagine an indicator that adds to GDP the increase of intelligence in a country—e.g., as measured by the Flynn effect, which has significantly decreased in recent years after decades of increase—on the model of definitions similar to GDH (Gross Domestic Happiness).

Priorities. Prioritize research in pure science over other investments and raise the issue as a real emergency for our civilization. Investing too little in pure science and its related educational values (based on critical thinking, see above, "Culture") would condemn us to an unprecedented social and economic decline, and also to an inevitable loss of competitiveness.

Funding. In addition to the traditional funding procedures, propose simpler ways to support research that directly involve citizens—such as tax discounts, a 1% levy on tax revenue, etc. Eliminate bureaucratic impediments (see Italy and Spain) and promote the adoption of German and U.S. best practices.

Business. Actively engage the business sector. Make top managers and CEOs aware of the fact that researchers' mindset and a functioning academic system are valuable sources of economic (and other) success over the long(er) term.

Managerial culture tends to be split: it regards financial, mathematical, and scientific abilities as arid and soulless, and cultivates the (mistaken) ideal of a humanism that is supposed to "replenish one's soul" in one's spare time. This old dichotomy must be overcome by a new culture (see above, "Culture"), which is pleasurable and spiritually rich in each of its components, since each of them equally involves curiosity, creativity, and a critical spirit.

Citizen scientists. Involve citizens in political choices that presuppose a knowledge of scientific data and facts. Scientific knowledge is important to elaborate and evaluate possible options, but it cannot and should not directly dictate political choices. Educate citizens on how science, politics, and society do/should interact, increase opportunities for their participation, and ensure that they both are and feel involved.

Ethical implications. Open up the discussion on the ethical implications of research, even or indeed especially in the thorniest cases (e.g. nuclear power, genetics, biotechnology). Promote ethical and meta-ethical research. Emphasize that it is everyone's responsibility—including scientists'—to contribute to contribute to set the ethical standards of knowledge and to abide by them, contrasting its immoral uses. As the U.S. report notes, ethical questions also have an important role in stimulating curiosity, in increasing the interest in and excitement for science, and in motivating careers in scientific research.

International cooperation commitments. Facilitate all research-related international exchange and cooperation, e.g. with more straightforward and flexible visa policies for researchers, etc., and offer researchers in every country attractive base salaries in order further to encourage exchanges. Scientific careers should be dictated as much as possible by genuine vocation, not by how profitable they may be in certain countries.

Communication. Set up national and international plans to promote a strong further development of the public understanding of science. e.g., advocate for science sections and reporters in all leading mainstream media, invite screenwriters and film makers to workshops about the methods and questions of science and how these may relate to their own profession (to overcome the prejudice that "science can't mop up its own mess," contrast the negative image of science as the Golem and the commitment to a "Frankenstein effect" ideological approach to science). Support public and private grants for fast-response teams in order to contrast ignorance, misinformation, and fake science news in social media, as well as for the experimental scientists who test how to "inoculate" the targeted audience against these.

Basic Research:
Definitions, Measurement, and Policies

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Matteo Lucchese *is the author of Chapters 4 and 5. The author also acknowledges Matteo Lucchese's contribution to the definition of this report and to data collection activities.*

1. R&D Measurement and the Frascati Manual

When entering into the realm of statistical measurement, an apparently globally accepted concept like “research and development” (R&D) needs to be carefully scrutinized in order to prevent any misinterpretation or potential confusion with similar but substantially distinct phenomena.

Indeed, several controversial issues have been discussed around the R&D drivers and effects and, even more, about its inner nature that includes different but partially overlapping activities—at least according to the definition provided by the OECD’s Frascati Manual (OECD, 2015): basic research, applied research, and experimental development.

What the Frascati Manual really says

Early in the 1960s, the OECD launched a project aimed at defining a few straightforward indicators to be used to measure scientific and technological research activity in a consistent fashion. This was to encompass not only research by OECD member countries but also by planned economies and developing countries. By chance, an agreement was found during a regular OECD meeting held in 1963 in a small town near Rome: Frascati. Thus, the final document of the project on research measurement was named the Frascati Manual (FM).[1]

Since then, the FM has become a standard not just for statistical measurements but for defining research and related activities within a broad range of purposes: business, administration, analysis, policy, and so on.[2] Indeed, the key purpose of the FM is often that of providing a sound basis for R&D statistics that rely on largely agreed definitions, methodologies, and classifications.

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[1] In Annex 1 of OECD (2015) a description of the development of the FM through its seven editions—from 1963 to 2015—can be found.

[2] Benoît Godin, who passed away a few months ago, has been, over the last thirty years, the main contributor to the public discussion on the origin and use of the most diffuse concepts in the realm of science and technology (S&T). In Godin (2008) he describes in detail the conceptual and institutional bases of the FM.

Box 1.1. Key R&D definitions from the Frascati Manual.

<table>
<tr><td colspan="3">Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge—including knowledge of humankind, culture and society—and to devise new applications of available knowledge.</td></tr>
<tr><td>Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.</td><td>Applied research is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily toward a specific, practical aim or objective.</td><td>Experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.</td></tr>
</table>

Above, the key R&D definitions, as given in the most recent edition of the FM, reflect the current understanding about what research means, at a global level. Every single statement in these definitions comes out of a long process of improvement based on an intense confrontation among different views and interests. Three points can help to frame the issue:

- Since the first FM, the generic concept of "research" has been replaced in the public discourse by a new concept, that of **"research and development"** (R&D). R&D is just what is described in the FM: a peculiar activity performed by institutions[3]—i.e., potential respondents to statistical surveys—whose volume could be measured in terms both of expenditure and number of personnel involved in it.
- As a basis for an accounting exercise, the FM standard is based on the distinctions between a) **R&D activities vs. non-R&D (although innovative) activities**; b) research in a broad sense vs. **"experimental development"**; c) **basic vs. applied research**.
- **FM guidelines are, by definition, not prescriptive.** In a way, it is a global standard essentially based on voluntary adoption[4] and, more harmful to data consistency across countries/time, on the interpretation that countries give of such guidelines when applied in a specific institutional, cultural, or economic environment.

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[3] Since the pioneering surveys carried out in the 1950s in the USA by the Department of Defense and the National Science Foundations, large public and private institutions have been the main targets of R&D surveys. Over the last twenty years, mostly in the context of the European Statistical System, more attention has been devoted to the R&D activities undertaken by small businesses and non-profit institutions (although both groups are contributing to the R&D effort for a few percentage points). In OECD (2015), the proposal of not excluding, by definition, individuals and households from the population of potential R&D performers has been, in principle, accepted but stressing the recommendation to exclude them from direct surveying: "10.41 Only the institutions that meet the conditions of R&D performance explained in this manual should be identified as possible statistical units for the R&D measurement. In accordance with the institutional approach used for R&D measurement, individuals and households should be excluded from the frame population.". OECD (2015), p295.

[4] As for every OECD official document, the whole process of designing, updating, and implementing of the FM guidelines is based on "consensus", not having, the OECD—unlike supra-national institutions, like the UN or the EU—the power of imposing any decision to member countries.

How R&D is defined

Some crucial decisions, although controversial, were taken already when releasing the first FM edition, including that of "… defining science as 'systematic" research and demarcating research from other activities so these other activities could be excluded: research/related scientific activities, development/production, research/teaching" (Godin, 2008). As pointed out by Godin (2001), This was part of the process of emphasizing the economic potential of "institutionalized" research compared to any other scientific activity undertaken outside universities, large research institutions, or businesses. On the other hand, the boundary between research and other non-research innovative activities has been kept blurred for decades in order to allow for the adaptation of the FM guidelines to national specificities.

Only in the 2015 edition of the FM has the concept of R&D been spelled out by identifying **five criteria** to be jointly met in order to identify a R&D activity (OECD 2015, ch.2):

1. To be aimed at new findings (novelty).
2. To be based on original, not obvious, concepts and hypotheses (creativity).
3. To be uncertain about the final outcome (uncertainty).
4. To be planned and budgeted (systematicity).
5. To lead to results that could be possibly reproduced (transferability).

The availability of a detailed definition has to be seen as a key improvement for the FM. Firstly, the FM stakeholders have agreed for the first time on self-reducing their freedom to develop country or sector-specific interpretations of what is R&D. Secondly, the new approach accommodates the needs of emerging R&D performers (in the field of Social Sciences and Humanities, for instance, or in connection to innovative activities specific of the digital economy) while preserving a high level of consistency with the traditional FM approach[5]. Thirdly, the R&D definition itself has become more easily applicable in other institutional contexts and, indeed, it is now extensively used to identify those activities targeted by policies aimed at funding R&D or providing R&D tax incentives[6].

The growing role of experimental development

Research results have often to be tested before being acknowledged as sound and valuable findings. This is essentially the role of experimental development in the R&D process. This role has indeed evolved over time because of a few factors influencing the R&D activity and its measurement. The most relevant has been a shift of the policy focus from R&D to

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[5] A key issue was that of including in the definition of R&D the "occasional R&D activities" (opposed to "continuous" ones, i.e. multi-annual R&D projects) very common among small businesses.

[6] To the extent the R&D definition has to be used for purposes other than the production of R&D statistics, it is highly recommended to use the examples given in the FM 2015 as a guidance to classify R&D borderline activities.

[7] The relevance of experimental development in the quantification of R&D at the macro level and its relationships with research on one side and innovation on the other side are described in detail in Godin & Lane (2011) and Godin & Lane (2012).

"innovation"[7], i.e., the improvement of production processes and the introduction of new products on the market[8]. Conceptually, experimental development—not to be confused with "product development"—is indeed, in the business context, the essential link between research and innovation[9]. This implies the need for stressing the use of the five criteria, chiefly of uncertainty, to identify and to report about experimental development activities as part of R&D. Nonetheless, in this difficult context, the improved coverage of business R&D surveys led to an increase of the percentage of small and medium size firms included in R&D statistical samples. Not surprisingly, most of these small firms were reporting experimental development as their only R&D activity (often by exploiting R&D results purchased from other companies, universities, or research laboratories).

To make the issue even more critical, it can be mentioned that—according to the guidelines given by the International Financial Reporting Standards[10] to allow for the capitalization of R&D investments in companies' balance sheets—the only component of R&D to be considered an investment in intangible assets is experimental development as it allows to foresee, with less uncertainty than research, how long the reporting firm could benefit of it[11].

The distinction between basic research and applied research is probably the most controversial issue in the area of R&D measurement. It will be discussed in the next chapter.

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[8] During the 1980s several OECD countries started piloting business "innovation surveys" aimed at collecting data on the actual use of R&D results by businesses, as well as on the adoption of external technologies by firms without previously investing in R&D. These activities were eventually codified in a new OECD statistical manual, the so-called Oslo Manual, first published in 1992.

[9] Barge-Gil & López (2015) confirm the analytical evidence already shown by previous studies that experimental development has a stronger impact on innovation than research.

[10] International Financial Reporting Standards, commonly called IFRS, are accounting standards issued by the IFRS Foundation and the International Accounting Standards Board (IASB). They constitute a standardized way of describing the company's financial performance and position so that company financial statements are understandable and comparable across international boundaries. IFRS have replaced many different national accounting standards around the world but have not replaced the separate accounting standards in the United States where U.S. GAAP is applied. (from Wikipedia).

[11] See the LSE Business Review article on "Capitalising or expensing: R&D accounting affects the amount that firms invest" about R&D capitalisation by British firms (https://blogs.lse.ac.uk/businessreview/2019/03/14/capitalising-or-expensing-rd-accounting-affects-the-amount-that-firms-invest/). A different approach is used for the capitalization of R&D at the macro level for the purposes of National Accounting (Ker & Galindo, 2017).

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2. The “Basic” Components of Research

The origin of the concept

Several studies have been looking for the origin of the “basic research” concept.[12] Beyond the ancient philosophers who introduced the distinction between *theoria* and practice, it seems that the idea that scientists should pursue some “pure research” emerged as a legacy of the Renaissance and is the *naissance* of the modern science.

Actually, basic research is seen by many scholars mostly as a science policy category emerged in connection to the demand for a public intervention in supporting science and technology and the need to improve the knowledge on size and features of the research phenomenon. According to Godin (2008), two British scientists—J. D. Bernal and J. S. Huxley—should be credited to have shaped the concept in their pioneering efforts to measure the research activity in a framework that replicated the scheme, at that time under development, of the National Accounts. The former identified a key issue of research accounting in reporting separately applied research, on the one hand, and “**pure or fundamental research**” on the other hand. The latter, who eventually became UNESCO Director General, proposed a similar reporting approach based on four research typologies: background, basic, ad hoc and development. Excluding development (now, *experimental development*) and ad hoc research (currently defined *applied research*), the first two typologies are framing what is meant by basic research: “**background research** is research “with no practical objective consciously in view,” while **basic research** is quite fundamental, but with some distant practical objective in view. As a conclusion: “Those two categories make up what is usually called pure science”.[13]

A new powerful wave of interest in science policy followed the Second World War and its successful alliance between science and the military. The Cold War brought the confrontation from the military field to the economic and scientific ones giving scientists an unprecedented role in accelerating the scientific research in order to assure at their countries security and economic progress (Calvert, 2006; Schauz, 2014). Conceptual schemes widely accepted by researchers and policymakers—like that of a “black box” where research outlays ware being translated into technological applications to products and processes or that of the so-called “linear model” describing basic research, applied research, development and innovation as an ordered chain of events—highlighted the need to foster funding and measurement of R&D.

Basic research in the Frascati Manual

The first FM edition (1963) already gave a definition of basic similar to the current one, although referring to **fundamental research.** In 1970 a further breakdown—still adopted by the current

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[12] A detailed review can be found in Schauz (2014).

[13] Godin (2008) citation of a 1934 article by J. S. Huxley.

FM—of basic research between "**pure**" basic research ("carried out for the advancement of knowledge, without seeking economic or social benefits or making an active effort to apply the results to practical problems or to transfer the results to sectors responsible for their application") and "**oriented**" basic research ("carried out with the expectation that it will produce a broad base of knowledge likely to form the basis of the solution to recognized or expected current or future problems or possibilities") was introduced.

Several times over the last fifty years, proposals have been made to change, or drop, the basic research definition in the FM. Often, the issue of a difficult identification of it was raised, as well as recurring skepticism about its relevance for analytical and policy purposes. Proposals included: to replace the basic/applied wording with **autonomous/exogenous** (1973) and introducing the concept of **strategic research** (1992). More in general, it has been discussed whether research shouldn't be rather classified according to its expected impact either on **radical** or **incremental** innovations[14] and even the definition of **blue-skies** research was introduced in the OECD terminology to better define forward-looking R&D efforts. In 2001, international OECD experts gathered in Oslo to join a workshop on "Basic Research: Policy Relevant Definitions and Measurement". The aim was that of discussing whether the basic research concepts should be kept as they were in the FM, changed or dropped[15]. Again, the OECD community stuck to the FM approach mostly stressing the need of continuity in statistical data collection. On the other hand, it has to be mentioned that several questions on the actual meaning of basic research have remained unaddressed.

The point of view by R&D performers is not irrelevant in this perspective. The academic community still considers basic research a key task of universities (Bentley *et al.,* 2015) and, in a different context, some analysts argue about the relevance of basic research in businesses also observing an on-going process of "scientification" of business R&D[16]. This view is, on the other hand, rejected by those rather highlighting a decline in "corporate science"[17] and in business basic research in general[18].

Main concerns about the basic research concept

The role of basic research as a component of R&D, on the one side, and as a driver of economic growth, on the other side, is still controversial. Some issues have still to be addressed both in the process of statistical data collecting and, even more, when using basic research data. A few selected remarks are described below.

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[14] Beck *et al.* (2016).

[15] Calvert & Martin (2001) served as the background paper for this workshop.

[16] Campbell & Gutten (2005).

[17] Arora *et al.* (2018). See also Coad *et al.* (2020).

[18] Chesbrough (2003).

[19] Calvert & Martin (2001), Calvert (2006).

- Basic research is a **science policy** (not statistical, not analytical) concept[19]. Its success is based on its use as a border territory between scientists (asking for increasing funding while claiming also for more freedom about to use them) and policy-makers (who have to justify investments on largely un-finalized R&D). On the other hand, it could be argued that research projects and activities, to the extent they are dependent on external, public or private funding, cannot be totally unconstrained.

- Basic research, as a curiosity-driven activity, is identifiable as such only by the researchers, thus with a high degree of **subjectivity**[20]. In fact, pure basic research, as defined in the FM, is hard to measure and most researchers admit that, to some extent, every research project aims at producing "applicable" results (with a remarkable disciplinary heterogeneity, of course). Since the 1960s, some scholars are, indeed, arguing for dropping the distinction between basic and applied research[21].

- Basic research is an **undetermined term** as it can be seen from at least four different points of view[22]: epistemological (two approaches: a. linked to unpredictability/novelty; b. generalist/ theoretical/ reductionist); related to applicability (intentional/ distance from application); and normative (institutional/ open to disclosure/ pre-competitive).

- Basic research is, in the end, **irrelevant** for both analytical and policy uses. Relatively few studies, compared to the past[23], are focusing on its impact to technological change and economic growth[24] and funding trends are declining[25]. Additionally, basic research, as a topic in the public debate, is overwhelmed by more attractive topics like "digitization" or "innovation" (Figure 2.1).

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[19] Calvert & Martin (2001), Calvert (2006).

[20] Godin (2008).

[21] Reagan (1967), Pielke & Byerly (1998).

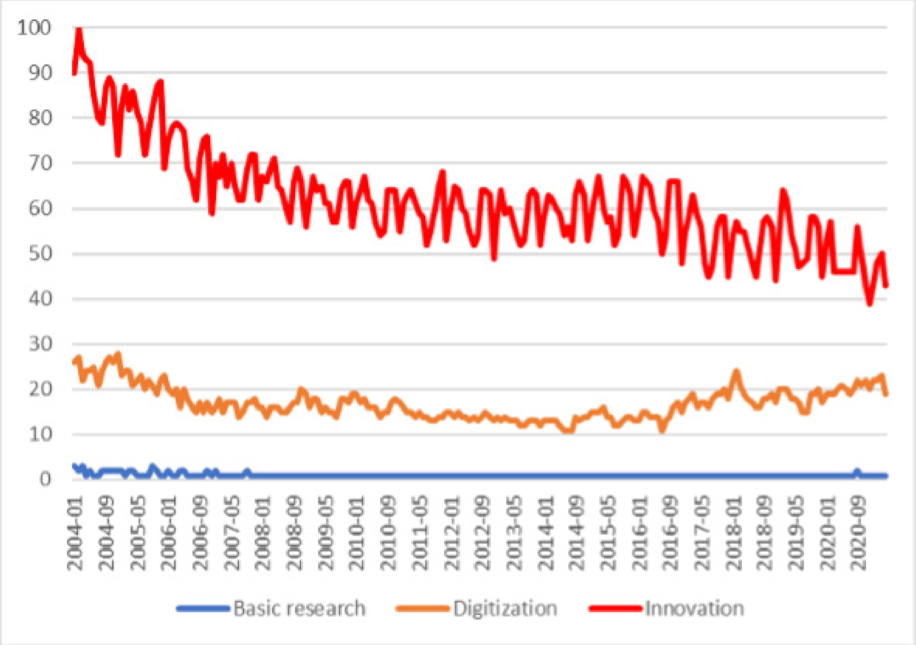
[22] Calvert & Martin (2001).

[23] Pavitt (1991).

[24] Salter & Martin (2001).

[25] The U.S. are a case in point: "The federal government is a major funder of basic research, and between 2000 and 2017, the share of basic research funded by the federal government declined from 58% to 42%. Federally funded applied research was an exception during this period, as both the level and share rose." https://ncses.nsf.gov/pubs/nsb20201/u-s-r-d-performance-and-funding#:~:text=The%20federal%20government%20is%20a%20major%20funder%20of%20basic%20research,the%20level%20and%20share%20rose.

Figure 2.1. Worldwide Google search trends (relative percentage) 2004-2020 of three selected topics: "basic research", "digitization" and "innovation".



Is this enough to neglect the relevance of basic research? Advocates of it claim that basic research is even more important now than in the past if looking at the new societal challenges to be addressed by humankind[26]. Possibly, the approach to basic research has to be changed[27], for instance moving to the right side of the Pasteur Quadrant (Figure 2.2) or to systematically framing basic R&D projects in missions aimed at dealing with globally relevant needs or emergencies.

Figure 2.2. Pasteur Quadrant as proposed by Stokes (2011).

		Considerations of Use?	
		Yes	No
Quest for Fundamental Understanding?	Yes	Pure Basic Research (Bohr)	Use-inspired Basic Research (Pasteur)
	No		Pure Applied Research (Edison)

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[26] Here is the issue as presented by the Harvard University SITN Project: https://sitn.hms.harvard.edu/flash/2019/not-so-basic-research-the-unrecognized-importance-of-fundamental-scientific-discoveries/

[27] Schot & Steinmueller (2018).

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3. R&D Statistics: The International Framework

Cooperation and competition in R&D statistics

Three main institutions (Figure 3.1) are regularly collecting R&D data at international level:

- Eurostat, the Directorate General of the European Commission responsible for collecting and disseminating official statistics on EU aggregated phenomena.
- The Directorate for Science, Technology and Innovation (DSTI) of the OECD that, in cooperation with the OECD Statistics Directorate, manages the OECD database on science and technology (S&T) indicators.
- The UNESCO Institute for Statistics in charge of training less developed countries in collecting and compiling R&D and innovation statistics and conducting an annual R&D survey among UN member countries (in parallel with a similar but multi-annual survey on innovation statistics).

All of them claim a full adherence to the principles and guidelines of the Frascati Manual even though the Manual is owned by the OECD only and its partner institutions have, in principle, no voting rights about when and how to revise it. Moreover, the three institutions feature different constituencies (only 23 EU countries are full members of the three organizations) and different objectives that affect their statistical activity, as well.

Eurostat, a Directorate of the European Commission, is serving the needs of an inter-governmental organization which is partly also a supra-national organization. Therefore, the official EU statistics have to match the level of quality of the best national official data in order to provide a high quality informative to support for the definition of EU-wide policies. In fact, the structure of the Eurostat R&D survey is governed by law[28] and the provision of a core set of data variables is mandatory for EU member countries. An interesting point is that an EU legislative act cannot be subdued to the decision of an extra-EU body like the OECD: as a consequence, the EU legislation acknowledges the authority of the Frascati Manual rather as a standard among others—including the Eurostat own guidelines—than as the only reference document to be followed in producing EU R&D statistics[29].

Within the OECD, the Directorate for S&T and Innovation is granted a peculiar role as analytical body, policy advising unit and, unlike most of the other OECD Directorates, producers of

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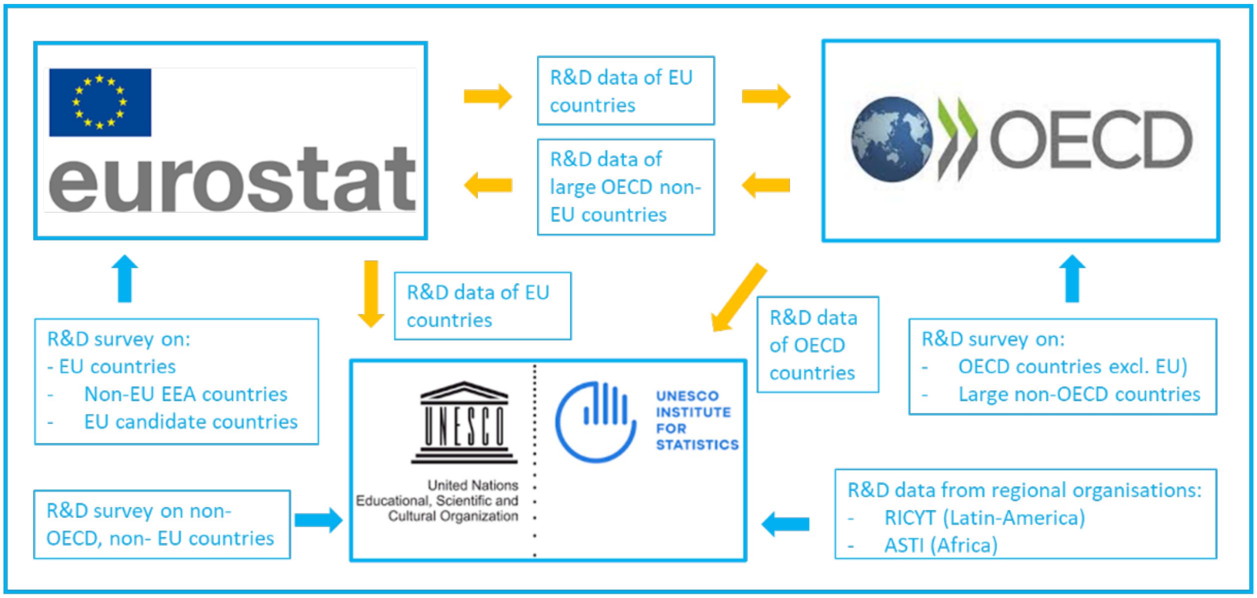
[28] Regulation (Eu) 2019/2152 of the European Parliament and of the Council of 27 November 2019 on European business statistics, repealing 10 legal acts in the field of business statistics. A regulation is a legal act of the European Union that becomes immediately enforceable as law in all member states simultaneously.

[29] According to the Regulation 2019/2152: *"International guidance, such as the Frascati Manual, which concerns R&D statistics, and […], and […], […], […] and other international and supranational organisations, are of relevance for European business statistics. Such guidance should, to the extent possible, be followed in the development, production and dissemination of Union statistics […], in order to ensure that the Union statistics are comparable with those compiled by the Union's main international partners.* ***However, Union standards, agreements and guidelines should be applied consistently when collecting data for European business statistics on the R&D inputs and innovation topics.".***

statistics. Its high reputation largely lies on the development and maintenance of the so-called *Frascati family* of statistical manuals[30]. Compared to Eurostat, OECD DSTI is focusing more on matching data from different sources in order to allow for their analytical use. An intensive cooperation between data producers and researchers is a key OECD asset. Another striking difference between the two organizations is about their geographical scope that allows the OECD to collect and compare data at global level, thus encouraging also non-member countries to contribute to its data collection effort in order to improve international cooperation and comparability on issues like the R&D performance.

The UNESCO Institute for Statistics (UIS) also plays a specific role in this context: that of bridging the gap in S&T statistics production between OECD or EU countries and less developed countries. Notably, UIS has published a technical paper aimed at helping countries starting to collect R&D data to design their own survey[31]. This is only part of a continuous effort in providing technical advice about the measurement of R&D and innovation to UN member countries asking for support. UIS as well is undertaking an annual R&D survey: its geographical scope is much broader than the OECD or EU surveys but, of course, the coverage in terms of variables is narrower. As to the methodological issue, UIS has been constantly asking the OECD to make some Frascati guidelines less strict in order to allow also countries in the process of catching up the quality level of R&D statistics in OECD countries to meet a "Frascati standard". Overall, the FM has taken into account these concerns, mostly in its last two editions, confirming its ambition to be seen as a global standard for R&D statistics.

Figure 3.1. R&D data collection at international level. Main actors and data flows.



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[30] Currently including, in addition to the Frascati Manual itself: the Oslo Manual on innovation statistics, The Patent Statistics Manual, the Manual for statistics on Human Resources in S&T, and the Manual on the technological balance of payments.

[31] UNESCO-UIS (2014), "Guide to conducting an R&D survey: For countries starting to measure research and development", Technical Report 11, UIS, Montreal. www.uis.unesco.org/ScienceTechnology/Documents/TP11-guide-to-conducting-RD-surveys.pdf

In Figure 3.1 the main inflows of R&D data concerning the three key institutions operating at international level in this domain are highlighted (blue arrows). Nevertheless, the picture would not be complete without considering the outflows as well (yellow arrows) and the constant exchange of data among these three big players. As a result of the complaints by EU countries about the potential burden to compile three quite similar questionnaires every year, an agreement has been reached that EU countries have to report about their R&D activities only to Eurostat (an activity already largely mandatory) and that Eurostat has to forward to the OECD and UIS a set of non-confidential R&D data produced by EU countries. In a similar way, the OECD makes available to Eurostat a set of R&D data from non-EU OECD countries and both organizations provide UIS with the data collected by them. Finally, UIS—as a kind of hub in the system—should be able to collect and compare R&D data with a global reach also thanks to its collaboration with other regional multinational organizations, like RICYT (Red Ibero-Americana de Ciencia Y Tecnologia) for Latin America and ASTI (Africa Science, Technology and Innovation Strategy of the African Union Development Agency, NEPAD) for Africa.

R&D data availability at international level

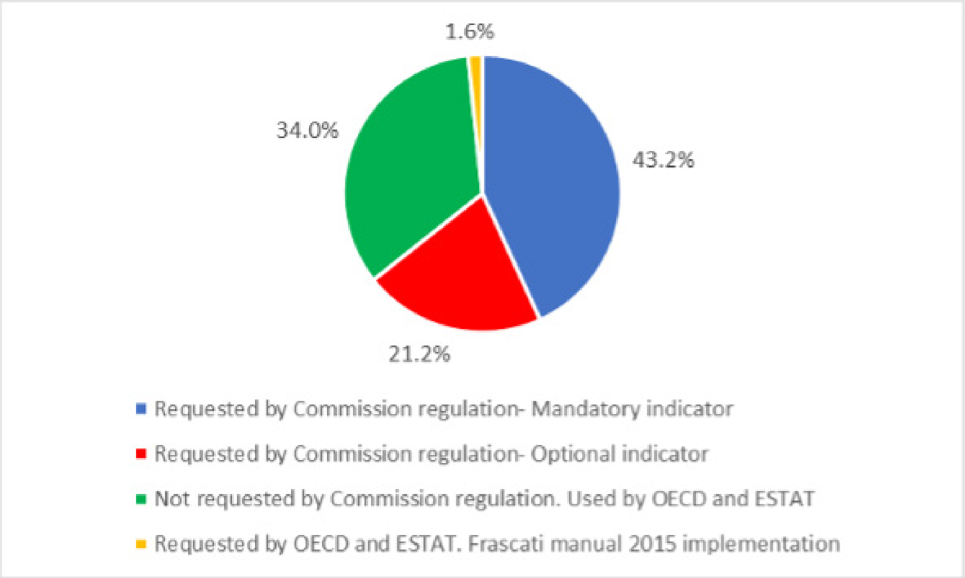
The international cooperation in R&D statistics data collection is still in the process of fully reaping all its potential benefits. In principle, a cooperation between data producers and users increases efficiency but, at the same time, generates some attrition as the users constantly ask for more (more variables, more data granularity, etc.) while the producers have to be sympathetic with the need of data providers (member countries, in this case) of keeping the statistical burden as low as possible.

Table 3.1. Main variables on R&D inputs to be produced by EU countries according to EU Regulation 2019/2152.

Variables to be produced biennially		Variables to be produced annually
Country level	*Region level*	*Country level*
R&D expenditure R&D employment R&D expenditure in foreign-controlled enterprises R&D employment in foreign-controlled enterprises Publicly funded R&D	R&D expenditure by region R&D employment by region	Sector of performance breakdown of: - intramural R&D expenditure - R&D personnel and - number of researchers Government Budget Allocations for R&D (GBARD) National public funding to transnationally coordinated R&D

Currently, the Eurostat R&D survey is by large the most burdensome compared to the OECD's and UIS's ones. The data structure is described in the EU Regulation 2019/2152 (Table 3.1) and covers all the dimensions of the R&D input (R&D output measurement is beyond the scope of the FM). Data transmission to Eurostat is based on four modules: the core R&D module, the module on Government Budget Appropriations on R&D (GBARD), the module on transnationally coordinated R&D and a module on R&D expenditure forecasts. By means of the large "core R&D module" 1,839 variables are collected (including 15 variables on R&D expenditure by type of research) but not all of them are mandatory.

Figure 3.1. Breakdown of the core R&D variables collected by Eurostat by status.

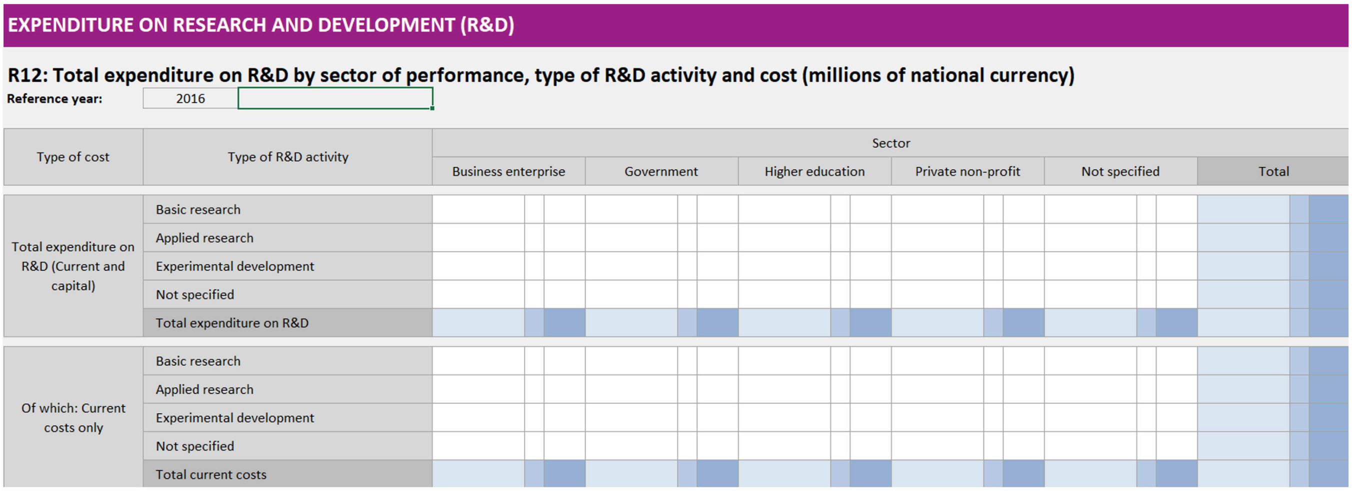


In Figure 3.1 the status of the variables requested in the Eurostat core R&D module is described. Only 43.2 percent of them are mandatory for EU countries, i.e., whose transmission is prescribed by the EU law. An additional 21.2 percent includes variables requested by the EU law but only on a voluntary basis. A share of 34 percent of them are not mentioned in the EU legislation but are requested to fill specific needs of either the European Commission services or the OECD. Finally, a handful of variables have been introduced on an experimental basis to test some new concepts introduced by the FM 2015. It is worth mentioning that around 80 new variables are currently under scrutiny for a potential inclusion in the core R&D module.

In terms of data availability, thanks to the high burden EU countries are charged, the Eurostat database features long data series with a low frequency of missing data. The coverage for the 15 variables on R&D expenditure by type of research for the 27 EU countries is, for instance, quite good: around 45 percent in the period 1981-2018, rising to 83 percent in the last ten years (as earlier mentioned, data provision on R&D expenditure by type is mandatory only every two years).

Unlike Eurostat, UIS is focusing its R&D data collection on a few variables (12 modules for a total of 242 variables) asked, on a voluntary basis, to a large number of countries (the module on type of research—10 variables—is displayed in Figure 3.2).

Figure 3.2. Basic research variables collected by UIS.



EXPENDITURE ON RESEARCH AND DEVELOPMENT (R&D)

R12: Total expenditure on R&D by sector of performance, type of R&D activity and cost (millions of national currency)

Reference year: 2016

Type of cost	Type of R&D activity	Sector					
		Business enterprise	Government	Higher education	Private non-profit	Not specified	Total
Total expenditure on R&D (Current and capital)	Basic research						
	Applied research						
	Experimental development						
	Not specified						
	Total expenditure on R&D						
Of which: Current costs only	Basic research						
	Applied research						
	Experimental development						
	Not specified						
	Total current costs						

Unfortunately, the UIS survey's rate of response is pretty low. By considering the variable on basic research, the coverage, over the last 6 years, for the 163 observed countries is 33 percent. Only 49 countries out of 163 have reported a figure on basic research expenditure for at least 4 out of the most recent 6 years.

The OECD annual R&D data collection competes with the Eurostat survey as to the total number of variables requested in the core questionnaires at country level. Four OECD questionnaires include more than 30 modules but the two core questionnaires—on R&D expenditure and R&D personnel—focus on a set of 1,372 key variables (including 25 variables on R&D by type). The questionnaires are sent to OECD non-EU member countries and are still using a spreadsheet for data entry, whereas Eurostat has already fully implemented a standard for automated communication and data transfer. By considering the R&D variables on type of research, the availability of figures in the OECD statistical database is pretty good. By considering the reporting by 30 OECD countries over the last nine years (2010-2018) the coverage is almost 80 percent.

As far as countries are members of both the OECD and the EU, most of the R&D variables in the OECD database match with the Eurostat data. Discrepancies in data availability largely deal with not consistent interpretation of new variables and breakdowns introduced in the FM 2015 but, as already mentioned, this does not affect "type of R&D" data.

4. R&D Trends and Intensity[32]

From 2000 to 2019, Gross domestic Expenditure on R&D (GERD) in the OECD area grew annually by 2.9 percent in real terms (Figure 4.1). In 2020, total GERD amounted to 1.45 USD trillion.

BERD (Business Enterprise R&D) is the most significant contributor to R&D, accounting in 2019 for over 70 percent of total spending. During the whole period, its pace of growth was sustained (+3.1 percent per year), suffering a limited impact from the 2008-2009 crisis and growing by 4.8 percent over the last four years.

Starting from 2011, and after a sustained period of growth in the early 2000s, HERD (Higher Education R&D)—the main performer of basic research—slowed down, although maintaining its weight on the overall expenditure (about 17 percent in 2019). HERD grew 2.1 percent per year from 2016 to 2019.

A similar trend—but with a less significant contribution to overall R&D—was performed by the Government sector (GOVERD), that raised at a slower rate (+1.7 percent)—even decreasing in some years—and fell to about 10 percent of total OECD R&D, from 12 percent in 2000.[33]

All in all, R&D growth in the OECD area was driven by the business enterprises sector, which accounted for around 75 percent of total R&D growth from 2000 to 2019.

Among the largest economies, China and Korea have significantly increased their share of R&D, expressed as a percentage of gross domestic product (GDP) (Figure 4.2). For the European Union as a whole, research intensity has grown by just a quarter of a percentage point in the last decade—mainly driven by Germany—, while the Chinese economy has increased by more than half a point, surpassing the EU.[34]

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[32] In this section R&D activity is measured using information coming from three different sources of data. Statistics on R&D expenditure, personnel and government budget allocations for R&D are collected every year by EUROSTAT for 27 European countries (https://ec.europa.eu/eurostat/web/science-technology-innovation/overview). The OECD MSTI, Main Science and Technology Indicators Database gathers the latest official statistics on R&D undertaken by OECD member countries and seven non-member economies in the field of science and technology (https://www.oecd.org/sti/msti.htm). OECD also releases a biannual publication that provides a set of indicators on R&D and innovation (OECD (2020), Main Science and Technology Indicators, Volume 2020, Issue 1, OECD Publishing, Paris, https://doi.org/10.1787/e3c3bda6-en). MSTI data are submitted by national contacts to the OECD (in co-ordination with Eurostat for EU countries) and reviewed in order to ensure consistency and international comparability of R&D measures (https://www.oecd.org/sti/inno/researchanddevelopmentstatisticsrds.htm). Finally, the UNESCO Institute for Statistics (UIS) provides internationally-comparable indicators on R&D and innovation for a large number of countries, also covering countries at lower stages of development; these data are collected through global surveys and partnerships with regional organizations that are able to collect information for non-OECD economies directly from national sources (http://uis.unesco.org/apps/visualisations/research-and-development-spending/).

Despite the common reference to the Frascati Manual (OECD, Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris, https://doi.org/10.1787/9789264239012-en), R&D measures often suffer of measurability issues and coverage gaps. This is the reason why, when data are disseminated by EUROSTAT, OECD and UNESCO, a rich set of metadata and flags is provided to assess possible deviations from the Frascati Manual, time series break, differences in methodology, etc. that affect international comparability and consistency (https://www.oecd.org/sti/inno/researchanddevelopmentstatisticsrds.htm). Moreover, government policies can also affect survey firm's reporting of R&D activity (more on this on: OECD, 2017, OECD Science, Technology and Industry Scoreboard 2017: The digital transformation, OECD Publishing, Paris, https://doi.org/10.1787/9789264268821-en).

[33] According to OECD, in the European Union (27 countries) the percentage of GERD performed by the Business Enterprise sector in 2019 was 66 percent, while higher shares are shown for the higher education (22 percent) and the government sector (11,5 percent); non-profit institutions account for 0.7 percent of total spending.

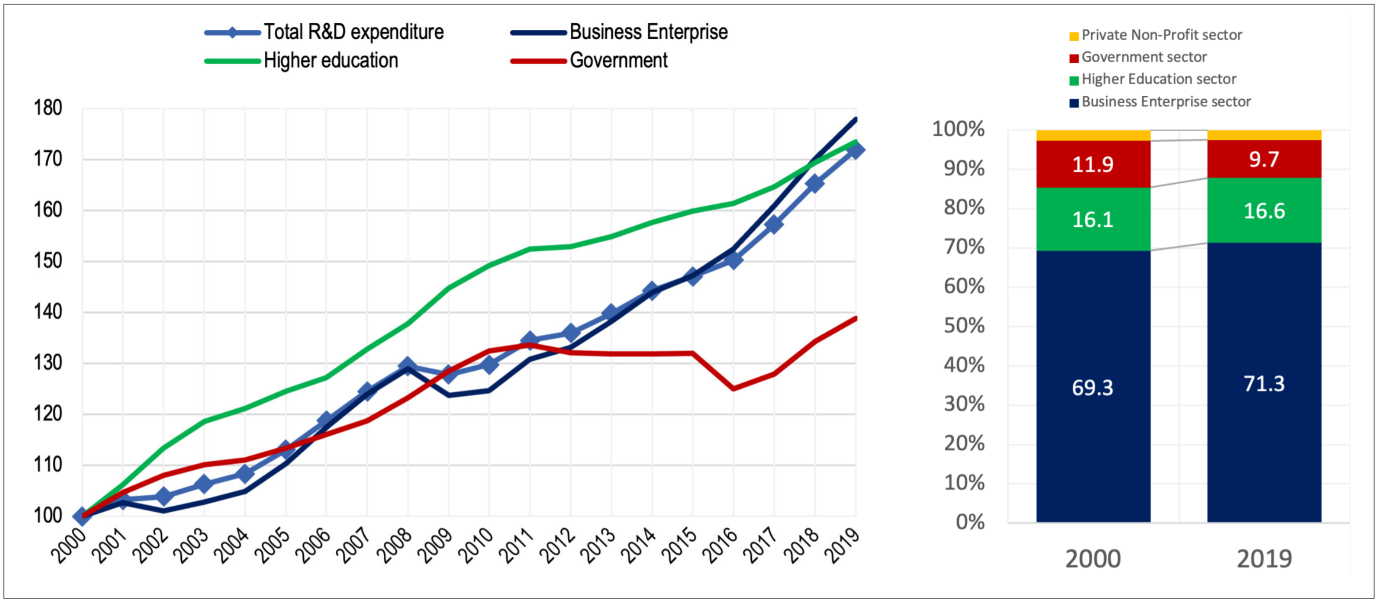
[34] At the growth rates observed over the past twenty years, China would exceed the U.S. level of R&D spending (as a percentage of GDP) in 2027.

R&D intensity is different in G20 and Aspen Institute countries (Figure 4.3). In 2018, the total amount of R&D expenditure as a percentage of GDP was approximately 4.5 percent in Korea, the highest level among these countries. The intensity of R&D spending in Japan, Germany and United States is close or exceed 3 percent, while EU27 remained just over 2 percent. Disparities among countries are mainly due to R&D intensity in the business enterprise sector and countries' specialization in high tech and knowledge intensive activities. In the higher education and government sectors, differences are less significant and, in some countries (Indonesia, Mexico, Argentina, South Africa), universities and public research centers perform the largest part of R&D expenditure.[35]

When we look at monetary levels, differences among countries become broader (Figure 4.4). Considering the total R&D spending per capita population—expressed in current dollar ($) PPP—Korea, United States, and Germany are the largest R&D performers. Korea and the United States invest over USD 1,800 per inhabitant in R&D, much more than the European Union (USD 924) and the United Kingdom (USD 816). Such values appear to be different within Europe, with Germany close to the levels of the best performers, France slightly above the European average and Italy and Spain lag behind. When we compare R&D expenditure with the whole population, China's R&D intensity is obviously trimmed (USD 334).

Figure 4.1. Total R&D expenditure by performing sector in OECD area - 2000-2019

Gross Expenditure in R&D (GERD) at constant prices and PPP U.S. Dollar (index 2000=100); share of GERD in 2000 and 2019.



Source: OECD, Main Science and Technology Indicators Database MSTI, https://www.oecd.org/sti/msti.htm. For more information on these data, see the Data Characteristic section of OECD, MSTI Database and MSTI Full Documentation (https://metalinks.oecd.org/msti/20210316/5d8c). OECD area includes all Member countries of the OECD i.e., Australia, Austria, Belgium, Canada, Chile, Colombia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

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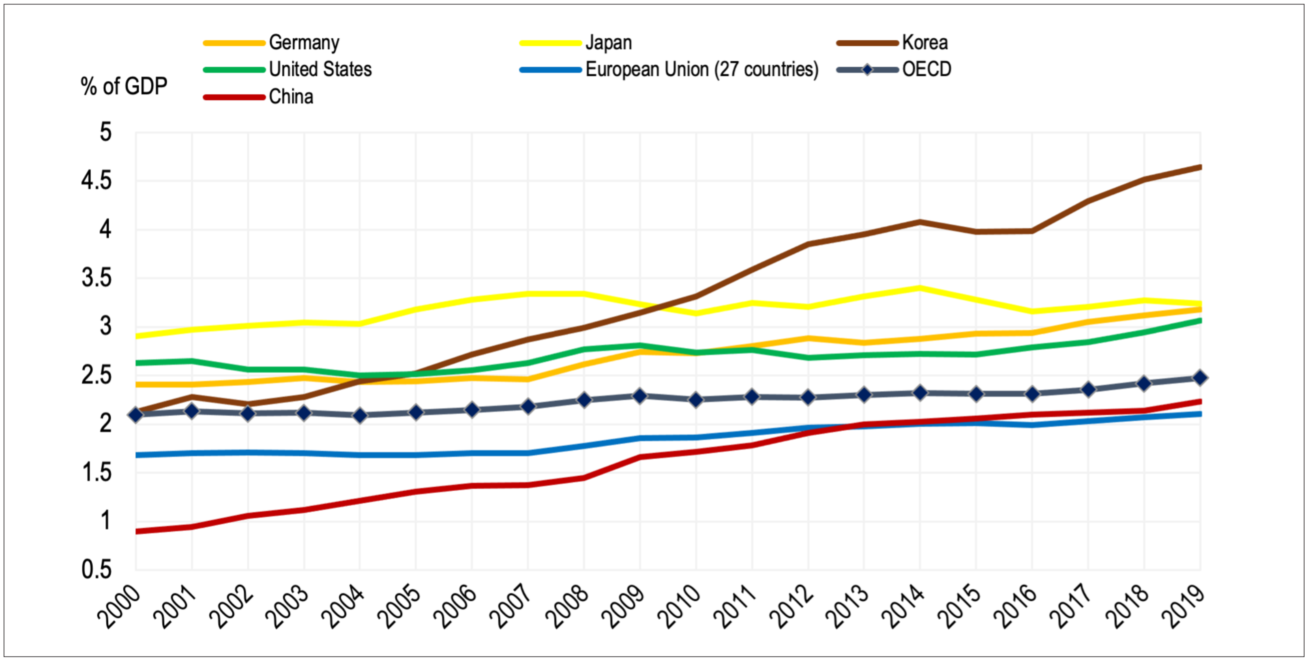
[35] Share of HERD varies from a minimum of 7 percent in the United Kingdom and Canada, 8 percent for Japan and about 9/10 percent for Japan, Turkey and the United States, to a maximum of 70 percent of Indonesia, 57 percent of India, 47 percent of Argentina. For the European Union (27) as a whole, HERD share is just over 11.5 percent.

Figure 4.2. Total R&D expenditure in selected countries and regions—2000-2019

Gross Expenditure in R&D (GERD) as a percentage of GDP

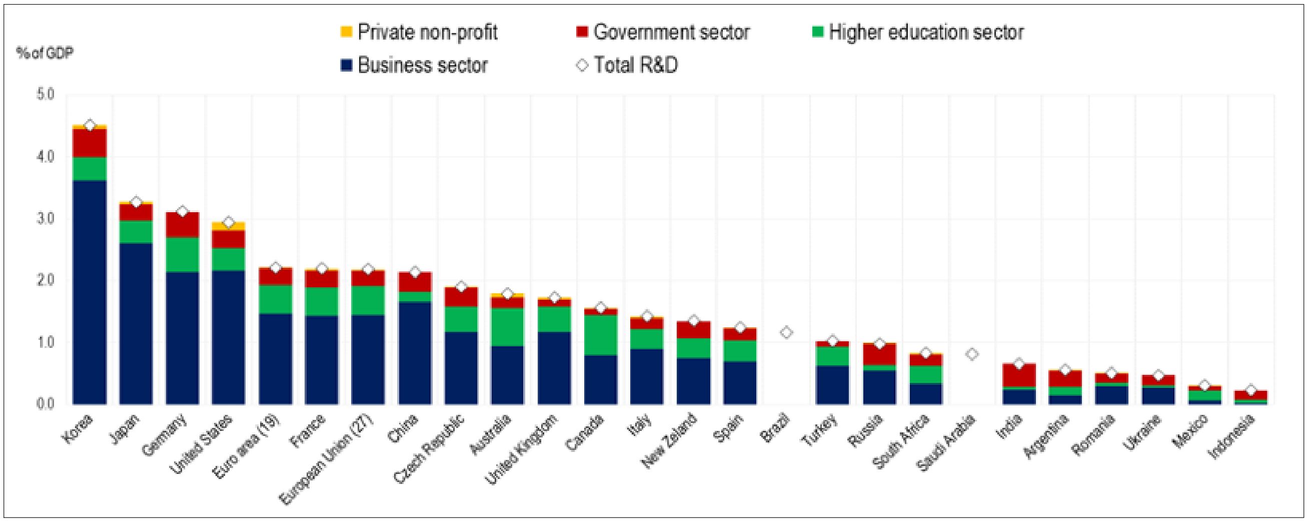


Source: OECD, Main Science and Technology Indicators Database MSTI, https://www.oecd.org/sti/msti.htm. For more information on these data, see the Data Characteristic section of OECD, MSTI Database and MSTI Full Documentation (https://metalinks.oecd.org/msti/20210316/5d8c).

Japan, 2008, 2013, 2018: time series break; 2018, 2019: estimated value. Germany, 2019: estimated value. Korea, from 2000 to 2007: definition differs. The United States, 2000-2019: definition differs; 2003: time series break; 2019: estimated value. The European Union and OECD, 2000-2019: estimated values (OECD estimates). China, 2009: time series break; China is except Hong Kong.

Figure 4.3. Total R&D expenditure in G20 and Aspen countries by performing sector in 2018.

Gross Expenditure in R&D (GERD) as a percentage of GDP

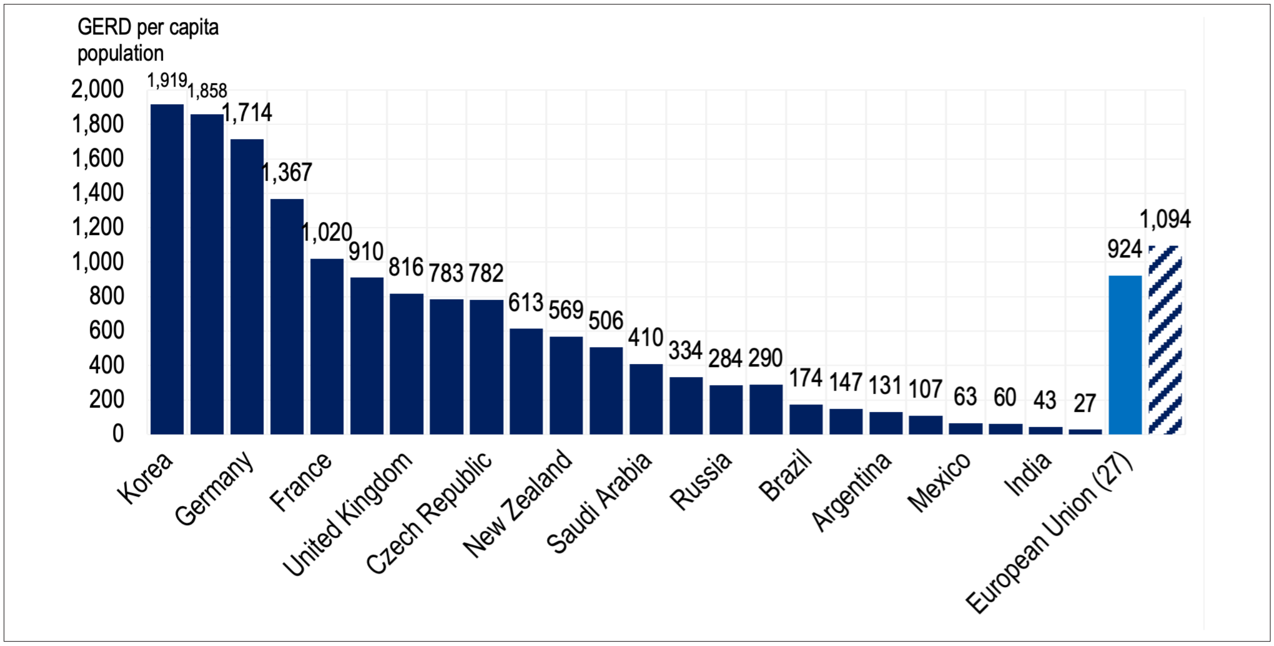


Source: OECD, Main Science and Technology Indicators Database MSTI, https://www.oecd.org/sti/msti.htm; UNESCO, Science, technology and innovation; EUROSTAT, Science and technology. Data for Saudi Arabia, India, Indonesia, Brazil, Ukraine is drawn from UNESCO. Data for the Euro Area (19) from Eurostat. For more information on OECD data, see the Data Characteristic section of OECD, MSTI Database and MSTI Full Documentation (https://metalinks.oecd.org/msti/20210316/5d8c).

For Brazil and Saudi Arabia, the breakdown of GERD by performing sector is missing. The United States: definition differs. France and Canada: provisional values. Australia, South Africa, Argentina and New Zealand: 2017 values. Australia and Mexico: estimated values. Saudi Arabia: 2013 value, based on R&D budget instead of R&D expenditure. India and Brazil: source from National Publication. Ukraine: excluding data from some regions/provinces/states. China is except Hong Kong. Germany, Turkey and India: Government sector includes private non-profit institutions. Italy: the value for the higher education sector is estimated.

Figure 4.4. Total R&D Expenditure per capita population in G20 and Aspen countries in 2018

Gross Expenditure in R&D (GERD); current PPP U.S. Dollar



Source: OECD, Main Science and Technology Indicators Database MSTI, https://www.oecd.org/sti/msti.htm; UNESCO, Science, technology and innovation. Data for Saudi Arabia, India, Indonesia, Brazil, Ukraine is drawn from UNESCO. For more information on these data, see the Data Characteristic section of OECD, MSTI Database and MSTI Full Documentation (https://metalinks.oecd.org/msti/20210316/5d8c).

The United States: definition differs. France and Canada: provisional values. Australia, South Africa, Argentina and New Zealand: 2017 values. Australia and Mexico: estimated values. Saudi Arabia: 2013 value, based on R&D budget instead of R&D expenditure. India and Brazil: source from National Publication. Ukraine: excluding data from some regions/provinces/states. China is except Hong Kong. The European Union and OECD, 2000-2019: estimated values by the OECD.

5. A Glimpse into Basic Research[36]

For the fifteen countries for which a breakdown of R&D by type of research is available, basic research represents one-fifth of the total R&D expenditure (on average) (Figure 5.1). However, the differences among countries are wide. In China, the share of basic research is approximately the 6 percent of total R&D. This share is higher in Japan (13 percent), Korea (14 percent), the United States (17 percent) and the United Kingdom (18 percent), and above 20 percent in Italy, Spain and France.[37] For industrialized economies, the largest part of R&D expenditure is concentrated in experimental development, driven mainly by business enterprise spending.

As expected, the higher education sector provides the main support to basic research (about 50 percent, on average); about one-third is performed by the government and one-fifth by the business enterprise sector (Figure 5.2). In the most industrialized economies—where high-tech industries and knowledge intensive services are more prevalent—the share of the business-performed research is higher, ranging from 60 percent in Korea, 49 percent in Japan, 36 percent in the United Kingdom and 27 percent in the United States. Interestingly enough, in this country,

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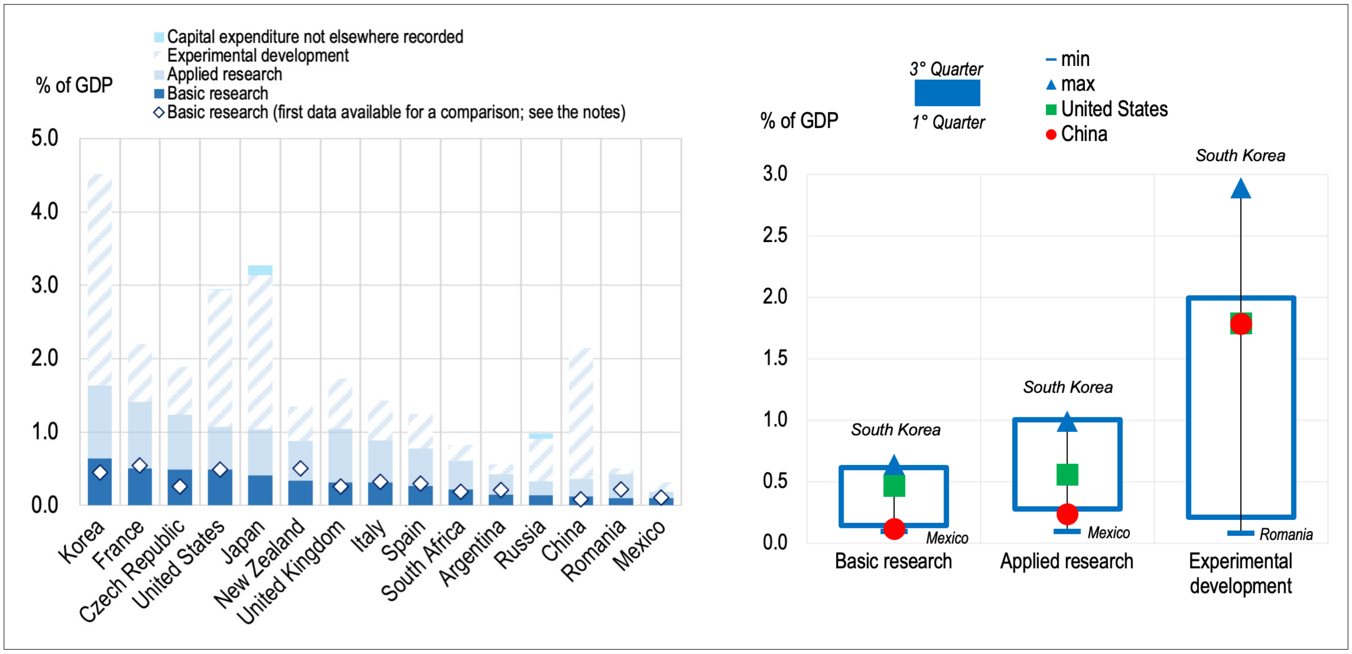
[36] See note 32 for details about the main sources used and data constraints.

[37] The breakdown by type of R&D is not officially available for GERD in Germany.

private non-profit institutions account for the 13 percent of total basic research (probably related to the role of some charities).

Figure 5.1. Total R&D expenditure by type of research in 2018 (for countries where data are available)

Gross Expenditure in R&D (GERD) as a percentage of GDP



Source: OECD, Main Science and Technology Indicators Database MSTI, https://www.oecd.org/sti/msti.htm; Eurostat, Science and Technology. For more information on these data, please see the Data Characteristic section of OECD, MSTI Database and MSTI Full Documentation (https://metalinks.oecd.org/msti/20210316/5d8c).

The United States: definition differs. France: provisional value, drawn from Eurostat. South Africa, Argentina and New Zealand: 2017 values. Mexico: estimated value. China is except Hong Kong. The United Kingdom: estimated value. Russia and South Africa: data for 2018 have been estimated based on the most recent data for which the breakdown was available. Due to the presence of missing breakdown for time series break in GERD by type of R&D, data for comparison are the following: for the Czech Republic and Mexico: 2000; New Zealand: 2001; the United States, South Africa: 2003; South Korea and the United Kingdom: 2007; China: 2009; France: 2010; Romania: 2011; Spain: 2013; Argentina: 2015; Italy: 2016. Graph on the right side is based on the distribution of R&D data for 15 selected countries.

As already mentioned, splitting basic, applied and experimental development is often challenging in some countries and sectors, leading to several coverage gaps. In fact, due to the presence of missing breakdowns and time series break, trends in basic, applied and experimental development R&D can be analyzed only for a limited number of countries. In Figure 5.3, we have selected a set of countries for which data are available from 2010 to 2018. While R&D total growth was mainly driven by large investments in experimental development, some characteristics on the evolution of the three types of R&D and, more specifically, of basic research, can be highlighted. Data show, across several countries a moderate increase in business-performed basic research and a lower growth of basic research in universities and research centers over the last years.[38]

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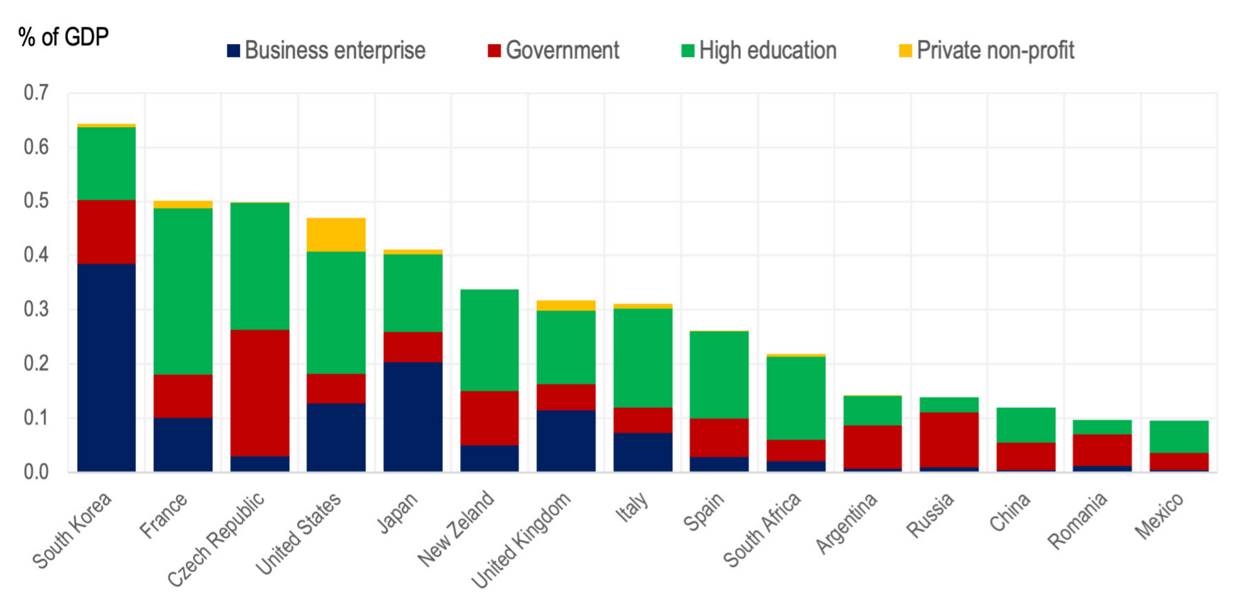
[38] On this point, see OECD, 2017, OECD Science, Technology and Industry Scoreboard 2017: The digital transformation, OECD Publishing, Paris, https://doi.org/10.1787/9789264268821-en).

In Korea, basic research grew by 3.8 percent annually, at a pace of growth less intense than other types of R&D (+8,4 percent for applied research and +7,5 percent for experimental development). Its increase was mainly driven by the R&D spending by business enterprises (+4,5 percent) that accounts for two-thirds of total basic research in the country.

In China, where the relative level of investments in basic research is low, basic research has featured a fast growth (+13.2 percent per year) evenly diffused across sectors although quite concentrated in the higher education and government sector.

Figure 5.2. Basic research by performing sector in 2018 (for countries where data are available)

Basic R&D expenditure as a percentage of GDP

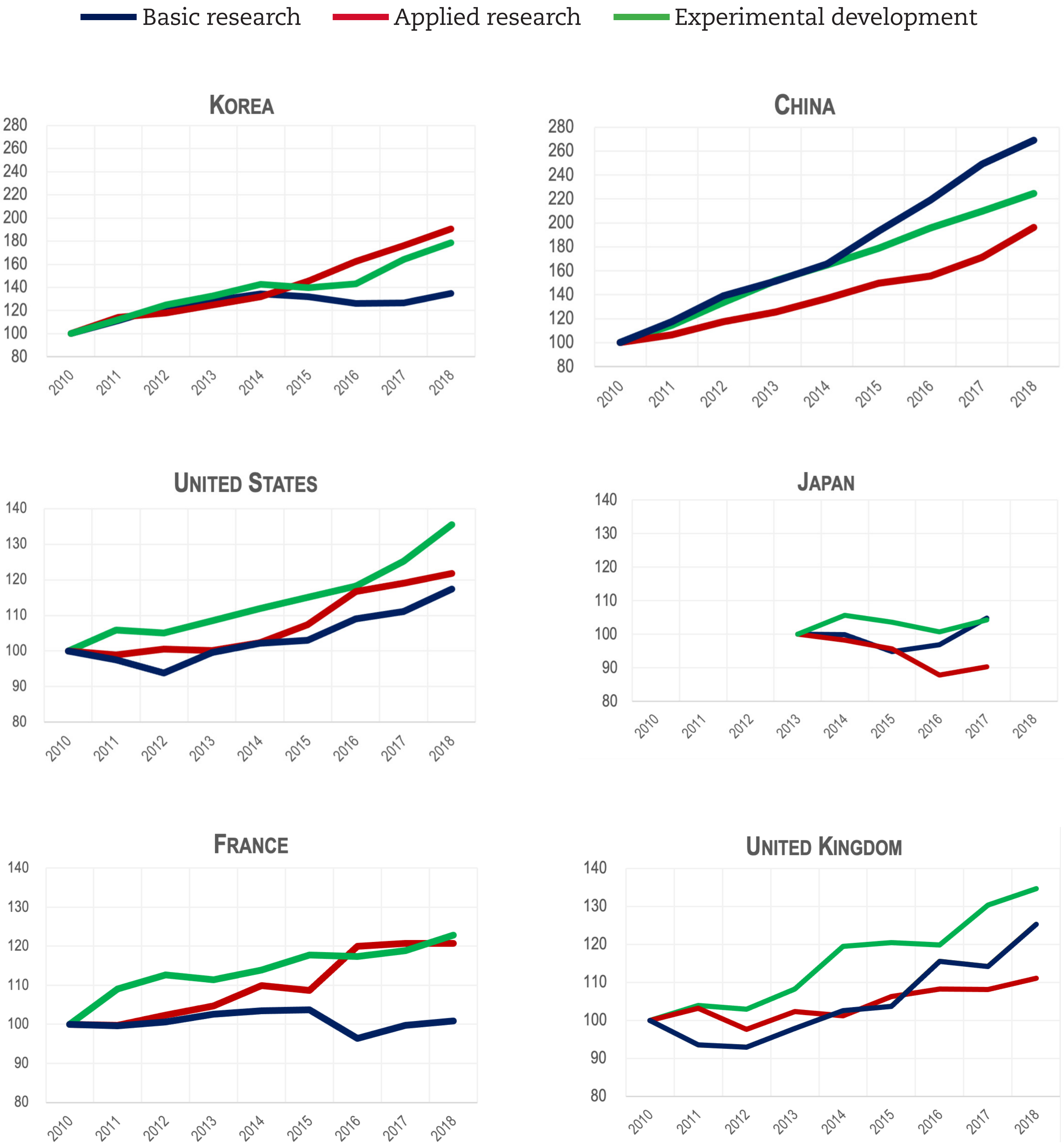


Source: OECD, Main Science and Technology Indicators Database MSTI, https://www.oecd.org/sti/msti.htm; Eurostat, Science and Technology. For more information on these data, please see the Data Characteristic section of OECD, MSTI Database and MSTI Full Documentation (https://metalinks.oecd.org/msti/20210316/5d8c).

United States: definition differs. France: provisional value, drawn from Eurostat. South Africa, Argentina and New Zealand: 2017 values. Mexico: estimated value. China is except Hong Kong. The United Kingdom: estimated value. Russia and South Africa: data for 2018 have been estimated based on the most recent data for which the breakdown was available.

Figure 5.3. Trend in basic and applied research and experimental development for selected economies, 2010-2018

Gross Expenditure in R&D (GERD) at constant prices and PPP U.S. Dollar (index 2010=100)



Source: OECD, Main Science and Technology Indicators Database MSTI, https://www.oecd.org/sti/msti.htm. For more information on these data, please see the Data Characteristic section of OECD, MSTI Database and MSTI Full Documentation (https://metalinks.oecd.org/msti/20210316/5d8c).

France: from 2010 to 2015 data exclude a part of the capital expenditure used for R&D; 2016 and 2018: estimated values; 2017 and 2018: provisional values. The United States: from 2012 to 2018 data exclude a part of the capital expenditure used for R&D; definition differs.

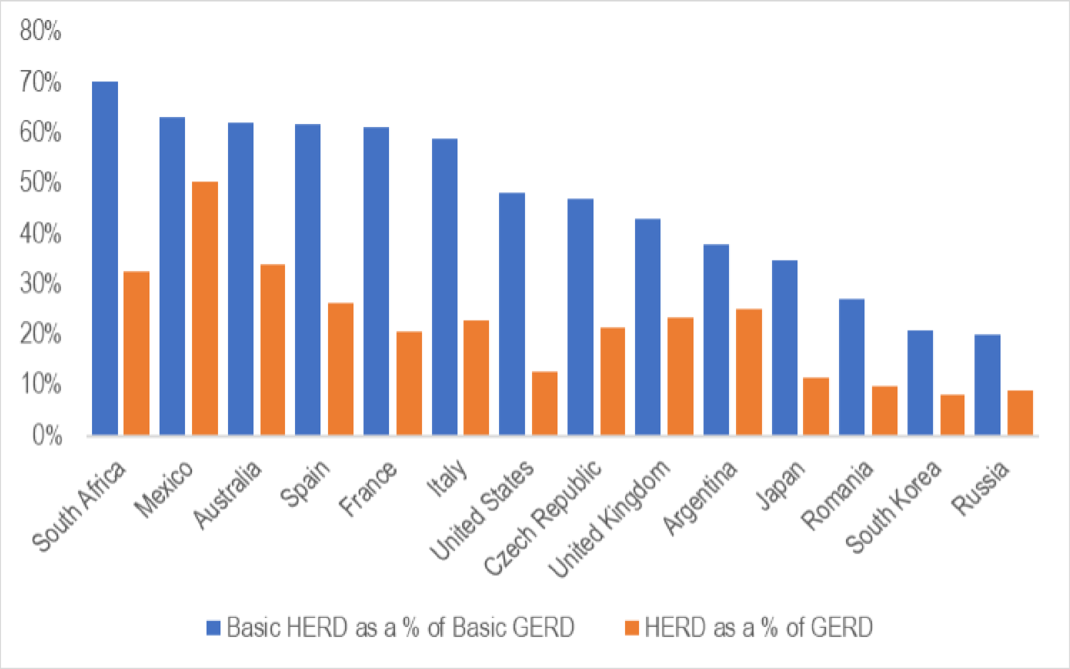
Basic research grew slightly in the United States (+2.0 percent) and with less intensity than other types of research (+2.5 percent for applied research and +3.9 percent for experimental development); as in Korea, the business-performed part of the R&D increased by 5.7 percent per year, accounting for about 70 percent of total rise in basic research (18 percent was due to non-profit institutions).

In France, from 2010 to 2018, basic research has been stagnant, growing by only 0.1 percent per year. This trend is due to a sharp decrease of basic research spending in the higher education sector (-2.0 percent), partially compensated by an increase in the business and government sectors. Similarly, in the United Kingdom, the decrease of government expenditure for basic research and a only small growth of R&D spending in the higher education sector, were more than compensated by the rise in business spending, reaching a +2.9 percent per year for basic research.

6. Basic Research in Universities

Universities still play in many countries a key role in supplying the society as a whole of new knowledge by way of findings from their research efforts. These largely include basic research projects both supported by ordinary funds and carried out in the framework of national or international R&D programs. As shown in Figure 6.1, universities in several countries account for less than 30 percent of total R&D expenditure in a country but feature, on average, from 50 to 60 percent of basic research.

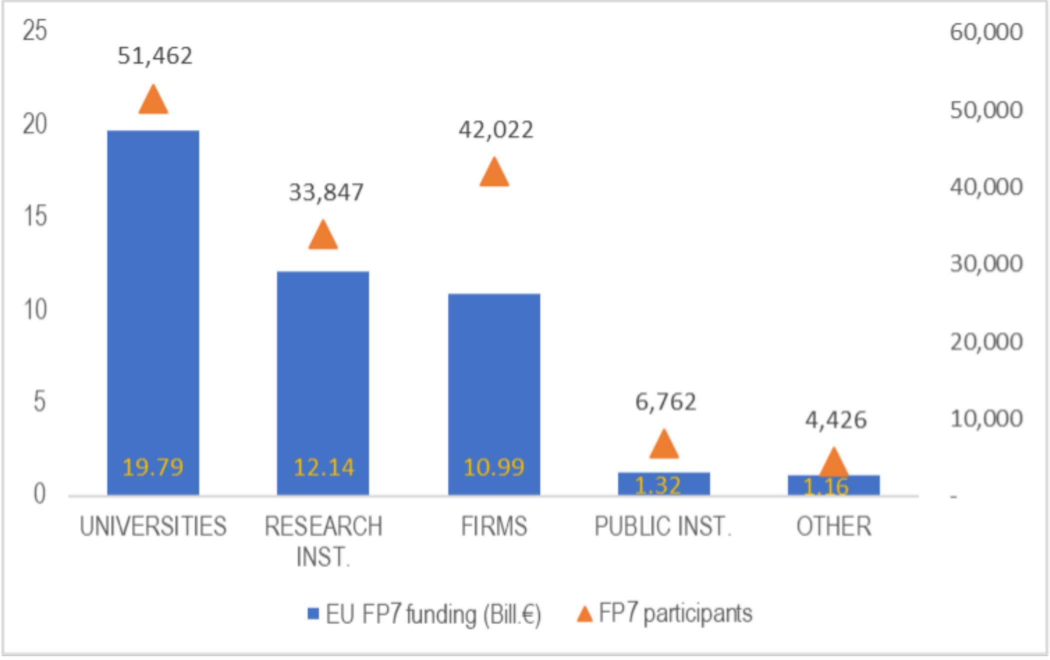
Figure 6.1. Percentage of Gross Expenditure on R&D (GERD) and Basic GERD performed in universities (HERD). Selected countries. Year 2018.



Similar indicators are available both when considering scientific publications, where the number of academic articles over the total published is overwhelming, and public R&D funding, commonly including a large share of funds for fundamental science research (like for the EU R&D Framework Program), is mostly attracted by universities (Figure 6.2).

The need for a high specialization by universities to perform basic research was a pillar of the post-WWII research policy in many countries as a consequence of the acceptance of the linear model of innovation and growth. Basic research was seen as the starting point of the process and governments were supposed to assure a constant support to it. As business enterprises could have not found economically sound to invest in basic research (a view still stressed by Richard Nelson, 1959), universities were seen as the *locus* where most of the budget for basic research should have been aimed to. This view was challenged by the emergence of new approaches in the interpretation of the innovation process. Gibbons *et al.* (1994) argued about the need for universities to evolve from a Mode 1 of knowledge creation to a Mode 2. Shortly, Mode 1 is about theorization and monodisciplinary approach (in a sense, focusing on basic research), while Mode 2 is about experimentation, the actual application of knowledge, trans-disciplinarity (thus, stressing the need for a shift toward applied research). This point was reinforced by another approach that emerged in the same decade: the Triple Helix of innovation (Leydesdorff and Etzkowitz, 1998). The Triple Helix is a model where the process toward a *knowledge economy* rests on a close interaction among universities, industry and public sector. This implies a new relationship between the academia and the productive sector and a more intense exchange of resources and competences. The adoption of a new role for universities, more oriented to applied research than before was again at stake.

Figure 6.2. EU R&D Framework Program (FP7) 2007-2013. Number of participants and total funding by legal entity.



The need for a substantial re-orientation of university research toward more "useful" experimentation became conventional wisdom as Nowotny *et al.* (2003) argued that: "… the research that is variously described as 'pure', 'blue-skies', fundamental, or disinterested, is now a minority preoccupation - even in universities''.

This claim is, indeed, not confirmed by available evidence. Bentley *et al.* (2015) collected the views of more than 12,000 academics in 15 countries and found that most of them, with some differences largely due to their disciplinary specialization, keep performing basic research although with some consideration for the potential uses of its finding[39]. The "Pasteur" approach in the Stokes' quadrant (Figure 2.2) seems growing in popularity among academicians.

More recent is the diffusion of the "quite nebulous" (Compagnucci and Spigarelli, 2020) concept of a third mission for universities beyond research and education. This approach has been also seen as a way to formalize a polarization involving universities and researchers alike: *"[…] Lam (2010) suggested a typology of scholars placed on a continuum between two polar types. On the one hand, the 'old school' traditionalists, who adhere to basic science and resist approaching entrepreneurial activities and relationships and, on the other, the author identified a 'new school' of entrepreneurial academics, those who participate both in the area of science and of business."*[40].

The issue about the role of basic research in universities is still far to be settled. In terms of measurement, the community of statisticians stick on the conclusions of the 2001 OECD Conference on measurement of basic research. There, Professor Signe Kjelstrup (2001) argued about preserving the concept of basic research, also with reference to universities, just as it had been being used for almost forty years. Her point was that: *"basic and applied research have not changed during the course of time. Concepts of basic and applied research have not changed for the scientist. The conception of basic science has changed, however"* concluding that: *"[…] this is mostly related to the funding situation"*. This is consistent with the view that that R&D statistics' approach is strongly influenced by the research policy needs. In a sense, Kjelstrup were arguing that scientist, chiefly the academic ones, have not changed their perspective by constantly balancing basic and applied research. On the other hand, the demand for research is cyclically influenced by opposite views highlighting, in turn, the need for more basic, rather than for more applied research.

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[39] "The majority of academics (61%) in our data material based on more than 10,000 researchers from 15 countries report significant engagement in basic research, and very few report no engagement in basic research (7%). […] the resilience of theoretical research lends stronger support to the more nuanced position of the triple helix model […]. The shift toward Mode 2 or practical research appears to be emergent, rather than complete, with universities remaining a core producer of theoretical knowledge.".

Godin & Gingras, (2000) came to similar results by performing a bibliographic analysis and emphasising the role of university-industry collaboration to reinforce the role of universities as knowledge producers. In a way, the results were supporting the Triple Helix more than the Mode 2 view: "Thus, far from receding from its central place, […] universities have been able to stay at the center of the knowledge production system by using collaboration mechanisms".

[40] Compagnucci and Spigarelli, (2020), pag.9.

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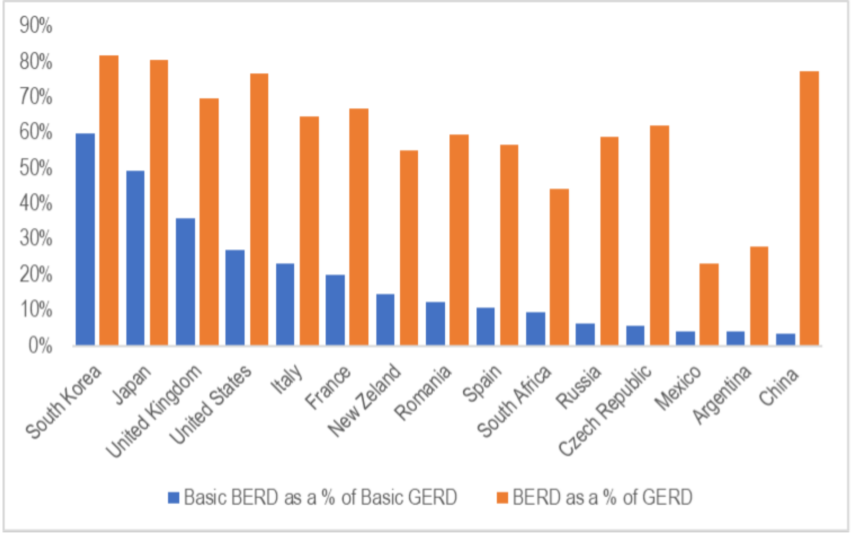
7. Basic Research in Business Enterprises

Some of the most influential economists of the twentieth century, including those who could be credited to have produced seminal contributions to the definition of the economics of innovation, have contributed to the discussion about the motivations that could induce business enterprises to invest in basic research.

A pillar in this discussion is the failure of the market. As Richard Nelson (1959) argued that: "[…] *basic research efforts are likely to generate substantial external economies. Private-profit opportunities alone are not likely to draw as large a quantity of resources into basic research as is socially desirable*". However, an additional point makes a difference between large and small firms: *"A firm with a narrow technological base is likely to find research profitable only at the applied end of the spectrum. […] On the other hand, a firm producing a wide range of products resting on a broad technological base may well find it profitable to support research toward the basic-science end of the spectrum."*.

Nathan Rosenberg (1989) stresses the Arrow (1962) arguments that the obstacles to a private appropriation of the benefits of research lead to an insufficient investment in research also in a condition of perfect competition and that policymakers have to deal with the dilemma of either providing incentives to private research at risk of being ineffective because of the lack of appropriability rights, or allowing firms to use the research result in an exclusive way but reducing the efficiency of the system by affecting the level of competition. In addition, Rosenberg reviews a range of factors leading firms to invest on basic research, like that to exploit the advantages of the "first mover" in a selected industry or to profit of the unpredictable spin off generated by the research performance. Of course, not all firms have the same incentives to get engaged in basic research. Favorable conditions include: the possibility to invest in large projects expecting long-term returns; bringing research as close as possible to the development and production functions in order to increase the potential for cross fertilization; featuring a broad range of products in order to be able to check for the exploitation of the research results across several technical fields.

Figure 7.1. Percentage of Gross Expenditure on R&D (GERD) and Basic GERD performed by business enterprises (BERD). Selected countries. Year 2018.



Although hampered by a number of factors (chiefly uncertainties and long-term returns) basic research is regularly carried out by firms, too. In Figure 7.1 the, sometimes remarkable, mismatch between the share of private R&D over the total R&D and the much lower share of basic research on total basic research is shown for selected countries. On average, business enterprises contribute by 60 percent or more to the total R&D and by 30 percent or less to basic research. Outliers seem falling in two opposite categories. On the one hand, South Korea and Japan where firms, mostly large firms, account, respectively, for 60 and 50 percent of the total basic research. On the other hand, Mexico and Argentina where the private sector plays a minor role in the research system so its contribution to basic research is even less relevant. China is an outlier by definition: in a framework where almost 80 percent of R&D is performed by firms, basic research is planned as a specific task of universities and public labs.

The European Commission survey on industrial R&D

More than ten years ago, the Joint Research Centre (JRC) Directorate General of the European Commission launched a program for monitoring size and characteristics of the Industrial R&D Investments at global level (within the research program on Industrial Research and Innovation, IRI). Currently, financial and economic data of the 2,500 leading private R&D performers at international level are collected and analyzed on an annual basis[41].

Since 2006, JRC is complementing the collection of company reports and financial statements with a direct survey targeting 1,000 large R&D performers[42]. The survey allows for exploring some areas of company activity not usually reported about in official documents. The information about the type of R&D performed by industry leaders is a case in point.

In 2020, the EU Survey on Industrial R&D Investment Trends has been collecting data from 61 firms accounting for 11.7 percent of the total R&D investment of the largest 1,000 R&D investors. This rate of response is not uncommon for voluntary business surveys. Notably, the average size of respondents is pretty high: 60 percent of the respondents have more than 10,000 employees.

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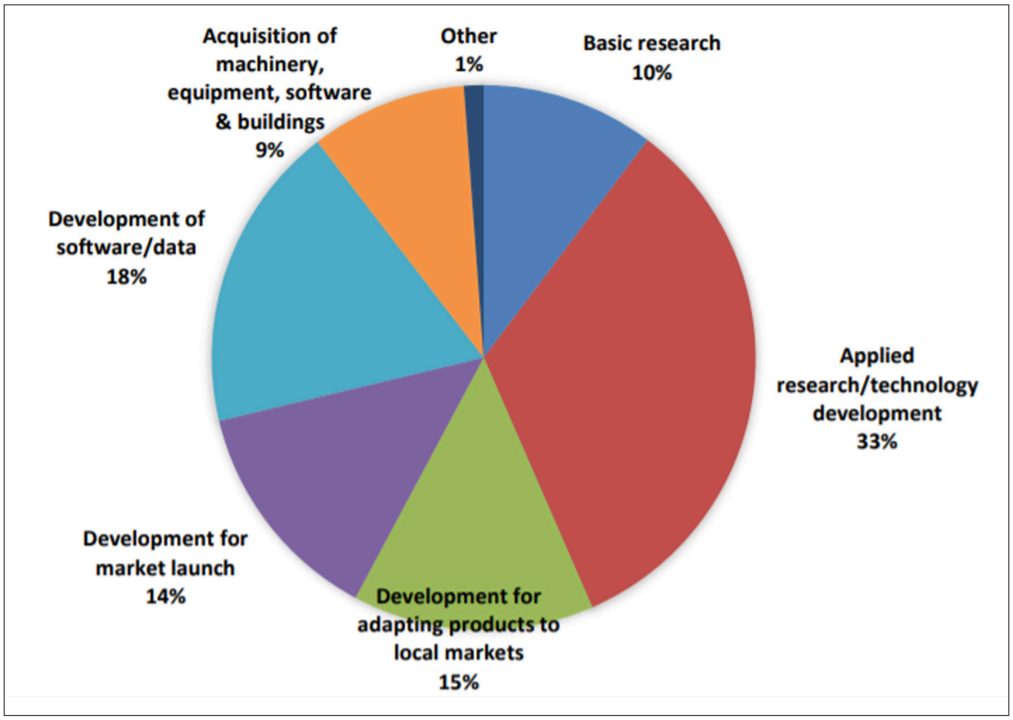
[41] https://iri.jrc.ec.europa.eu/rd_monitoring

[42] https://iri.jrc.ec.europa.eu/sites/default/files/2020-12/2020%20RD%20Survey%20online%20final.pdf

Figure 7.2. EU JRC R&D Survey 2020. Proportion of R&D investments, by type of investments

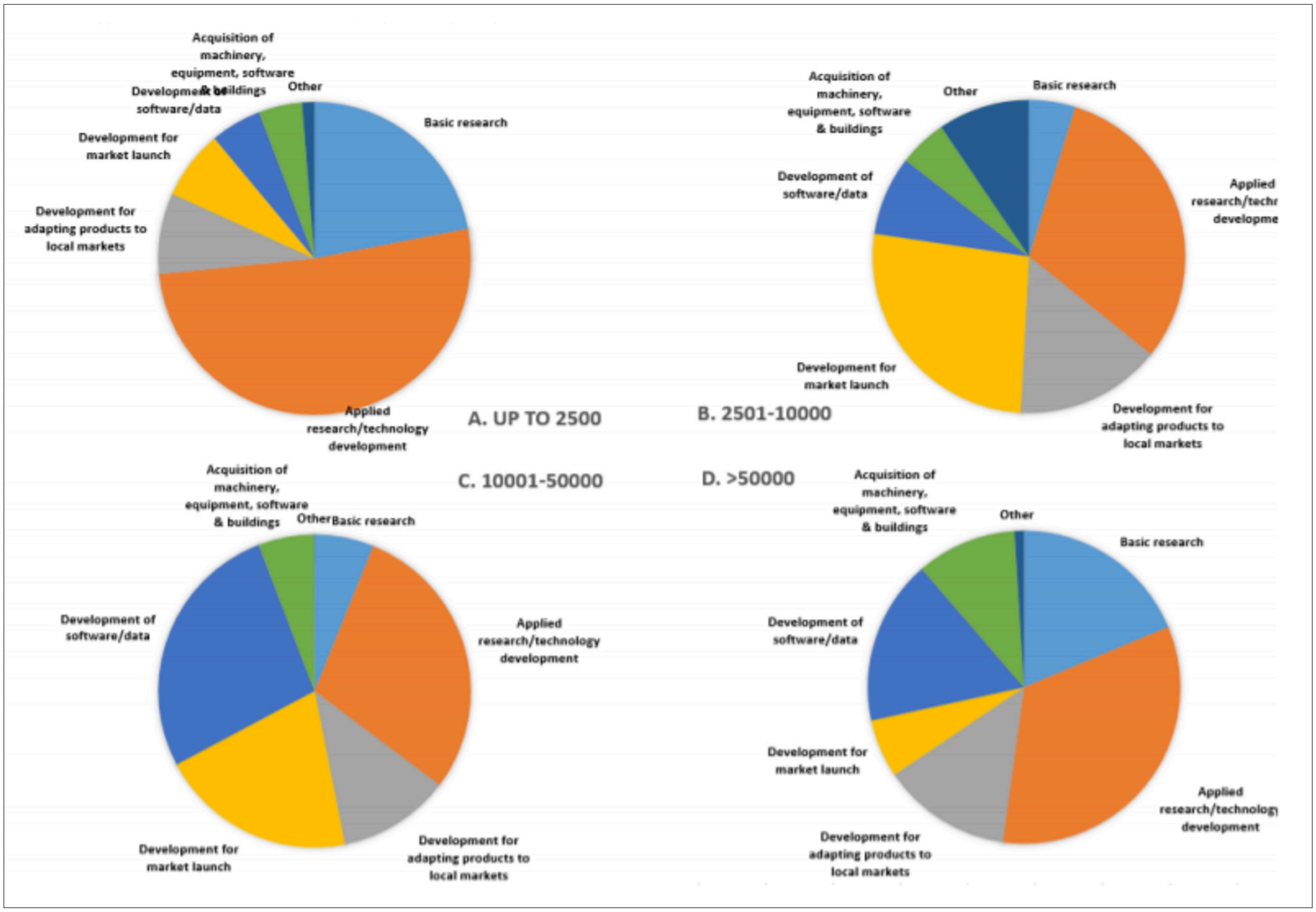


In Figure 7.2, the answers to a question about the type of R&D performed are displayed. As expected, basic research is estimated to be only 10 percent of the whole R&D budget with a strong orientation toward applied research and a range of complementary development activities.

The same information is also shown in Figure 7.3 but with an additional breakdown by size (number of employees). These results look interesting because of an uneven distribution of basic research investments by size. The firms with highest share of basic research as percentage of the total R&D budget are those with less than 2,500 employees—medium-large enterprises, roughly 20 percent—and those with more than 50,000 employees—very large enterprises, around 20 percent, too. The other size categories feature a share of basic research around 10 percent.

What do medium-large enterprises and very large enterprises have in common? Probably, not so much in terms of strategies and scientific capabilities. Nevertheless, they share the need for strengthening their knowledge basis for either preventing newcomers to jeopardize their market position (as far as they would be market leaders) or looking for new knowledge to profit of the advantages of being first-movers in highly competitive markets.

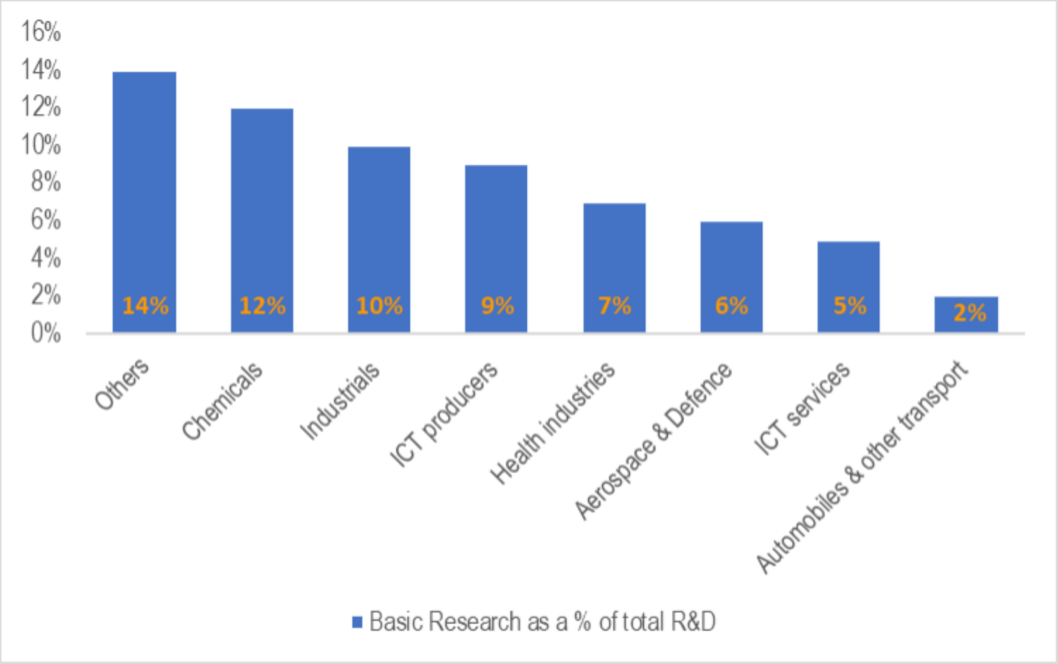
Figure 7.3. EU JRC R&D Survey 2020. Proportion of R&D investments, by type of investments, by company size (number of employees).



An information seldom available from official R&D surveys is the percentage of investment on basic research out of the total R&D budget by industry. This information is not available from the EU JRC Survey 2020 but can be drawn from the previous year survey. In 2019, the respondents who provided an estimate for their basic research budget were 111, almost twice the respondents at the 2020 survey.

In the category "other industry" the average share of basic research (14 percent) was much higher than the overall average in 2019 (9 percent). In this category are included several service sectors (Media, Real Estate), a few manufacturing sectors (Household goods, Personal goods) and, more relevant as to basic research is concerned the industries of Mining, Oil and Gas Producers and Oil Equipment, Services and Distribution. It is worth to mention that large firms operating in the Energy sector are often controlling subsidiaries in a range of related economic activities, including the high-tech area of renewable energy.

Figure 7.4. EU JRC R&D Survey 2019. Proportion of R&D investments in basic research, by industry.



Remarkable are also the basic research budgets of Chemical companies (12 percent), including Biotech companies. Just above the average in basic research spending (10 percent) is positioned the Industrials category that includes a number of manufacturing and service activities as Industrial Machinery or Industrial Transportation. Other industries have a basic research share of R&D in line with or below the average: ICT production, Health Industries (including Pharmaceuticals), Aerospace & Defense, ICT Services, Automobiles & other transport. All these industries have a strong potential for R&D and basic research in particular. By assuming a biased effect for the automotive sector—not infrequent in surveys with a low number of respondents—it should be pointed out that a 5 or 6 percent of basic research in a company R&D budget is not negligible at all if observed with reference to very large companies.

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8. Basic Research in Context: Profiling of the “Aspen Countries”

The fourteen countries hosting a local Aspen Institute have been selected as a sample of different approaches to management and support of fundamental research.

Six indicators have been identified in order to cover various features of the national R&D strategies. The **overall effort to support R&D investments** in all sectors is measured by the ratio of Total R&D spending on Gross Domestic Product (GDP). This is a headline indicator at international level and a political target for European EU countries (6 out of 13 in the Table below). The common EU target has been set to 3 percent for the whole Union: as shown in the Table, only Germany is performing above the target, while other countries lag behind (from Romania, 0.50 percent, to France, 2.19). Japan and United States are top performers at global level featuring, respectively, 3.28 and 2.83.

The orientation to **basic research activity** is measured by the ratio of Basic research expenditure on total R&D. This indicator is strongly dependent on the economic structure of a country: mostly on the percentage of Total R&D carried out by business enterprises (which have, usually, a lower percentage of basic research on Total R&D compared to public institutions and universities). This the main reason why, for instance, Mexico outperforms the U.S. (30.5 percent vs. 16.6 percent). Japan is a case in point with more than 80 percent of the national R&D carried out by businesses and a very low percentage of basic R&D (12.6 percent). On average, the percentage of R&D spending devoted to basic research in European countries is set in a range from 19 to 26 percent.

A complementary information is that about the non-business share (i.e., government + higher education) of Total R&D expenditure. This is complementary to the Basic R&D indicator in the sense that government (or public) owned research institutions, as well as universities (both public and private ones) commonly have a higher propension to basic research than business enterprises. To stress the issue, Mexico non-business R&D accounts for 76.7 percent of Total R&D while in Japan only 19.3 percent. Highly industrialized countries have indeed a lower percentage of non-business R&D even though in the EU context a 2/3 (66 percent) target of business out of Total R&D is seen as a desirable level (i.e., a non-business R&D share around 33 percent)[43].

The fourth indicators proposed in this study about the inputs of the R&D process is that about the percentage of researchers in the Labor Force[44]. Although not all researchers are involved in basic research, nevertheless a critical mass of creative workforce is a key condition for a valuable R&D output across all sectors and R&D fields. To take a lead at international level in

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[41] Such a target dates back to the EU “Lisbon strategy” for growth launched by the European Council in the year 2000.

[42] The number of researchers is measured according to the Frascati Manual guidelines. According to the Manual, researchers are *“professionals engaged in the conception or creation of new knowledge. They conduct research and improve or develop concepts, theories, models, techniques instrumentation, software or operational methods”* OECD (2015), p.162. For our purposes, researchers are measured in “full-time equivalents” rather than in heads’ number. The concept of Labour Force in statistics is defined as follows: *“The labour force or workforce or economically active population, also shortened to active population, includes both employed (employees and self-employed) and unemployed people, but not the economically inactive, such as pre-school children, school children, students and pensioners.”* (Eurostat Glossary, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Labour_force).

the researchers/labor force ratio a percentage above 1 percent is needed (i.e., France 10.39 per thousand, followed by Germany, Japan and New Zealand). Of course, countries with a large labor force, like India, or a not fully developed R&D system, cannot compete with them.

Two output indicators have been proposed to complement the four R&D input indicators just described: the number of articles in refereed S&T journals (as percentage increase in the total number from 2000 to 2018) and the number of patents' applications in some high-tech fields in 2018 (number of patents for Million Population). Among the different options to quantify the outcome of a basic research activity, to focus on formal dissemination of scientific results (articles) and formal protection of findings in selected high-tech fields (patents) seems to be relevant to allow for a meaningful comparison of national research performances. About articles, the dynamic approach highlights the catching-up process of countries with a lower number of researchers and research institutions. It has to be stressed that—among the sampled countries—a low increase in the number of articles over the last two decades is often associated with a high number of published articles already achieved in the past[45]. On the other hand, the number of high-tech patents, even if weighted by total population, emphasized the scientific and industrial potential of the largest OECD countries.

Table 8.1. Key fundamental research indicators* for 14 "Aspen" countries. Year 2018.

Indicators	R&D output (publications)	Total R&D	Basic R&D	R&D output (pat)	Public R&D	Researchers
Countries	S&T journals' articles: 2000 to 2018 increase (%)	R&D/GDP 2018 (%)	Basic research 2018 (% on total R&D)	High-Tech Patents per Million Population 2018.	Public R&D 2018 (% on total R&D)	Researchers per Thousand labor force (FTE)
Colombia	16.13	0.23	n.a.	0.12	35.23	0.17
Czech Republic	6.22	1.93	25.82	7.36	37.83	7.53
France	1.66	2.19	22.67	28.56	33.01	10.39
Germany	2.37	3.13	26.00	52.86	31.18	9.92
India	10.76	0.65	14.40	0.91	63.21	0.70
Italy	3.89	1.39	21.76	10.76	36.19	5.35
Japan	0.13	3.28	12.57	168.06	19.31	9.87
Mexico	6.80	0.31	30.52	0.22	76.74	0.71
New Zealand	3.52	1.35	25.06	8.57	44.79	9.83
Romania	9.21	0.50	19.31	1.28	40.44	1.90
Spain	4.51	1.24	21.05	5.44	43.23	6.08
Ukraine	4.07	0.47	22.40	0.25	41.53	2.15
United Kingdom	1.34	1.70	18.10	26.81	28.65	8.92
United States	1.87	2.83	16.59	55.36	23.21	8.73

*) - Number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences. Data from 2000 to 2018. Source: World Bank (https://data.worldbank.org/indicator/IP.JRN.ARTC.SC).

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[45] To further clarify the nature of this indicator, it can be said that it has a low negative correlation with the total number of publications (-0.28) and a high positive correlation with the average number of articles per researcher (+0.73).

- R&D on GDP ratio (2018). Source: UNESCO UIS (http://data.uis.unesco.org/Index.aspx?DataSetCode=SCN_DS&lang=en). National data for NZL (https://www.stats.govt.nz/reports/research-and-development-in-new-zealand-2018).

- Basic research on Total R&D (%, 2018). 2017 data for NZL and IND; 2016 data for GBR. Source: UNESCO UIS. German data from national sources and authors' calculations.

- High-Tech patents per Million Population 2018. Source: OECD (https://stats.oecd.org/Index.aspx?DataSetCode=PATS_IPC#). Data selected: IP5 patent families, by inventors' countries of residence, by priority date. Patents refer to the following WIPO technology fields: biotechnology, ICT, artificial intelligence, nanotechnology, medical technologies, pharmaceuticals.

- Public (Government+Higher Education) R&D on Total R&D (%, 2018). Source: UNESCO UIS.

- Researchers per Thousand Labor Force (Full Time Equivalent, 2018). 2017 data for NZL; 2016 data for IND and MEX. Source: UNESCO UIS.

The current state of the research system in fourteen countries across four continents—i.e., those countries where an Aspen institution is based—will be shortly described below in a comparative exercise. A quantitative profile will be provided for each country by the six indicators from Table 8.1[46]. Additionally, a short description of the main features of the R&D undertaking in the concerned countries will be shortly provided for with a focus on the external perception of the countries' potential compared to a summary of current actions and policies implemented at national level in the R&D and innovation field.

8.1. United States

Key figures

It is obvious to say that the U.S. plays in a league by its own: by looking only to the scientific articles published in the 13 countries of the sample, 38 percent of them comes from the U.S.. For all indicators in the chart, the U.S. compete with JPN and GER for the leadership. The private sector has a key role in the R&D performance (76.8 percent of Total R&D) with a potential deficit in the undertaking of basic research (similarly to JPN).

Short country profile

Most of the R&D work in the United States takes place in the private sector, including more than three-quarters of the research and development (R&D) paid for by the Federal Government. Nevertheless, most of basic research—roughly 70 percent of the total—is managed by the non-business sector (11.0 by the Government, 46.5 by universities, 13.6 by non-profit organizations according to 2018 data, the latest available from the National Science Foundation[47]). While the basic research in the business sector is almost totally self-funded by the firms themselves[48], the

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[46] In order to draw comparable charts, figures from Table 8.1 have been log-linearised.

[47] https://ncses.nsf.gov/pubs/nsf21324#:~:text=U.S.%20R%26D%20Increased%20by%20%2451,Billion%20%7C%20NSF%20%2D%20National%20Science%20Foundation

public sector (Federal + local Government) is largely funding basic research performed by public research institutions, federal agencies and universities. Overall, 43.6 percent of the U.S. basic research in 2018 was financed by the public sector. Around 40 billion US$ have been devoted by the U.S. Government sector to basic research in 2018 (with almost 60 percent aimed at supporting basic research in universities). Life sciences (including medicine) is the scientific field whose basic research is mostly funded by the U.S. Government (50.2 percent of total public funding to basic research) followed by Physical sciences (16.4), Engineering (9.9), Environmental Sciences (8.3), Computer Sciences and mathematics (5.8) and other sciences (9.5).

Current research policies

A main concern in the U.S. is that of losing ground in the international R&D competition[49]: China is catching up with the U.S. R&D spending and the U.S., according to OECD data, are now only tenth in an international ranking by R&D intensity (R&D/GDP). While waiting for the definition of a clear R&D strategy by the new U.S. Administration, the public debate is focusing on a number of issues often linked to higher investments on basic research. The first need is that of restructuring the governance of the S&T Policy giving the authority for the coordination of the national R&D and technology policies a higher status in the Federal Administration.[50] The second need is that of increasing the Federal R&D budget. A recent proposal by the U.S. President provides a summary of the political measures that are going to be implemented in the next years:

> *"… includes a 9% increase, or $13.5 billion, in total federal spending on R&D, bringing the total to $171 billion.* ***Spending on basic research would rise by 10%,*** *or $4.4 billion, to $47.4 billion, whereas applied research would get a 14% bump ($6.3 billion) to $51.1 billion."*[51]

Additional sensitive topics will have to be addressed in this context: research to deal with the environmental risks, preventing health-related emergencies or assuring equal opportunities and ethical behavior in the research environment[52].

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[48] In the U.S. an incremental R&D tax credits scheme is applied, covering also selected firms' basic research investments. See: https://www.oecd.org/sti/rd-tax-stats-united-states.pdf

[49] See: https://www.aaas.org/news/snapshot-us-rd-competitiveness-2020-update

[50] https://www.executivegov.com/2021/01/president-biden-directs-establishment-of-sandt-advisory-council/

[51] https://www.sciencemag.org/news/2021/05/biden-seeks-big-increases-science-budgets

[52] https://www.pnas.org/content/117/35/20977

8.2. Japan

Key figures

Japan is a unique case in the sample. The highest R&D/GDP ratio is associated with a well-developed capacity of the R&D system to serve the industry needs (with a top-level patent productivity by Japanese researchers). In such a context the contribution by the non-business research institutions is the lowest in the sample (less than 20 percent) as it is the basic research ratio on Total R&D: 12.57 percent.

Short country profile

In April 2017, the OECD briefed the Japan Government about its innovation policy[53], arguing that:

> *Japan is amongst the world's largest investors in science and innovation, spending almost 3.5% of GDP on research and development (R&D) in 2015, the third highest in the OECD area. However, this investment in innovation has not translated into strong productivity growth and business investment in R&D only topped pre-crisis levels in 2014. Japan's overall investment in knowledge-based capital also lags that of other major OECD countries.*
>
> *Japan's public R&D expenditure per GDP amounted to 0.71% in 2014. Although slightly above the OECD median, this is modest in light of Japan's high overall R&D intensity. The number of universities of global stature, the level of publications in top academic journals and the international mobility of researchers rank low compared to the OECD median. Moreover, there is little cooperation between universities and industry. These indicators suggest that Japan's public research could be strengthened further.*

Thus, some shortcomings were emerging also in the S&T system of Japan, recognized as a global technological leader. Indeed, the issue was not neglected by the Japan Government that, between 2016 and 2020, has been undertaking the ambitious 5th Science and Technology Basic Plan[54] aimed to develop fields at the knowledge frontier as well as to implement innovative concepts like Industry 4.0/Society 5.0.

Nevertheless, the outcome of a huge effort in terms of both S&T planning and funding (on average, more than 45 billion US$ per year from 2016 to 2020[55]) has neither allowed to meet the expected targets[56] nor be seen as successful by national and international observers[57]:

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[53] https://www.oecd.org/policy-briefs/japan-strenghtening-innovation-for-productivity-and-greater-wellbeing.pdf

[54] Council for Science Technology and Innovation. (2016). Outline of the Fifth Science and Technology Basic Plan. (https://www8.cao.go.jp/cstp/english/basic/5thbasicplan_outline.pdf)

[55] https://www.br.emb-japan.go.jp/files/000373819.pdf

[56] https://www.nistep.go.jp/en/wp-content/uploads/NISTEP-RM295-SummaryE.pdf

[57] Leo Lewis, "Japan's innovators seek their lost mojo", *Financial Times*, 7 March 2021.

> *"Japan now has only one company, Toyota, in the world's top 50 by market value. Once an innovative technology leader, the country is today far from being an instinctive, fearless challenger of boundaries. Three decades ago, 32 of the top 50 companies were Japanese. That slide coincides with the steady fall of Japanese universities through the global academic rankings and a worldwide decline in Japanese research paper citations from fourth place to 11th since 2000. […]*
>
> *Over the past two decades, Japan's global share of patent awards has fallen from more than 30 percent to 10 percent. Researchers last year found that the total planned $160bn R&D spending of just five U.S. companies (Amazon, Facebook, Apple, Microsoft and Alphabet) was bigger than that of the whole of corporate Japan.".*

Current research policies

The Japanese Government has proven to be very reactive in dealing with a loss of research and innovation capabilities potentially harmful for the perspective country's economic growth[58]. First, an increase of R&D spending in 2020 has been included in the recovery package to deal with the economic downturn due to the COVID-19 crisis:

> *""We expect Japan to maintain its high levels of R&D spending," said Shigeto Nagai, head of Japan economics at the Oxford Economics said. The world's third-biggest economy is projected to maintain an R&D investment ratio to GDP of 3.2%—higher compared with fellow G7 members, namely, the U.S. (2.8%), U.K. (1.7%) and Germany (3.0%), the research firm said in a note. […]*
>
> *"We expect this will mitigate the decline in fixed investment, at least in 2020," Nagai said.*
>
> *R&D has a 15% share in Japan's gross capital formation in GDP, the third-largest contributor next two machinery and equipment (34%), and non-residential buildings and structures (30%)."*[59].

Second, by introducing a brand-new Fund for University research. The plan for the new endowment's assets is such that, starting by March 2022 with about 43 billion US$ in public seed money, is expected to grow over time to 10 trillion Yen (about 97 billion US$)[60]. This target, if achieved, would make it one of the world's largest endowment funds to support science research. The Government will place the new Fund under the Japan Science and Technology Agency, but it will be professionally managed to achieve gains from the stock and bond markets and will invest in internationally competitive research and shared facilities for universities, increased R&D infrastructure for universities to scale up research, and a national innovation ecosystem.

Opinions about the effectiveness of this new Fund are, indeed, mixed ones. On the one hand, financial experts regard the Government forecasts of a 3-4 percent annual return for a university

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[58] https://www.openaccessgovernment.org/how-can-japan-remain-a-world-competitor-in-science-and-technology/94861/

[59] https://www.icis.com/explore/resources/news/2020/08/18/10542063/japan-r-amp-d-investments-to-stay-resilient-despite-recession-amid-pandemic

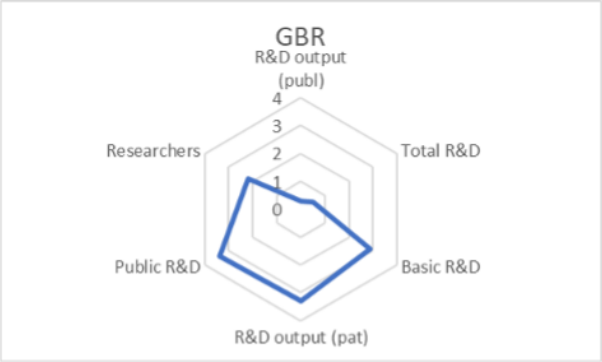
[60] https://www.bloomberg.com/news/articles/2021-02-08/japan-s-100-billion-innovation-fund-risks-playing-it-too-safe

endowment fund quite ambitious. On the other hand, researchers are afraid that a potentially powerful tool to boost basic research in Japanese universities could be mostly used to fund short-term research project under the pressure of financial investors[61].

In the private sector, where a potential for recovering from the decrease in R&D productivity suffered in recent years is confirmed by industry analysts[62], a relevant support to R&D is still given by fiscal incentives. Two schemes of R&D tax credits are currently implemented in Japan: a volume-based R&D tax credit (6-10 percent of R&D expenses according to the previous years' activity) and an Open innovation activity-based R&D tax credit (20 to 30 percent for expenses from research project) which can be used in combination[63].

8.3. United Kingdom

Key figures



The pattern of the U.K. R&D system can be compared with other leading European countries, like FRA and GER. Indeed, the U.K. can rely on a more efficient private R&D sector but with a poor impact on indicators like scientific (articles) or technological (patents) productivity. On the other hand, the effects of a different private/public balance in R&D performance are evident: lower share of basic research on Total R&D and lower share of researchers on the labor force.

Short country profile

The excellence of the U.K. research and innovation system is internationally recognized. However, improvements are always possible and, to some extent, needed to preserve its leadership. Back to 2015, the European Commission identified four areas of potential improvement for research and innovation policies in U.K.[64]:

> *"Increasing public and private sector investment in R&I;*
> *R&D specialisation and commercialising public R&D;*
> *Boosting support to scale-ups, including high-growth innovative enterprises;*
> *Ensuring future supply of human resources in S&T.".*

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[61] https://www.universityworldnews.com/post.php?story=20210203130630432

[62] https://www.mckinsey.com/business-functions/operations/our-insights/a-new-era-for-industrial-rnd-in-japan

[63] https://www.oecd.org/sti/rd-tax-stats-japan.pdf

[64] https://rio.jrc.ec.europa.eu/country-analysis/United-Kingdom

Additional remarks can be found in the annual country report (2020) by the European Commission, possibly the last formal review of the U.K. economy before getting divorced[65]:

> *"While the U.K. is considered a 'Strong Innovator', R&D investment intensity has remained flat, and below the EU average, for the past decade. In 2018, R&D expenditure reached £36.5 billion (€41.3 billion). However, research intensity (total R&D expenditure as a percentage of GDP) was still only 1.71%, below the EU average of 2.11%. In 2018, although the business sector spent £25.2 billion (€28.5 billion)—representing 69% of U.K. total R&D expenditure —business research intensity was at 1.18% of GDP also significantly below the EU average of 1.41% […].*
>
> *R&D investment in the U.K. remains concentrated in a limited number of companies and regions. 400 firms account for the bulk of business R&D investment. The South-East, the East of England and London regions undertook the majority of total U.K. research and innovation activity […].*
>
> *Although U.K. universities are regarded as global research leaders, science-business linkages could be strengthened. U.K. universities are a leader in terms of highly cited publications, and the U.K. has improved in international rankings of knowledge diffusion. Nevertheless, there is scope for the business sector to capitalise more on the U.K.'s scientific strength.". The approach to future R&D funding in the U.K. was laid out in the December 2019 Queen's Speech. The U.K. plans to increase public R&D funding, with greater emphasis on high-risk, high-payoff research in emerging fields, a fast-track immigration scheme and reducing bureaucracy in research funding (HM Government, 2019a). Delivering on these ambitious proposals will be a challenge, as will the aim to increase R&D investment intensity to 2.4% of GDP by 2027.".*

Current research policies

The governance of the U.K. R&D and innovation system is an example of effective public management: since 2018, a single agency—U.K. Research and Innovation (UKRI)—acts as an umbrella for the whole system[66]:

> *"The purpose of U.K.RI is to create a strong, agile and joined up funder of research and innovation for the U.K.. UKRI brings together the seven Research Councils, Innovate U.K. and Research England (formally the Higher Education Funding Council for England (HEFCE)). […] UKRI delivers the majority of public funding for research and innovation in the U.K.. It will play a central role in realising the U.K. Government's ambition of 2.4% of gross domestic product (GDP) investment in research and development (R&D) by 2027.".*

UKRI's activity relies on a robust network of institutions, thus allowing for a clear differentiation of roles[67]. Three main areas of specialization can be identified:

> *"**Innovate U.K..** The U.K.'s innovation agency, works with companies to de-risk, enable and support innovation, including through providing innovation grants and investing in Catapult centres.*

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[65] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1584543810241&uri=CELEX%3A52020SC0527

[66] https://royalsociety.org/-/media/policy/Publications/2019/03-10-19-ukri-explainer.pdf

[67] https://royalsociety.org/-/media/policy/projects/investing-in-uk-r-and-d/how-does-the-UK-government-invest-in-R-and-D-07-11-17.pdf

> ***Research Councils.*** *The seven Research Councils, divided by scientific discipline, support excellent research by providing grant funding, access to excellent research facilities and investing in infrastructure and institutions.*
>
> ***Research England.*** *Research England takes over the England-only funding of knowledge exchange formerly performed by HEFCE. This takes the form of quality related block grants to Higher Education Institutions.".*

Once framed the system, in order to identify the priorities of the current U.K. R&D strategy, the key reference document is the U.K. Research and Development Roadmap, published in July 2020[68]. The Roadmap's objectives are very ambitious but defined as guidelines to be provided to a set of independent and highly specialized institutions like the Research Councils and the universities.

In addition to the R&D activity carried out by existing institutions within the UKRI framework, another Agency has been recently established:

> *"The […] Roadmap […] sets out the Government's intention to cement the U.K.'s position as a science superpower. The R&D Roadmap described the Government's plans to invest £800 million in a unique and independent funding body for advanced research, broadly modelled on the U.S. Advanced Research Projects Agency (ARPA). The creation of ARIA [**Advanced Research and Invention Agency**] is part of the Spending Review 2020 commitment to invest £14.6 billion in research and development (R&D) in 2021-22 with a view to increasing economy-wide investment in R&D to 2.4% of GDP by 2027. As the R&D Roadmap sets out, ARIA will champion bold and transformative R&D which has a high chance of failure but can produce the greatest long-term rewards. ARIA "will back breakthrough technologies and basic research by experimenting with new funding models across long-term time horizons" and "invest in new ideas and empower researchers to deliver radical technological advancements"."*[69] .

The role of basic research in such segmented, although interlocked, system is central but interpreted differently according to the context the main actors of U.K. R&D operate. On the one hand, the Roadmap, with reference to the traditional R&D sector, states as follows:

> *"**Supporting long-range, fundamental, underpinning science and research.** We have set out an ambitious commitment to increase public investment in R&D by 2024/25. A significant proportion of this will be to restore and increase our support for long-range discovery research. We will diversify the way we fund discovery research to enable researchers to embrace the cutting-edge techniques and approaches needed to solve the most complex and difficult questions. This could include more support for investigator-led and team based funding, supporting projects for a longer timeframe, and introducing lighter-touch and quicker ways to fund good research ideas. We should be prepared to take risks. Research by its very nature has uncertain outcomes, but we need to accept this uncertainty, and the risk of failure, if we are to garner the successes. We are committed to supporting the most creative, innovative and radical ideas for the long term, accepting inherent risk where there is transformative potential.".*

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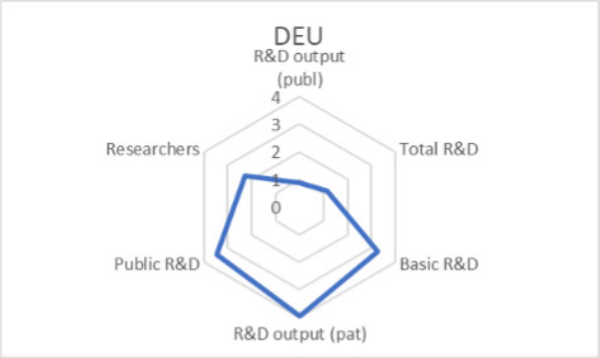
[68] https://www.gov.uk/government/publications/uk-research-and-development-roadmap/uk-research-and-development-roadmap

[69] https://publications.parliament.uk/pa/bills/cbill/58-01/0264/en/200264en.pdf

On the other hand, the newly established ARIA, looking for a new model of R&D funding, is proposing a different approach in a pioneering adoption of a High-Risk-High-Reward approach[70]:

> *"ARIA may set highly ambitious research goals which, if achieved, would bring about transformative scientific and technological advances. These advances would yield significant economic and social benefit. These goals may be highly ambitious meaning that it is likely that only a small fraction will be fully realised. The Bill allows ARIA to have a high tolerance to project failure".*



8.4. Germany

Key figures

Among the EU leader countries, Germany is a powerful generator of scientific knowledge in the European context. It features 60 percent more scientific publications than France (but with a similar slowdown in recent years), a higher R&D/GDP ratio, more basic research and almost twice the number of patents by population. The role of businesses is crucial in the German R&D sector but, even more, the degree of co-operation between the public and the private sector.

Short country profile

As part of the effort to assess the quality of the research and innovation systems in EU countries, the European Commission has produced a set of reports including a study on the German R&I system, although it is usually ranked very high among its European partners. Some challenges have been identified for Germany, as well[71]:

> ***Digital economy and society:*** *Germany ranks only in an intermediate position with regard to exploiting opportunities from digitalization. […].*
>
> ***Start-up ecosystem:*** *The number of entrepreneurs in Germany continues to decline, partly due to promising career opportunities for potential entrepreneurs in established firms given the strong labour market. Recent policy changes and developments for the increased availability of venture capital, favourable tax regulations and the establishment of a dedicated stock market segment as an exit option for early-stage investors hold much promise to improve entrepreneurship in Germany.*
>
> ***Strengthening innovation in established firms, particularly SMEs:*** *While overall business expenditure for R&D show strong growth rates, innovation activity has become increasingly concentrated in large firms and medium-high tech manufacturing sectors, especially automotive production. Major policy initiatives have been put in place to strengthen existing R&D policies*

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[70] https://www.gov.uk/government/publications/advanced-research-and-invention-agency-aria-statement-of-policy-intent

[71] https://rio.jrc.ec.europa.eu/country-analysis/Germany/country-report

> *favouring SMEs. R&D investments of SMEs have improved in 2015 which may signal a trend reversal. Political discussion has returned to considering R&D tax credits which would have the potential to foster R&D investments broadly with comparatively low administrative costs.*
>
> ***Resource availability for excellent science system:*** *The German science system has significantly improved its ambition for differentiation and excellence following the joint initiative of Federal and State (Länder) 1-governments, e.g., the Initiative for Excellence. These joint initiatives have large potential but require strategic decision-making. The Excellence Strategy and the Programme for the Support of Young Scientists hold much promise. However, it remains unclear whether they are sufficient to create attractive career opportunities for excellent researchers in Germany.*
>
> ***Smart specialisation:*** *Overall, Germany has made good progress in the strategic planning of the smart specialization strategies. Research and innovation are major objectives on a national and Länder-level. The officially confirmed national strategy for Germany is the High-Tech Strategy, which is being planned and implemented with the active participation of all ministries".*

The German approach, rather than increasing the R&D performance, seems aimed at making R&D results more useful for the country's economy. More information can be found in the annual European Commission Report on the German economy[72]:

> *R&D intensity has increased during the last years, from 2.46% of GDP in 2007 to 3.13% in 2018 (3rd highest in the EU). A new national R&D intensity target of 3.5% by 2025 was included in Germany's High Tech Strategy […]. With two thirds of the R&D performed in the business sector, German business R&D intensity (2.16% in 2018) is the third highest in the EU. However, business R&D is predominantly performed by large firms in R&D-intensive industries, whereas small and medium-sized enterprises' R&D expenditure has stagnated over the past decade.*

A specific effort has, then, been devoted by Germany to help small enterprises to afford R&D projects:

> *The German Parliament adopted a new law introducing a tax incentive for R&D from 1 January 2020. The law allows businesses to claim a tax credit worth 25% of the eligible expenses (personnel costs of research staff or 60% of the fees for subcontracting). All companies regardless of size are entitled to the incentive for qualifying R&D projects. However, the base is capped at € 2 million, translating into a maximum tax credit of € 500,000 per company per year, which should benefit mainly SMEs. The tax credit can be paid out even where there is no tax liability.*

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[72] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1584543810241&uri=CELEX%3A52020SC0504

Current research policies

Any assessment of the role of basic research in the German S&T system is going to be strongly influenced by the combination, impossible to disentangle, between R&D and innovation. A truly original activity has been that of establishing a Federal Agency for Disruptive Innovation (SPRIN-D) with a budget of roughly 1 billion Euros until 2029, aimed at discovering highly innovative research projects with disruptive potential, at supporting their development and helping them break into a market. Innovation competitions intend to help find the brightest minds with the best ideas and examine the potential of existing research and development efforts[73]. This is an example of very intensive R&D (including basic research) undertaken in a context finalized to its market exploitation.

Another example is the Pact for Research and Innovation that aims to improve the competitiveness of German research[74]. This involves strengthening the large non-university research organizations and the Deutsche Forschungsgemeinschaft, Germany's most important research funder. Basically, it provides top quality research support and funding to selected R&D performers in Germany. Since 2005 the pact has guaranteed the basic funding and further development of the research institutions that are jointly funded by the Federal Government and the German states as well as the Deutsche Forschungsgemeinschaft. The pact will continue until 2030: the Federal Government and the German states will increase basic institutional provision by 3 percent per year. In total, there will be around 17 billion Euros made additionally available for research.

Although, basic research is not explicitly targeted by the German Pact, an extension of it at EU level—the *EU Pact for Research and Innovation*—currently under development by the European Commission will have even a broader approach, as mentioned in the 2020 EC Communication on the European Research Area (ERA):

> *"To support the implementation of the new Industrial Strategy and speed up the transfer of research results into the real economy, the Commission will guide the development of common technology roadmaps with industry to include R&I investment agendas from basic research to deployment."*[75].

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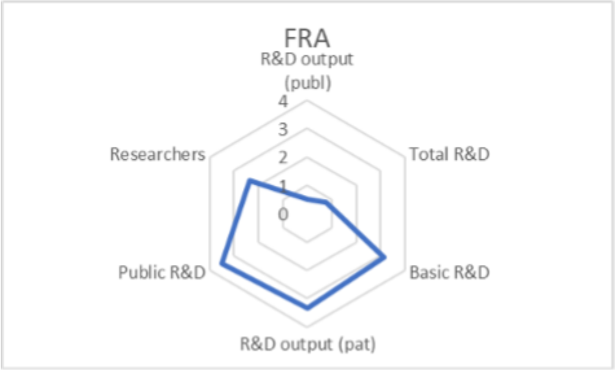
[73] https://www.research-in-germany.org/en/research-landscape/r-and-d-policy-framework/agency-to-promote-breakthrough-innovations-%E2%80%93-sprind.html

[74] https://www.research-in-germany.org/en/research-landscape/r-and-d-policy-framework/pact-for-research-and-innovation.html

[75] Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions, *A new ERA for Research and Innovation*, COM(2020) 628 final;Brussels, 30.9.2020. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0628&from=EN



8.5. France

Key figures

France can be included among the top performing countries in the R&D sector. A low dynamic of scientific publication is only evidence of a slowing down of its expansion process in 2018. All other indicators are placing France in a leading position in Europe, together with Germany and the U.K. (no longer an EU member). Remarkable is the combination of R&D investments in the non-business sector and in high-tech businesses (some of them, indeed, under State control).

Short country profile

France is a leading country, at international level, in the R&D and innovation domain. Nevertheless, mostly if seen from the perspective of a European Union Observatory, some challenges affecting (2017) the French S&T system are also evident:

> ***Simplification of Innovation policies:*** *In recent years, the French government has made significant efforts to improve the coordination of innovation policy. These efforts mainly consist of concentrating competences in some key operators and giving incentives to improve the coordination between these central players and other institutions (local or national) to ensure that they have a role in this field. […]*
>
> ***Fostering R&D and innovation in SMEs:*** *Despite continuous efforts to improve their involvement in R&I systems and their participation in regional or national programmes, small and medium-sized enterprises (SMEs) remain the weakest links of the R&I cycle. […]*
>
> ***A more efficient funding system for higher education and research:*** *The French research and innovation system has undergone profound reforms since 2013 to develop more consistent systems, reinforce public and private partnerships, and optimise the use of human and financial resources. These mainly consist in the creation of the third round of the Investments for the Future Programme ("Programme d'investissement d'avenir", or PIA3) Excellence Initiatives, which aim to improve cooperative behaviour in R&D-related areas but represent a small part of the budgetary endowments. […]*
>
> ***Promote R&I evaluation:*** *Policy evaluation is a continuous challenge in France. A dedicated organism, the National Commission for the Evaluation of Innovation Policies (CNEPI), has been created to assess R&D and Innovation policies and identify their economic impact."*[76]

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[76] https://rio.jrc.ec.europa.eu/country-analysis/France

A review of the most recent R&D-related policies and their impact can be found in the annual Report (2020) on the French economy by the European Commission[77]:

> *"Public support for R&D is characterised by complexity and low levels of efficiency, which may hamper the growth prospects of small and young firms and the development of new research activities. […]*
>
> *French research and development (R&D) investment as share of GDP is still below the 3% target for 2020. Total R&D intensity remained stable in 2018 at 2.20% GDP, above the EU average of 2.12%. However, it decreased from 2015 where it stood at 2.25%. Public R&D spending […] for 2017 and for 2018 (0.73% of GDP) were almost the same as in 2007. Business sector R&D spending for 2017 and 2018 (1.44% GDP) were the same as in 2012. As mentioned in last year's country report […], France is not on track to 2020 R&D intensity target of 3%.*

The EC Report is also observing limited results in the support to innovation in connection to R&D:

> *"Some evaluations of the R&D tax incentive (Crédit d'Impôt Recherche[78]) have been carried out and point to a limited impact on innovation. Additional impact studies, focused on macroeconomic aspects, are on-going. The Innovation and Industry Fund is not yet operational as pointed by the Court of Auditors. […] Overall, the R&D&I system in France remains very complex with numerous funding tools and structures."*

Current research policies

According to the 2020 EC Report, a clear description of the French strategic orientation for R&D is not easy to find:

> *"Six years after its creation, the Strategic Research Council (Conseil Stratégique de la Recherche) has yet to identify research priorities as required by its mandate. While the National Institute of Research in Digital Sciences fully coordinates all actions in the artificial intelligence sector, the coordination of other research actions and the strategic planning are widely dispersed."*

The main source of information on the qualitative and quantitative choices of the French Government is currently the Law for Research Planning (Loi de Programmation de la Recherche, LPR), passed by the French Parliament in November 2020.[79] Such French R&D planning is quite ambitious, served by an overall budget of roughly 25 billion Euros to be spent by 2030. A summary of the contents is provided by the Ministry of Higher Education, Research, and Innovation[80]:

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[77] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1584543810241&uri=CELEX%3A52020SC0509

[78] The R&D tax credit scheme in France is the 'Crédit d'Impôt Recherche'. It is one of the most generous tax credit scheme among OECD countries (€5.6 bn, 0.24 percent of GDP in 2018). This R&D tax credit alone accounts for about 60 percent of the total financial public support to business R&D in France.

[79] https://www.enseignementsup-recherche.gouv.fr/pid39124/loi-de-programmation-de-la-recherche-2021-2030.html

[80] Our translation.

> ***"A program for scientists, built with them [...]***
>
> ***A 10 year program.*** *It takes into account: the inherently long research time and give back time and visibility to laboratories; provides a coherent and lasting framework for the reforms undertaken to multiply the effects of public investment in research; prepares a framework in perfect resonance with the Horizon Europe program which will come into force in 2021; and identifies the major research programs that will be conducted to meet the needs of the nation—while giving full place to so-called "basic" research, which pushes forward the frontiers of knowledge.*
>
> ***An unprecedented funding effort.*** *The research programming bill provides for an increase in the research budget compared to 2020 of 400 million euros from 2021, 800 million euros in 2022 and 1.2 billion euros in 2023. Over the same period, the combined contribution of the recovery plan and the PIA4 will result in investing at least 4.6 billion euros in a strict research scope and more than 6.2 billion euros in the extended scope of the research operators concerned by the programming bill. French research will thus benefit from an unprecedented funding effort since 1945. Reinvestment will reach (real estate excluded and LPR included), 1.85 billion euros in 2021, 2.3 billion euros in 2022 as well as in 2023.*
>
> ***The 3 areas of the agreement on the improvement of remuneration and careers.*** *Engage in a new compensation deal based on the harmonization of bonus schemes for higher education and research staff. Define a new balance of the corps and ranks of teacher-researchers and researchers in order to align the career prospects of these two scientific fields. Reclassify the jobs in the field of engineers and technical research, and training personnel, in order to better recognize the skills of agents and to better meet the growing qualification needs of the jobs assigned or in the service of research units."*

In spite of some criticisms on the new regulation about the recruitment and the careers of the researchers and the university staff,[81] the potential impact of this new Law is remarkable. A key policy issue of this unprecedented planning is choice to be done for the prioritization of French (mainly public) R&D in the coming years, i.e., the role of basic research. Will it have a central place in the R&D policy orientation (as described in the Annex to the Law)?

> *"More broadly, the ambitions of French science are such of helping to meet the major challenges of society as defined by the United Nations Sustainable Development Goals and by the French roadmap of the 2030 Agenda, through a continuum ranging from education to basic and applied research, involving interdisciplinary and intersectoral collaborations on complex research fields."*[82]

Or will a "selective" approach to R&D funding, based on the potential for innovation, prevail?

> *We must also continue to step up our efforts to help actors "transform the trial" and allow them to carry out large-scale projects with ambition. It will be an advantage to "transform the trial" at the team level; it means that it is needed to pursue risk-taking and the culture of transfer and impact: filing a patent is something that can be seen as a scientific and technological achievement, but transferring it and working it out from invention to real innovation is at another level.*

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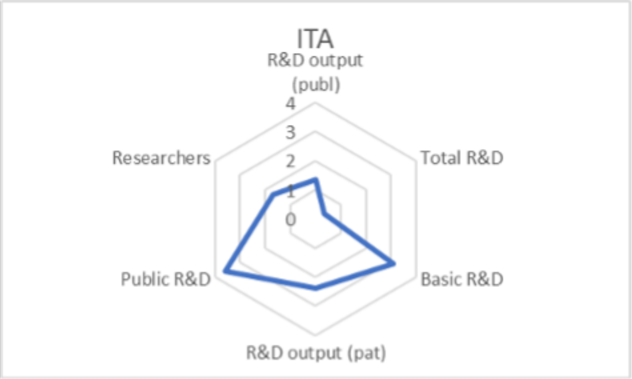
[81] https://www.lemonde.fr/sciences/article/2020/11/20/le-controverse-projet-de-loi-de-programmation-pour-la-recherche-definitivement-adopte-par-le-parlement_6060513_1650684.html

[82] Our translation.

8.6. Italy

Key figures



Italy follows a pattern already seen in Czechia and largely based on non-business R&D. R&D spending as a percentage of GDP is below the EU average and the intensity of researchers is almost half that of France or Germany. This poor structural dimension is only partially compensated by a relatively large role of non-business research institutions with a number of scientific publications higher than those of France and Spain.

Short country profile

The last formal assessment (2017) by the EU of the state of the Italian research and innovation system highlighted some long-standing issues affecting its governance and overall performance:

> *"**The low level of business R&I activities and unfavourable framework conditions**. […] The Italian economy is characterised by an overwhelming majority of small and micro enterprises active in industries with a low R&D intensity. […]*
>
> ***The public sector funding of R&I.** Preserving the activities of the public research system and of Italy's universities is a serious challenge, in particular after the budget cuts affecting R&D expenditure and university staff; limited job opportunities are currently available for researchers in the public sector; and outward migration of researchers and Italians with tertiary education is increasing.*
>
> ***Governance and management of the R&I system and policies** The Italian R&I system has been characterised by a number of issues affecting the management of R&I policies: fragmentation of strategies, with many initiatives at both national and regional levels; delays in the implementation of measures; and instability regarding budget availability and allocations. […]*
>
> ***Addressing territorial disparities** Italy has long suffered from large divergences between the North and the South with respect to economic structures, technological activities, incomes, unemployment, female participation, etc. […]"*[83]

Similar concerns have been highlighted also by the annual (2020) report by the European Commission on the Italian economy[84]:

> *R&D expenditure remains relatively low. […] Italy has achieved limited progress in the last years, and it is not on track to meet its target. In 2018 R&D intensity corresponds to 1.39% of GDP.*

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[83] https://rio.jrc.ec.europa.eu/country-analysis/Italy

[84] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1584543810241&uri=CELEX%3A52020SC0511

> *Public R&D expenditure reached 0.5% of GDP in 2018, the second lowest level among EU15 countries, and on a declining trend since 2013. While business R&D expenditure has been increasing in the last years reaching 0.86% of GDP in 2018, its level remains significantly below the EU average (1.41%). As a consequence, the number of researchers per thousand in the active population employed by business is only half the EU average (2.3% against 4.3% in 2017). Since 2017 most of the R&D growth is due to the activity of new firms investing in R&D, while firms that were already R&D performers recorded stable expenditure. Preliminary 2019 data show an increase of private R&D expenditure.*

Overall, Italy features a weak S&T system in terms of number of actors and volume of R&D performed, as well as in terms of governance and planning.

Current research policies

A remarkable point in the new Research National Program 2021-2027 (*Programma Nazionale della Ricerca*) is that of acknowledging the key role of basic research in the process of knowledge creation[85]:

> *"[…], research nourishes at every step its own dimension related to the pure generation of new knowledge: otherwise, it is not research. The distinction between fundamental and applied research is useful to generate a conscious balance between the two dimensions: it simply describes the two symbiotic faces of research that cannot live without each other. Any preconception such as any purist obsession that artificially divides fundamental science from applied science is a cultural bias, makes less effective the dynamics of knowledge and separates science from society. […] The basic research is characterized by leaving freedom of choice on topics and motivations. This widens the spectrum of potential uses and, in the long run, produces higher performance. Given such a context of unpredictability, serendipity and long-term work provide for a structure of strategic knowledge to understand the role of basic research in pursuing the priorities identified at social level. Unpredictable change is addressed by the flexibility provided by the multiplication of response capacities, skills differentiation, expansion and solidity of basic knowledge."*[86]

Unfortunately, the Program does not include a dedicated budget and the implementation of the actions envisaged in it will be subject to the availability of funds from the annual budget of the Ministry for University and Research (in combination with the EU-sourced research funding).

Indeed, Italian business enterprises have access to a scheme of R&D tax credits that covers, in principle, also basic research activities. As described by the OECD,[87] the measure has proven to be effective in increasing the volume of business R&D although undergoing several changes in its regulation over time:

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[85] Ministero dell'Università e della Ricerca, *Programma nazionale per la ricerca* 2021-2027. December 2020.

[86] Our translation.

[87] https://www.oecd.org/sti/rd-tax-stats-italy.pdf

Companies may offset earned credits against regional taxes and social security contributions, instead of their income tax liability, and carry forward any excess claims. The ceiling on R&D tax benefits amounts to EUR 3 million in 2020 (previously EUR 10 million). […]

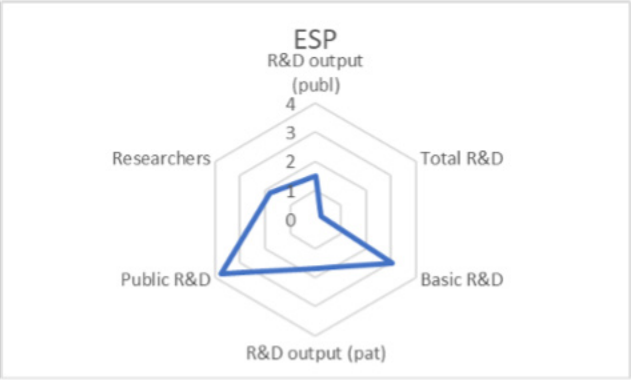
The generosity of R&D tax incentives varied significantly in Italy over the 2000-20 period […]. An increase in implied marginal tax subsidy rates is observable in 2007 when Italy introduced a volume-based R&D tax credit (Law 296/2006) for intramural R&D. With no refund or carry-over option, the implied tax subsidy rates of loss-making firms reflect the status of no tax support.

The marked decline in implied tax subsidy rates in 2010, followed by an upturn in 2015, relate to the abolition of the volume-based tax credit in 2009 and the introduction of a refundable, incremental R&D tax credit for intra- and extramural R&D in 2015. The introduction of a uniform tax credit rate of 50% for all types of eligible R&D expenditure in 2017 and its revocation in 2019, explain the increase in implied subsidy rates from the 2016 level in 2017 and their subsequent reversion to 2016 levels in 2019.

With the introduction of a volume-based R&D tax credit in 2020, replacing the existing incremental tax credit in Italy, the implied R&D tax subsidy rate estimated for SMEs and large firms increased notably from 0.07 to 0.11 in both profit scenarios, reaching the level of generosity that the former volume-based R&D tax credit, available in Italy from 2007 to 2009, provided to firms in the profit-case.

8.7. Spain

Key figures



The Spanish R&D system shares some common features with those of countries like Italy or New Zealand. A comparison with Italy is interesting as the quantitative evidence about the two countries' R&D systems is quite similar with Spain usually performing slightly less effectively than Italy with three main exceptions: the increase in the number of scientific publications (4.5 vs. 3.9 percent), the number of researchers on labor force (6.1 vs. 5.3 per 1000) and the percentage of R&D undertaken by non-business institutions (more than 43 percent in Spain). Even in Spain, the lack of a strong private R&D sector is affecting the overall S&T performance.

Short country profile

The 2017 evaluation of the Spanish research and innovation system by the European Commission[88] allows for the identification of the main challenges Spain has to face in this context, from both a quantitative and qualitative point of view:

> *"**Improving framework conditions for R&I.** The high GDP growth rate over the last two years has not triggered an increase in R&D intensity. In this context, a number of support schemes have been developed. The consolidation of the governance framework in this regard is essential to stimulate a favourable R&I ecosystem.*
>
> ***Improving funding and governance of the R&I system**. Despite the slight increase in total GERD in 2016, R&D intensity has continued to fall since 2010 and remains below the 2007 level. Fiscal deficit and public debt constraints have limited the action that the government can take regarding R&I funding. […]*
>
> ***Improving the labour market for researchers**. Human resource constraints were considered one of the most pressing challenges for the Spanish R&I system after the economic crisis. In recent years, a number of policy measures targeting R&I human resources have been adopted. These include the recognition of research as a 'priority sector', which has made it possible to set a special rate for replacement of retirees (maximum of 100% in 2017). […]*
>
> ***Stimulating regional R&I potential and performance**. Spanish R&D activities and funding are highly concentrated in four regions, all of them displaying an R&D intensity below the EU average."*

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[88] https://rio.jrc.ec.europa.eu/country-analysis/Spain

Some issues raised in the report are common also for other EU countries—e.g., a weak governance, a slow growth, etc.—but also lasting and hard to be properly addressed in the short run. Not surprisingly, a few progresses are mentioned in the annual (2020) report by the European Commission on the Spanish economy[89]:

> *Spain's innovation performance is below the EU average in all regions. Innovation suffers from public and private underinvestment in R&D, and the coordination of research and innovation policy across different levels of government remains a challenge. Lack of cooperation between academia and businesses hampers knowledge diffusion. Business innovation is constrained by the low absorption capacity of small firms. Regulatory fragmentation across regions also makes it more difficult for firms to scale-up. Regulatory barriers continue to restrict competition in certain professional services and in retail. […]*
>
> *Spending on R&D remains low compared with other Member States. Coordination of research and innovation policies across government levels remains a challenge and the evaluation of research programmes and policies is not systematic. […]*
>
> *Low investment in R&D is holding back Spain's innovation performance. Total R&D expenditures declined from 1.35% of GDP in 2009 to 1.24% in 2018. Public R&D expenditure was cut during the crisis and the cuts have not been reversed. Public investment in R&D declined from 0.65% to 0.54% of GDP between 2009 and 2018, well below the EU average of 0.69%. Private investment in R&D fell from 0.73% of GDP in 2007 to 0.64% in 2016. It has since recovered to 0.7% in 2018, but it is still low compared with the EU average of 1.41% (2018).*
>
> *Although the quality of the Spanish public research system has improved in recent years, on average the quality is still lagging behind. The research system has changed in various ways, including an update of the evaluation criteria for research staff. This has spurred growth in the volume of research. However, the quality of research, measured by the percentage of Spanish scientific articles in the top 10% most cited publications worldwide, is still lagging behind […], and it remains below the EU average. […]*

Current research policies

Two documents are setting the framework for the development of the Spanish S&T system over the next years: the Spanish Strategy for Science, Technology and Innovation 2021-2027 (*Estrategia Española de Ciencia, Tecnología e Innovación 2021-2027*[90]) and the State Plan for Scientific and Technical Research and Innovation (*Plan Estatal de Investigación Científica y Técnica y de Innovación*). The current version of the Plan is covering the 2017-2020 period, but the 2021-2023 Plan is expected soon. These two documents are complementary as the Strategy defines a multi-annual program to meet some objectives of improvement of the Spanish research system in co-operation with all

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[89] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1584543810241&uri=CELEX%3A52020SC0508

[90] Ministerio de Ciencia e Innovación, (2021). *Estrategia Española de Ciencia, Tecnología e Innovación 2021-2027*. Secretaría General Técnica. https://www.ciencia.gob.es/stfls/MICINN/Ministerio/FICHEROS/EECTI-2021-2027.pdf

the concerned institutions, while the Plan assures a consistency with the State Budget making the needed resources available.

It is worth to mention that in July 2020 the Spanish Government has issued an additional policy paper called “Shock plan for science and innovation” (*Plan de choque para la ciencia y la innovación*[91]). This additional Plan aims at fostering—in a very short period: 2020-2021—investments in three key areas and 17 measures. The three areas (or axles) are: research and innovation in health; transformation of the science system and talents’ attraction and retention; promotion of business R&D&I and of science industry. This Shock Plan is worth 1.056 billion Euros in only two years.

The Spanish R&D (and innovation) policy is, thus, very dynamic in the effort to address the enduring issues often highlighted by experts and international institutions. The role of basic research in this context is indeed marginal and this is justified by the strong emphasis on innovation rather than in fundamental science.

In the Strategy, basic research is mentioned only with reference to two strategic objectives. The first one refers to the coordination with the UN’s Global Development Goals (GDS):

> *“The thematic prioritization […] will enable the development of basic research lines and will promote the interdisciplinarity that generates high impact on science and knowledge. Likewise, will encourage multidisciplinarity that will allow for the development of scientific missions and the support to SDGs-related projects.”*[92]

Another one is related to the measures to be taken by the Centre of Technological and Industria Development (Centro para el Desarrollo Tecnológico e Industrial, CDTI):

> *“At the national level, the Science and Innovation Missions financed by the CDTI will contribute to integrating the work of businesses, researchers and institutions, public and private, in order to receive sufficient financial resources to achieve the planned impact. The actions included in the missions will cover the whole value chain: from fundamental research oriented to the action considered, to the development and integration of advanced and emerging technologies, and support for the technological innovation process with impact on new advanced products and services.”*[93]

In the Shock Plan, only one measure includes some support to basic research: “Enhance and connect the basic science by public research centers with business enterprises”. A support to basic research is thus framed, in this document as well, into a translational context.

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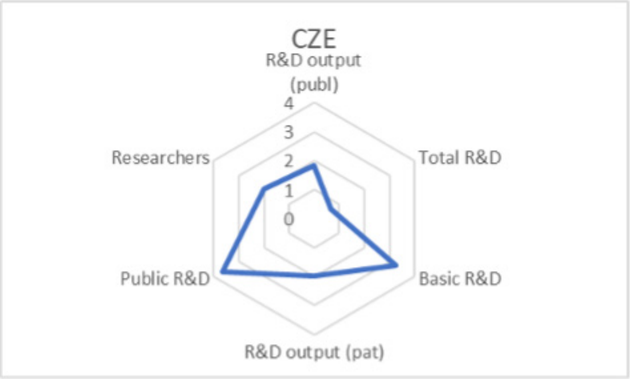
[91] https://www.ciencia.gob.es/stfls/MICINN/Ministerio/FICHEROS/Plan_de_choque_para_la_Ciencia_y_la_Innovacion.pdf

[92] Our translation.

[93] Our translation.

8.8. Czech Republic

Key figures



Some OECD countries included in the sample feature a similar shape of the chart (Czechia, Italy, New Zealand, Spain). This is the outcome resulting from the combination of a few factors: relatively low increase in the number of scientific articles and a low number of patents' applications although a strong effort to support non-business R&D, including basic research. Definitely, the weakest point is a relatively small private high-tech sector thus unable to significantly increase the overall investments in R&D and the country's patenting activity.

Short country profile

In 2017, a team of experts submitted to the European Commission a report on the state of the research and innovation system in Czechia. Some systemic challenges were identified:

> ***Reforming the governance of public research:*** *Governance of the R&I system suffers from a lack of coordination, fragmented division of competences and poor evaluation standards.*
>
> ***Opening the labour market for researchers:*** *Human resource management practices in the public sector could be improved by reducing scholar in-breeding, intensifying competition both internally and from abroad and making careers more attractive for young people.*
>
> ***Strengthening public-private linkages:*** *Despite the sustained policy efforts, linkages between public and private R&D sectors could be further improved. Knowledge transfer incentives are set at the level of individual organizations. A national strategy for knowledge transfer is lacking.*
>
> ***Deepening innovation capabilities and demand-driven innovation:*** *The current policy mix is dominated by R&D subsidy programmes with limited efforts devoted to supporting venture capital or business angels and revolving funds."*[94]

Like other countries, the potential for R&D and innovation is constrained by an inefficient management of available resources with a negative impact on the volume of investments. Three years after the publication of the above-mentioned report, the annual assessment of the Czech national economy by the European Commission confirms some enduring issues[95]:

> *Low returns, fragmentation, moderate scientific quality and low internationalisation lead to a modest performance. The total R&D expenditure has grown steadily since 2010, reaching 1.93%*

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[94] https://rio.jrc.ec.europa.eu/country-analysis/Czech-Republic/country-report

[95] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1584543810241&uri=CELEX%3A52020SC0502

> *of GDP in 2018, slightly below the EU average of 2.11%. Public R&D expenditure also rose from 0.56% in 2010 to 0.73% in 2018, still below the 2020 target of 1% of GDP. Despite the substantial increase in public R&D funding, the quality of scientific outputs (top 10% most cited scientific publications at 5.1% in 2016) remains modest at around half the EU average. Although the research system is more internationalised (as measured by international co-publications, at 46.5% in 2018), Czechia still ranks low at the EU level. In addition, the high fragmentation of the public research sector results in R&D funding being thinly spread. […]*
>
> *Public R&D expenditure is not supported by systemic and comprehensive reforms. Although some measures have been adopted, and expenditure is increasing, it is still too early to assess their impact. […]*
>
> *Business R&D intensity increased from 0.77 % of GDP in 2010 to 1.19% in 2018 (EU average 1.41%). A significant gap exists between the innovation performance of domestic firms and that of the large foreign-owned ones with a higher R&D spending. […]*

A key priority seems to be to strengthen the technology-oriented R&D and to improve both the business R&D funding system and the cooperation between academia and industry.

> *"The effectiveness of the* ***institutional governance of research and innovation policy remains limited.*** *Competence for research and innovation policy is shared between different authorities without an adequate coordination mechanism or synergies. A leading central institution with a cross-cutting coordination and practical overview role is lacking. Consequently, the decision-making bodies mostly work in silos. While research and innovation policy is supported by several strategies, these strategies lack coherence and coordination, leading to potential overlaps, uncertainties and lack of ownership by different entities." […]*
>
> *"**Funding for innovative enterprises remains limited.** Various public financial resources are distributed through individual entities, mostly in the form of direct support incentives, particularly grants and matching grants […]. Without other types of financial instruments or a vibrant entrepreneurial and financial ecosystem, innovation continues to be hampered." […]*
>
> *"**Links between academia and business are insufficient to support knowledge and technology transfer.** A low degree of public-private scientific co-publications (2.9% compared to an EU average of 5.5%) suggests a weak public-private cooperation. Regulatory barriers persist for spin-off creation and cooperation is often informal. In the public sector, researchers' careers largely depend on their publications track record, discouraging them to work with the industry. Still, there are signs that knowledge flows may be improving, notably via increased researchers' mobility."* [96]

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[96] Ibidem.

Current research policies

The Czech Government has been quite active, during the last five years, in promoting an improvement of the S&T system. Some actions—at both strategic and implementation level—are described it the EC report 2020[97]:

> *"The Innovation Strategy 2019-2030,*[98] *adopted in January 2019, supported by the majority of stakeholders, aims to move the country up the value chain and help it become an innovation leader by 2030. However, it remains to be seen how effective the shared ownership and implementation of the separate pillars of the strategy will be. The effectiveness of the strategy will depend on the successful implementation of the action plans prepared by the authorities." […]*
>
> *"Authorities introduced an amendment to the Investment Incentives Act in 2019. The aim is to provide further financial support to innovative enterprises that draw more from R&D and, in particular, to projects with higher value added."*
>
> *Additionally, the Tax Incentives Act amended in 2019 is supposed to address some of the shortcomings of the R&D tax incentives scheme and to boost the uptake of R&D tax breaks for innovative enterprises."[…]*
>
> *"The on-going Metodika 17+ reform is yet to be fully implemented by research organisations and higher education institutions (a comprehensive rollout is expected in 2020)."*

As to basic research is concerned, it has to be highlighted that, besides universities, most of it is carried out by only the Czech Science Foundation: *"an organizational unit of the state whose mission is to provide targeted support for fundamental research exclusively from public funds. It is the only institution of this type and with this mission in the Czech Republic."*[99]

From a policy perspective, although the National Research, Development and Innovation Policy stresses the need for a support to every type of research—applied research and experimental development, as main drivers of technological innovation, are currently the main priorities of the Czech R&D system:

> *"Research, experimental development and innovation (hereinafter only as "R&D") is one of the inseparable parts of development of every competitive society. However, for R&D activities to lead to the desired competitiveness, it is necessary that R&D activities and expenses are directed to areas, which could lead to competitiveness, i.e., priority areas."*[100]

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[97] Ibidem.

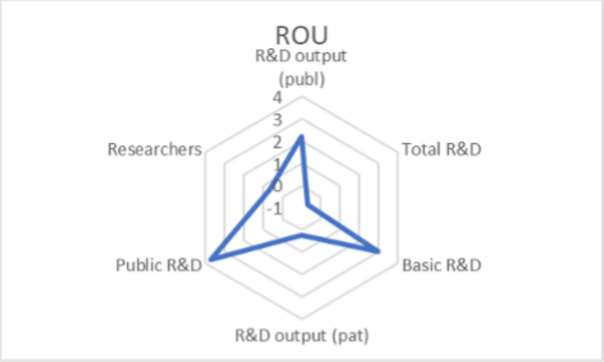
[98] Government of Czech Republic, (2019). *Innovation Strategy of the Czech Republic 2019—2030*, February 2019.

[99] Government of Czech Republic, (2016). *National Research, Development and Innovation Policy of the Czech Republic 2016—2020.* Section for the Science, Research and Innovation.

[100] Government of Czech Republic, (2012). *National priorities of oriented research, experimental development and innovations,* July. 2012.

8.9. Romania

Key figures



Romania is committed to rapidly catching up its EU partners in the R&D domain. As of today, it is still the least R&D-performing country in the EU R&D/GDP 0.50 percent, ranking low in the patents' application performance. On the other hand, the R&D system can further develop relying on its key assets: several highly reputed non-business R&D institutions and a large number of highly qualified researchers.

Short country profile

A European Commission report[101] highlighted in 2018 the main challenges the Romanian research and innovation (R&I) system was facing:

> ***"Increase public R&I expenditure:*** *The R&I system is chronically underfunded. With a GERD value per capita 14 times smaller than the average spent in EU28 (Eurostat, 2017), Romania had in the last ten years, one of the lowest, if not the lowest, GERD in EU28.*
>
> ***Significant brain drain generating lack of skilled human resources:*** *Romania has one of the highest share of researchers working abroad (World Bank, 2014).*
>
> ***Improve the governance of the R&I system at national, regional and institutional level.*** *Ensure predictability and stability: The R&I governance is characterised by excessive and burdensome bureaucracy, predisposition to overregulation, frequent legislative and institutional changes, lack of human resources.*
>
> ***Enhance the efficiency of public expenditure in R&I and education:*** *The limited funds for R&I are dissipated across a large R&I system which lacks funding schemes rigorously based on the results of the regular evaluation of the research and education performance.*
>
> ***Improve the framework for private RDI investment and the collaboration with the public sector:*** *The level of R&I funds invested by businesses is very low: 0.18% of GDP in 2015 (EU28 average in 2013: 1.12%)."*

Along the same lines, the 2020 Country Report, another document issued by the European Commission, stresses the need for increasing the R&D investments:

> *"In terms of research and development, the country is amongst the worst performers in the EU, spending just 0.5% of GDP in R&D activities in 2018 compared to the 2020 country target*

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[101] Chioncel, M.F. & Del Rio, J.C. (2018). *RIO Country Report 2017: Romania, European Commission, Research and Innovation Observatory* country report series.

> *of 2%. All peer countries in the region invest substantially more in R&D than Romania. This underinvestment has resulted in poor scientific quality and performance. Academia-business cooperation occurs mainly on an ad-hoc basis and its development is hampered by regulatory barriers. Without significant regulatory and budgetary changes, current measures are insufficient to tackle the underfinancing and structural problems affecting the research and innovation sector."*

The EU assessment of the measures implemented by Romania, and of their expected results, is also highlighting a structural weakness:

> *"Public expenditure on R&D has continuously fallen since 2011 from 0.32% of GDP to 0.20% in 2018. On the other hand, business enterprise expenditure on R&D (BERD) has increased from 0.12% of GDP in 2013 to 0.30% in 2018. EU-funded investments in R&D infrastructure are slowly taking off, but they are unlikely to address the chronic under-funding of the research and innovation system."*

Current research policies

Romania is currently committed to a full implementation of the National Strategy for Research, Development and Innovation 2014-2020 (updated in 2017).[102] Apparently, a new strategy has not yet been designed and the Government is focusing on the implementation of actions already formally adopted. As a consequence, it is not possible to assess whether the objectives set by the 2014-2020 strategy had been met.

A measure, recommended by the European Union in order to reinforce the direct support to private R&D, is the tax allowance (and accelerated depreciation of R&D capital) for business R&D spending[103] introduced in Romania in 2010. This measure is not very generous, at least compared to similar ones implemented in other EU countries,[104] as the expected advantage for the applicants is half the OECD average.[105] Nevertheless, BERD has increased from 0.12 percent of GDP in 2013 to 0.30 percent in 2018.

While proposals have been forwarded by the Government early in 2021 to launch a funding initiative to get the EU target of 2 percent of R&D/GDP, an issue largely debated in the Romanian research system is that of the governance: an issue encompassing both the political level (i.e., whether a Ministry of Research should be established) and the need for a simplified bureaucracy.[106]

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[102] https://www.edu.ro/sites/default/files/_fi%C8%99iere/Minister/2016/strategii/strategia-cdi-2020_-proiect-hg.pdf

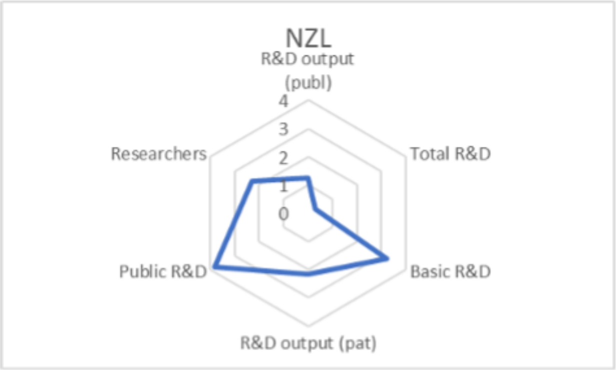
[103] https://www.oecd.org/sti/rd-tax-stats-romania.pdf

[104] European Commission, (2021). *Annual Report on Taxation 2021. Review of taxation policies in the EU Member States.* DG TAXUD.

[105] Differences in the design of R&D tax incentives drive significant variation in the "expected" generosity of tax relief per additional unit of R&D investment. In 2020, the marginal tax subsidy rate for profit-making (lossmaking) SMEs in Romania is estimated at 0.08 (0.07), well below the OECD median of 0.20 (0.18). The tax subsidy rate for large enterprises equals 0.08 (0.07) in the profit (loss)-making scenario, below the OECD median of 0.17 (0.15). These estimates model the provisions for the R&D tax allowance and the accelerated depreciation of R&D capital. (https://www.oecd.org/sti/rd-tax-stats-romania.pdf)

[106] https://sciencebusiness.net/news/romanian-researchers-push-reform-national-rd-funding

8.10. New Zealand



Key figures

As previously mentioned, the R&D system in New Zealand is comparable to some European cases: fair balance between business and non-business R&D performance (55 vs. 45), average R&D spending, basic research covering 25 percent of Total R&D. Since New Zealand is, by large, the smallest country in the sample by population a negative 'size effect' affects its R&D performance by reducing the competitiveness of its research system focusing more on scientific excellence in some fields, than on an overall impact in terms of publications or patents.

Short country profile

In 2016, the OECD provided for an assessment on the state of the innovation system in New Zealand[107]:

> *"…as an export-oriented economy that still relies heavily on the primary sector, there is room for diversification and the government is seeking to spur further investment in high-value manufacturing and services sectors through its actions in science and innovation. Investments in knowledge have been growing substantially since the crisis: public investments in science and innovation increased by 60% since 2007-08 and are expected to expand in the coming years. Yet, investment in R&D still remains low compared to the OECD average (GERD was only 1.15% of GDP in 2013 down from 1.25% in 2009) and is lower compared to leading small OECD economies […]. Increasing investment in R&D and complementary intangible assets such as firm-specific skills, data and new organisational processes is a key challenge given that productivity gap (when compared with the OECD average) could be the result of low investment in knowledge-based capital […]. To help address this challenge, New Zealand has committed to reinforcing investments in research and innovation."*

Three years later,[108] the OECD was still stressing the need for increasing investments on R&D:

> *"Despite generally good macroeconomic- and structural policy settings, New Zealand has relatively low productivity levels and hence earnings. This is due to lack of international connection and scale, qualification and skills mismatches, weak competitive pressures and low rates of capital investment and R&D activity."*

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[107] This is an addendum of: *OECD (2016), OECD Science, Technology and Innovation Outlook* 2016, OECD Publishing, Paris. http://dx.doi.org/10.1787/sti_in_outlook-2016-en

[108] OECD (2019), OECD Economic Surveys: New Zealand 2019, OECD Publishing, Paris, https://doi.org/10.1787/b0b94dbd-en.

Current research policies

The current strategic orientation of S&T policy in New Zealand is described in the *National Statement of Science Investment* 2015—2025, published in October 2015.[109] At that time, with reference to its financial engagement, the Government was stressing that public science and innovation expenditure (not just R&D) had increased by over 70 percent from 2007/08 to 2015. In parallel, there was a clear commitment to increase research investments in the years to come:

> *"The most significant market failure occurs in investigator-led discovery research. Given government's role as the primary investor in investigator-led research, this points to focusing a greater proportion of additional investment at the discovery end over time. We expect New Zealand's total investment in more certain or close-to-market research to grow in parallel, but to see that growth driven primarily by industry, with ongoing government contributions where appropriate."*

The *Research, Science and Innovation System Performance Report 2018*[110] is a detailed description of the results achieved by New Zealand in the R&D and innovation fields, as well as of the open challenges.[111] A key issue is that of the Total R&D spending and the R&D/GDP ratio. As a matter of fact, not only New Zealand has a low performance as R&D investor but the 2 percent target, set more than 10 years ago, it seems increasingly difficult to be met. Nevertheless, even though is acknowledged that public funding for R&D remains lower than OECD average, the policy target of increasing it from Budget 2017 on is confirmed.[112]

Focusing on business R&D, New Zealand features a sharp increase of investments in 2019 (+12 percent than in 2018 and twice the 2012 level) also thanks to the introduction of an effective scheme of fiscal incentives for R&D performed in New Zealand as a 15 percent tax credit.

The current attitude of the New Zealand Government toward basic research can be, even if in an incidental way, in the draft of a future *New Zealand's Research, Science & Innovation Strategy* published, for consultation, in November 2019.[113] In the document, some sentences are revealing of a strong support to innovation-oriented R&D emerging in the country.

About research impact:

> *"In the research sector, all of our publicly funded research should have a strong line of sight to impact. This means researchers and institutions receiving public funds should be able to articulate the impact of their research portfolios. Line of sight to these benefits does not mean focussing exclusively on applied, 'close-to-market' research or on individual projects. Historically, basic research has been*

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[109] https://www.mbie.govt.nz/assets/2eaba48268/national-statement-science-investment-2015-2025.pdf

[110] This report is based on the review of information needs carried out in the *Research, Science and Innovation Domain Plan*, published in September 2016.

[111] https://www.mbie.govt.nz/assets/7693f53535/research-science-and-innovation-system-performance-report-2018.pdf

[112] Latest available R&D data from Statistics New Zealand (https://www.stats.govt.nz/reports/research-and-development-in-new-zealand-2018) including figures on the overall funding of Total R&D by the Government give a contradictory message with Government funding peaking to 43 percent in 2014, then going down to 39 percent in 2016 and reaching 40 percent in 2018.

[113] https://www.mbie.govt.nz/dmsdocument/6935-new-zealands-research-science-and-innovation-strategy-draft-for-consultation

> *essential to expand the knowledge frontier and challenge paradigms. However, even if the outcomes of more basic or high-risk research cannot be predicted, we need to be able to demonstrate its contribution—even if attribution is imprecise or we do so after the research is completed."*

About the "knowledge frontier":

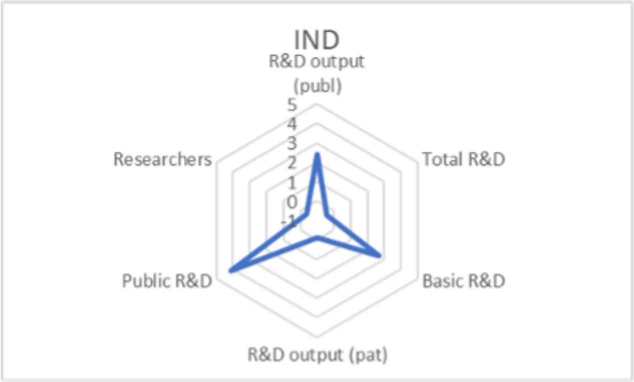
> *"Innovating toward the frontier does not imply exclusively novel activities, nor does it imply only basic or 'blue skies' research. Applied research can extend the global knowledge frontier as much as basic research. What we do know is that where people are working at the global frontier in one aspect of their business, they are more likely to be drawing on leading technology and knowledge from elsewhere in the world."*

About research excellence:

> *"Often, international literature and indicators providing information on RSI consider 'excellence' to refer solely to the number of times an academic paper is cited. That is not the definition we use here. Excellent RSI does not have to result in a publication. It is as likely to occur in a small start-up firm as in a large academic institution. Excellence is a term that can apply just as easily to applied research as it can to basic or fundamental investigation."*

8.11. India

Key figures



Among the fourteen sampled countries, India is an example of a large country struggling to keep the pace with the international leaders in R&D performance (a similar strategic posture will be observed in Mexico and Romania). High increase of scientific publications over the last two decades (and the second largest number in 2018, after the U.S.), remarkable investments on public R&D and, notably, on basic research. On the other hand, several weaknesses: a low number of researchers compared to its large population, a low level of private R&D spending and, as a result, a low patent productivity.

Short country profile

The context observed by independent experts in the last years was not encouraging as:

> *"In 2018, India spent 0.69% of its gross domestic product on research and development, compared with 0.84% a decade earlier. This compares with China's 2018 spending of 2.1% and South Korea's of 4.2%."*[114]

The Indian Government itself recently highlighted the key issue of a structural under-investment on R&D mainly due to a low contribution by the private sector:

> *"The business sector in India contributes much less to gross expenditure on R&D (about 37 percent) when compared to businesses in each of the top ten economies (68 percent on average). This is despite the fact the tax incentives for R&D were more liberal in India when compared to those in the top ten economies. The Government does a disproportionate amount of heavy-lifting on R&D by contributing 56 percent of the gross expenditure on R&D, which is three times the average contributed by governments in the top ten economies. Yet, India's gross expenditure on R&D at 0.65 percent of GDP is much lower than that of the top 10 economies (1.5-3 percent of GDP) primarily because of the disproportionately lower contribution from the business sector. Indian government sector contributes the highest share of total R&D personnel (36 percent) and researchers (23 percent) amongst the top ten economies (nine percent on average). Indian business sector's contribution to the total R&D personnel (30 percent) and researchers (34 percent) in the country is the second lowest amongst the top ten economies (over 50 percent on average)."*[115]

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[114] *Nature*, "India must protect the independence of its landmark science agency", 9 February 2021, (https://www.nature.com/articles/d41586-021-00327-1)

[115] Government of India, Ministry of Finance (2021), *Economic Survey* 2020-21, January 2021, p.238, (https://www.indiabudget.gov.in/economicsurvey/).

Current research policies

Several initiatives are currently going to be implemented by the Indian Government in the R&D field. Most of them are incorporated in the new Science, Technology, and Innovation Policy (STIP) strategy unveiled in December 2020 in a draft version.[116] This document, the fifth of this kind since 1958, provide a comprehensive plan for a ground-breaking support to innovation and R&D in India. The vision proposed by this document is impressive including the objective of: "*To double the number of Full-Time Equivalent (FTE) researchers, Gross Domestic Expenditure on R&D (GERD) and private sector contribution to the GERD every 5 years.*"

In general, some emphasis is given to the support to both "foundational" and "translational" research even though actual measures to be adopted have not been fully identified yet but the institution of a National Research Foundation (NRF). This agency:

> *"will distribute 100 billion rupees (US$1.37 billion) annually for its first five years, starting this year [2021]. It will have a particular focus on interdisciplinary work, and research in colleges and universities. … it is the most significant development in India's research-funding policy in at least a decade. For more than 70 years, researchers at India's many thousands of colleges and close to 1,000 universities have had few sources of large grants. Most of India's research and development funding has been concentrated in government laboratories and a network of prestigious institutes of science and technology, whereas the focus of universities has been on teaching. As a consequence, India had just 255 researchers per million people in 2017—a fraction of that in many other countries. For example, Israel had 8,342 per million, Sweden 7,597 and South Korea 7,498 in the same year."*

Less clear is the strategy that the Indian Government will adopt to support the increase in private R&D. According to the STIP strategy, the intention of the Government is that of:

> *"Boosting fiscal incentives for industries investing in STI through incremental R&D based tax incentives, tax credit for investing in facilities for commercialization, tax holidays, tax waivers, target-based tax incentive for specific domains, tax deduction, expatriate tax regimes, remodelling of patent box regime etc. There will be a reassessment of the possibility of reviving weighted deduction provisions (of expenditure incurred on in-house R&D)."*

It is an open question whether only fiscal incentives will be sufficient to encourage Indian businesses to invest more on R&D. Of course, there is a huge potential for it: India is the top exporter of IT products, has the third largest pharma sector in the World, and a fast-growing R&D industry. On the other hand, even the Government's *Economic Survey 2020-2021* warns against the risk to keep adopting a kind of non-conventional, frugal innovation ("jugaad" in Hindi):

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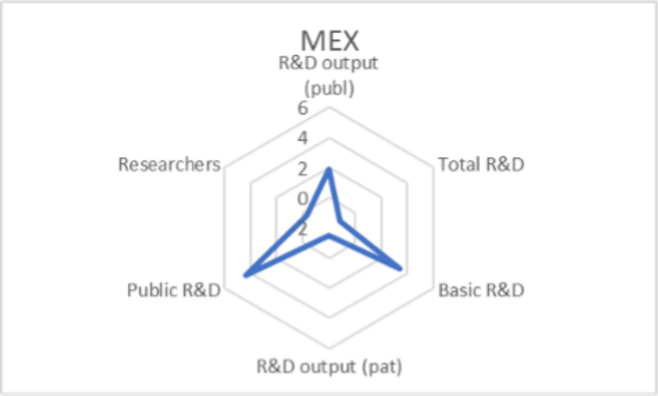
116 Government of India, Ministry of Science & Technology (2020), *Science, Technology, and Innovation Policy*, December 2020, draft for public consultation (https://dst.gov.in/draft-5th-national-science-technology-and-innovation-policy-public-consultation#:~:text=The%20new%20Science%2C%20Technology%2C%20and,of%20both%20individuals%20and%20organizations).

117 *Nature* (2021), ibidem.

> *"India must significantly ramp up investment in R&D if it is to achieve its aspiration to emerge as the third largest economy in terms of GDP current US$. Mere reliance on "Jugaad innovation" risks missing the crucial opportunity to innovate our way into the future. This requires a major thrust on R&D by the business sector. India's resident firms must increase their share in total patents to a level commensurate to our status as the fifth largest economy in current US$. India must also focus on strengthening institutions and business sophistication to improve its performance on innovation outputs."*[118]

8.12. Mexico

Key figures



As it is clear from the shape of the chart, Mexico's research system features some similarities with India. It largely relies on the non-business research sector, undertaking more than 76 percent of R&D activity, but with the lowest R&D/GDP ratio in the sample (0.31 percent). Without a substantial contribution by the private sector, the R&D system does not match the patent productivity levels of other countries (still, the lowest in sample) although a high rate of basic research and a remarkable increase of scientific articles over time.

Short country profile

In 2016, the OECD published a comparative analysis of the innovation systems in some Latin-America countries. In this context, concerns emerged about the ability of Mexico to give a boost to its knowledge basis and to recover from a slowdown in economic growth:

> *"Since 2013, Mexico's economic growth has slowed […]. Within this context, The Mexican government continues to reinforce the instruments and strategies described in the National Development Plan (PND) (2013-18) to make socioeconomic growth sustainable. The Special Program for Science, Technology, and Innovation (PECITI) (2014-18) was designed to transform Mexico into a knowledge-based economy, by: 1) increasing national investment in STI; 2) training highly qualified human resources in science and technology (RHCT); 3) strengthening the regional development; 4) promoting links between science and industry; and 5) developing the S&T infrastructure. The federal government budget for STI is expected to grow by 25.6% during the 2014-18 period, with R&D expenditure that will grow to 1% of GDP by 2018."*[119]

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[118] Government of India (2021), ibidem.

[119] Our translation from : OECD, (2016). Perspectivas de la OCDE en Ciencia, Tecnología e Innovación en América Latina 2016 (Extractos). This is an addendum of: OECD (2016), OECD Science, Technology and Innovation Outlook 2016, OECD Publishing, Paris. http://dx.doi.org/10.1787/sti_in_outlook-2016-en

At least the last objective has not been met as in 2018 the R&D/GDP ratio was as low as 0.31 percent. In 2019, a new assessment of the Mexican economy was produced by the OECD reporting a higher macro-economic stability associated to a number of long-standing issues: from a lack of market competition to a low institutional quality, or to a high income inequality levels.[120]

The inability of the innovation system to drive the evolution of the Mexican economy and society if not as part of a comprehensive effort was already observed by an independent report in 2018[121]:

> *"Although Mexico has seen significant investment in recent decades in manufacturing capacity and transportation infrastructure, it still lags in building an ecosystem that will support innovative behavior and the entrepreneurial spirit. It is clear that much work has yet to be done before Mexico can see the flourishing of an innovation ecosystem that encourages a culture of R&D, start-ups, and creative thinking. Some of the challenges are specific to the area of innovation: funding, infrastructure, community, and innovation-friendly public policy. Other issues are common to Mexico's overall development story, such as corruption, red tape, and the rule of law."*

Another expert assessment, published in 2019, did rather emphasize the assets of the Mexican innovation system.[122] It argues that, although a low scoring in global innovation metrics, Mexico could build on several comparative advantages to improve its innovation record: high quality human resources ("*…a population that is favorable for innovation and start-ups. With a median age of 27, an 86 percent penetration of the mobile phone market, and with 90 percent of smartphone users active on social media*"); strong intellectual property rights; an effective 2018 "Law Regulating Financial Technology Institutions"; a vital start-up environment. As main shortcomings, the following are mentioned: the lack of an innovation ecosystem, a lack of financing for new ideas, a poor-balanced uneven growth across regions and groups.

Current research policies

At the core of the Mexican innovation system is placed CONACYT (Consejo Nacional de Ciencia y Tecnología), established in 1970 in order to promote scientific and technological activities, setting government policies for these matters, and granting scholarships for postgraduate studies. CONACYT is currently engaged in the implementation of its Institutional Program 2020-2024[123] based on six main objectives:

> *1. Strengthen the STI and other knowledge communities, by means of training, consolidation and linkage with different sectors of society, in order to face national priority problems with a focus on*

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[120] OECD (2019), OECD Economic Surveys: Mexico 2019, OECD Publishing, Paris. https://doi.org/10.1787/a536d00e-en

[121] Viridiana Ríos, (2018). *Innovation Happens in Mexico. It Should and Could Happen More.* Woodrow Wilson International Center for Scholars, Washington D.C.

[122] Robert Miles, (2019). *How Innovative Is Mexico?* A Report of the Csis Americas Program.

[123] https://www.conacyt.gob.mx/PDF/Programa_Institucional_2020-2024_Conacyt.pdf (Authors' translation).

> *inclusion to contribute to the general well-being of the population.*
>
> *2. Articulate an innovation ecosystem that integrates the different actors of scientific, technological and innovation development of the country to attention to national priorities, with strict care for the environment, respectful of biocultural wealth and supporting the society.*
>
> *3. Increase the incidence of humanistic, scientific and technology in the solution of priority problems of the country, through National Strategic Programs and for the benefit of the population.*
>
> *4. Strengthen and consolidate the capacities of the scientific community of the country, to generate frontier scientific knowledge with the potential to influence the well-being of the population and care for the environment.*
>
> *5. Articulate and strengthen the scientific, humanistic and technological capacities of the country by linking with regional actors to influence strategic national problems for a social benefit, environmental care, biocultural wealth and common goods.*
>
> *6. Expand the impact of the sciences, humanities and technological ones, by means of the articulation, collaboration and definition of standards between HEIs, research centers and government agencies, improving, by adopting scientific methods, the national public policies for social welfare.*

Less clear is the financial planning behind this Program. Funding for research and innovation policies comes from the Mexican Federal budget and its quantification is not always straightforward. Available analyses[124] suggest that Federal funds for research and innovation have slightly decreased, rather than growing as expected, since 2016. By considering two aggregated S&T-related functions covered by the Mexican Federal Budget—the one including CONACYT spending under Item 38 of the Budget on the one hand, and the S&T budget items managed by the Ministry of Finance on the other hand, they have both a similar trend with an increase from 2003 to 2015 and a sharp decline afterwards. For instance, with reference to the Budget Item 38:

> *"In 2003, the approved budget for Item 38 was worth 7.9 billion pesos (equivalent to 17.9 billion pesos in 2020 prices), accounting for* ***0.52 percent*** *of programmable federal spending for the year. As an effect of the structural adjustment in public spending, from 2016 the trend was reversed: it has declined nominally between 2017 and 2019 and increased again, although slightly, in the 2020 and 2021 budgets. At constant values, as expected, the negative trend is more prominent: it has decreased every year; in 2021 it represents 25.7 billion pesos in 2020 prices and* ***0.42 percent*** *of programmable spending."*[125]

A general agreement can be found on the effectiveness of the fiscal incentive supporting business R&D in Mexico.[126] This is a tax credit for technological R&D carried out in Mexico equal to 30 percent of expenses and investments for R&D related to scientific or technological breakthroughs.

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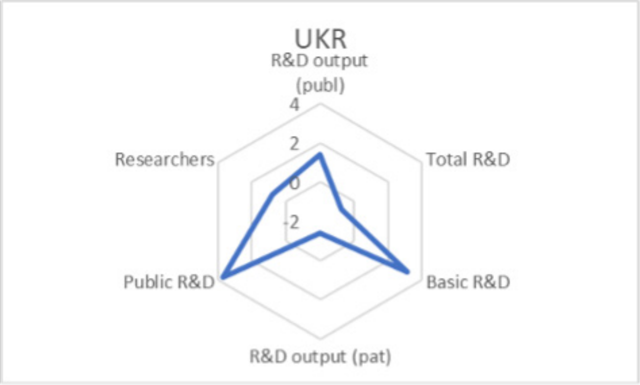
[124] https://educacion.nexos.com.mx/la-desinversion-en-ciencia/

[125] Ibidem. Authors' translation.

[126] https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Tax/dttl-tax-survey-of-global-investment-and-innovation-incentives-mexico-2020.pdf



8.13. Ukraine

Key figures

Ukraine can be described as another country in transition toward the model of the leading R&D system in (Western) Europe. It is quite similar to Romania as to the large role of non-business R&D institutions but also with reference to the number of researchers (even larger in Ukraine as percentage of the labor force) and the R&D/GDP ratio. The lack of a strong private industrial base, able to support the R&D effort is confirmed by the low patent productivity although a remarkable rate of basic research (22.4 percent).

Short country profile

Experts' views do stress the need for boosting economic growth and industrialization through a combination of actions from both the public and the private sectors:

> *"Low growth and deindustrialization of Ukraine's economy resulted from deficient public fundamentals + weak private fundamentals for investments and innovations, among which: inadequate infrastructure for industries, lack of long-term and accessible funding needed for risky investments, "brain drain" and insufficient human capital to produce high-tech products, decline of national R&D sector and lack of targeted incentives for innovations, poor investment climate and inability to attract foreign capital and new technologies in manufacturing."*[127]

In 2016, a team of international experts also gave some indications about how to improve the Ukrainian S&T system:

> *"(1) Ukraine needs to innovate its ways to growth. This will require a cross-government effort: Place science, research and innovation high on the political agenda. Develop a cross-governmental Research and Innovation Strategy. The new Law on Scientific and Technical Activity is an important first step. (2) The science community has to increase its internal effectiveness to benefit society and economy: This requires fundamental change in the way science, research and innovation is oriented and conducted in Ukraine. (3) Concentrate resources in priority areas based on the principle of scientific excellence and the principle of relevance in line with the opportunities for an innovation-driven economy in Ukraine."*[128]

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[127] Presentation by Tetiana Bogdan on "Ukraine's Economy in 2018-2019: Slow Recovery and Build-up of Risks". June 2019, The Vienna Institute for International Economic Studies.

[128] Presentation by Klaus Schuch on "Peer Review of the Ukrainian Research & Innovation System. Preliminary Policy Directions and Options". September 2016. Centre for Social Innovation, Wien; Technopolis Group; Univ. of Manchester.

Current research policies

A World Bank Report in 2017[129] identified strengths and weaknesses of the Ukrainian S&T system:

> *"a) Despite the difficult fiscal position, the Government of Ukraine has recently renewed its commitment to STI policies and launched two strategies that target innovation in the Ministry of Economic Development and Trade (MEDT) and the Ministry of Education and Science (MESU). b) Ukraine's innovation underperformance is reducing economic competitiveness and compromising growth in firm productivity. c) The existing innovation policy mix and relevant public funding do not respond to the critical needs of the Ukrainian NIS. d) Difficult framework conditions represent a significant constraint to innovation and competitiveness. e) Industry-university collaboration is weak and prevents firms from acquiring the latest industrial advances. f) The current governance arrangements with large transfers of block funding to the national academies do not provide strong incentives to business innovation. g) Finally, the Ukrainian NIS remains deeply fragmented, lacking an effective integration platform that can articulate a national STI strategy."*

The same Report drew some policy recommendations:

> *"First, Ukrainian policy practitioners should strengthen governance, planning, and learning mechanisms for better innovation policy efficiency. Second, Ukrainian policy practitioners should shift budget allocation to induce enterprise innovation. Third, Ukrainian policy practitioners should invest resources in instruments that build firm capability, induce industry-specific research collaboration for business innovation, and improve the enabling environment of innovative firms."*

A common finding about the Ukrainian R&D policy is the concentration of public resources in a few public research institutions, mainly the Academy of Sciences. This implies a strong consideration of **basic research** but, at the same time, that a support to the development of a high-tech and research-intensive private sector has been often neglected by the Ukrainian Government. This gap, if not by means of public incentives to private R&D, could be filled by leveraging on the competitive advantages of the Ukrainian research system: "expertise among local developers and the low cost of running an R&D office."[130] A potential driver could be the R&D performed in the IT sector that is potentially going to become the core sector of the Ukrainian economy.[131]

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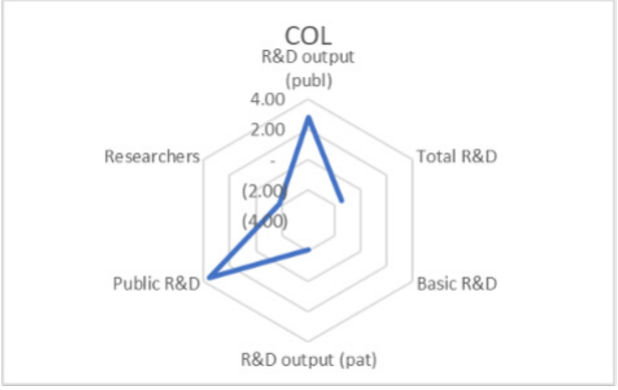
[129] Frias,Jaime Andres Uribe; Zolotarev,Andrey P.; Cirera,Xavier; Aridi,Anwar. (2017). *Ukraine - Science, technology, and innovation public expenditure analysis* (English). Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/314581509695378056/Ukraine-Science-technology-and-innovation-public-expenditure-analysis. See also: UNECE, (2020), *Sub-regional Innovation Policy Outlook 2020: Eastern Europe and the South Caucasus.* United Nations Publications.

[130] https://www.forbes.com/sites/forbestechcouncil/2017/09/07/why-building-rd-in-ukraine-is-a-great-idea/?sh=300b03477ea0 . See also: https://www.globallogic.com/insights/blogs/the-rd-potential-of-ukraine/

[131] As of today, "IT is the second largest industry in Ukrainian export" as reported in "Ukraine: A Country of Emerging Technological Innovation", by Andrii Smytsniuk, HUSI 2020, March 24, 2021 (https://huri.harvard.edu/blog/ukraine-country-emerging-technological-innovation).

8.14. Colombia

Key figures



The driving force of the research system in Colombia is the higher education sector with a relatively high volume of scientific research (35 percent of R&D is carried out by non-private institutions compared to less than 20 percent in Mexico) and an increasing number of scientific publications. Other indicators tell a different story: Colombia features a very low R&D/GDP ratio (0.23 percent), a low number of researchers as a ratio of the labor force and an irrelevant number of patents. No data on basic research has been made available by Colombian authorities to international institutions over the last ten years.

Short country profile

In 2014, a thorough review of the innovation system in Colombia shed some light on the relevance and role of basic research in the country's innovation policy:

> *"The complementary roles of basic and innovation-oriented research, for example, mean that the one cannot effectively be pursued in the absence of the other. However, in an emerging economy such as Colombia, the balance typically, and for good reason, leans more toward applied research than in most OECD economies. […]*
>
> *The balance of basic and more applied research varies over time, as shown both in national R&D statistics and in the spending pattern of certain R&D funders at national level. As long as national technologies are behind the technological frontier, companies operate in "catch-up" mode. They need to be supported by a state research infrastructure with significant applied research capability. Once the frontier is in sight, however, companies and countries need to search more widely for knowledge. This typically leads to an increase in the share of basic research in order to generate or absorb new knowledge. […] The implication for Colombia is that university research and PhD education are necessary and important, but that the amount of effort needed in these areas today is less than what is needed in the most advanced countries. The production of PhDs and university research can only be put to social use if complementary skills in design, engineering and production are in place."*[132]

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[132] OECD (2014), OECD Reviews of Innovation Policy: Colombia 2014, OECD Publishing. http://dx.doi.org/10.1787/9789264204638-en

Overall, the OECD saw in 2014 a "window of opportunity" for Colombia to boost its R&D and innovation system through a strong public-private co-operation. A more recent OECD assessment, carried out in 2019, found that those opportunities had been only partially exploited:

> *"Innovation performance is hampered by low investment in R&D and complex support programmes. Additional funding has become available, but a large part remained unused due to weak governance. Efforts to simplify the innovation system and reduce the fragmentation of support programmes are warranted. […]*
>
> *Spending on research and innovation is relatively low […], amounting to 0.25 % of GDP, which is well below the OECD average of 2.4%. The gap is especially pronounced for business R&D […]. Acknowledging that innovation is a key pillar for boosting growth and diversifying the economy, the authorities aim at increasing R&D spending to 1% of GDP."*[133]

Current research policies

Two specific policies have been implemented by the Colombian Government in the last years to increase investment in research: a R&D tax credit scheme to support businesses investing in research and a science fund fed by royalties for mining, oil and gas extraction.

> *"Innovation programmes, such as the R&D tax credit, have improved overtime. Until 2016, it was mainly used by one company, Ecopetrol. Efforts to promote its use have proven to be useful and the take up increased to 150 companies in 2017. Any company can use the tax credit regardless of size or sector; however, most tax credits have been awarded to large companies (89% in 2017).*
>
> *Additional resources have become available to fund R&D activities, including allocating 10% of natural resources royalties to a specific R&D fund (Fondo de Ciencia, Tecnología e Innovación). However, weak governance implies that a large part of funding remains unused. Recent reforms have tried to improve governance by allocating the funding directly to research centres. This could also avoid excessive fragmentation in projects and would favour larger projects with larger impact."*[134]

The governance of the S&T system is a responsibility of the Ministry of Science, Technology and Innovation (MinCiencias) established in January 2019 by replacing Colciencias, a government agency charged since 1968 of the support to R&D and innovation in Colombia. Although a formal support by the Government—confirmed by a law in 2009 (No.1286/2009) aimed at strengthening its role—Colcencias, according to some observers, "never had the resources—financial or human, to be able to fulfill [its] objective."[135] Key issues for the new Ministry are those (a) to raise adequate funding for the R&D and innovation system and (b) to effectively coordinating the actors influencing the S&T policy in Colombia. About S&T funding, in 1994 a team of consultants

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[133] OECD (2019), OECD Economic Surveys: Colombia 2019, OECD Publishing, Paris, https://doi.org/10.1787/e4c64889-en.

[134] Ibidem.

[135] https://www.portafolio.co/opinion/rosario-cordoba-garces/de-colciencias-a-minciencias-532051

(*Misión de Sabios*) recommended a level of S&T spending for Colombia of 2 percent of GDP. Since 2000,[136] a S&T/GDP 1 percent target has become a policy objective of the Government but with poor results: 0.74 percent in 2019. As to the R&D/GDP ratio—R&D expenditure in Colombia is roughly 40 percent of S&T spending, with the indicator peaking ins 2014 (0.306 percent), but decreasing afterwards (0.237 in 2018).

Steering the complex S&T system in Colombia is not less challenging. The Ministry has indeed to deal with other key institutions like CONPES (Science, Technology and Innovation's National Council of Economic and Social Policy, an advisory body of the Government) and SENA (The National Training Service, *Servicio Nacional de Aprendizaje*). In addition, the Ministry has to coordinate its efforts with other Ministries and institutions contributing to the National System of Competitivity, Science, Technology and Innovation (*Sistema Nacional de Competitividad, Ciencia, Tecnología e Innovación,* SNCCTI).

Evidence of a definite policy of support to basic research can be found in a few documents but without a clear commitment in terms of funding. A National Program in Basic Sciences (*Programa Nacional en Ciencias Básicas* from MinCiencias) formally exists with the aim of:

> *"Defining and implementing the national scientific policy and contributing to the promotion of the generation of new knowledge in the areas of biology, physics, chemistry, mathematics and basic biomedics, Promoting its insertion in the international context. Basic Sciences constitute the fundamental base of the processes of scientific and technological development, without which the insertion of the country in the global dynamics of development is unthinkable."*[137]

Unfortunately, in the official plans of the MinCiencias/CONPES, while is acknowledged the relevance of basic research, no quantitative targets are made explicit in the process of supporting it.[138]

9. Basic Research: Related Concepts and Policies

The concept of basic research has proven to be able to survive throughout seven editions of the Frascati Manual and still being largely used in statistics after several decades from its introduction. In other areas where research matters the usefulness of the concept has been often questioned or, even more frequently, it has been adapted to specific needs and circumstances.

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[136] *"Since 2000, the government goal in the country has been to reach to 1% of the GDP of investment in STI. Although this goal has not been reached, in the current Development Plan Pacto por Colombia—Pacto for Equity is set as a goal for the end of the four-year term (2022) doubling investment in STI as a percentage of GDP (reaching the 1.5%), as well as doubling private investment in R&D as a percentage of GDP (reaching 0.7%).".* Observatorio Colombiano de Ciencia y Tecnologia, (2020). Indicadores de Ciencia y Tecnología, Colombia 2019. Our translation.

[137] https://minciencias.gov.co/node/1119

[138] CONPES, Consejo Nacional de Política Económica y Social, República de Colombia, Departamento Nacional de Planeación, (2020). *Política Nacional de Ciencia, Tecnología e Innovación 2021—2030.* Ministerio de Ciencia, Tecnología e Innovación, 1/9/2020.

This is usually observed from the perspective of basic research funders, rather than from the performers' point of view. The issue is: what is the rationale for funding basic research (rather than applied research, for instance). The question is crucial for policymakers as the funding of basic research is a key issue of innovation policy and it is not surprising that in several countries described in the previous chapter, public funding of R&D is seen as a component of the national innovation strategy with a minor role for basic research.

Direct vs. indirect funding of business R&D

Around 2010, the number of OECD countries offering tax incentives to businesses in order to increase the R&D performance was rapidly growing. This led the OECD to start collecting data on indirect R&D funding in parallel with the more traditional collection of statistics on direct public funding of R&D.[139] Indirect funding may have many advantages compared to the bureaucratic procedure firms had to go through before their applications for project funding would be approved by public institutions. On the other hand, several studies—like Akcigit *et al.* (2021), have highlighted that the shift from direct R&D to indirect funding results in a reduction of the public support to basic research. According to an OECD study on R&D tax credits implementation in 20 OECD countries between 2000 and 2017: *"The effect on experimental development is about twice as large as the effect on basic and applied research."* (Appelt et al., 2020). As a consequence, *"R&D tax incentives are effective in achieving their generic R&D-raising objectives as long as they are consistently designed and implemented. However, they are insufficient as a means to guide innovation to broader societal needs and represent suboptimal instruments to encourage investment in knowledge at the interface between basic research and actual product or process development"* (OECD, 2021a). Thus, public authorities are reducing their ability to influence some crucial choices for the future of their countries by using basic research as a tool to address systemic risks for public health, the environment or human wellbeing through long term, highly uncertain research programs.

The COVID-19 alarm

Among the most striking effect of the COVID-19 crisis there has been a growing awareness in the public that some systemic challenges, like pandemic events, can be tackled—or better, prevented, only by investing in science. The issue has been extensively discussed in two authoritative yearbooks by the OECD (2021a) and by UNESCO (2021). The OECD stresses the responsiveness of the industry to the Covid crisis: *"The speed with which research groups and biopharmaceutical firms are developing COVID-19 vaccines builds on years of* ***basic research*** *investment, as well as the recent institutionalisation of international co-ordination efforts (in the form of CEPI*[140] *and its partners) to develop*

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[139] "R&D tax incentives have overcome mechanisms for direct funding of business R&D as the largest channel through which OECD governments financially support R&D investment by the business sector. In 2017, R&D tax incentives accounted for around 0.10% of GDP and 55% of total (direct and tax) government support in the OECD area." https://voxeu.org/article/effectiveness-rd-tax-incentives-oecd-economies

[140] Coalition for Epidemic Preparedness Innovations (CEPI).

agile technology platforms that can be activated as new pathogens emerge." While UNESCO highlights the need of adapting the national innovation policies to the new demand for basic research: "*Two global leaders for innovation, Switzerland […] and the USA […], have undergone a notable shift in the traditional division of labour whereby basic research is conducted and funded by the public sector while applied research and experimental development remain the preserve of the business sector. In 2017, Swiss businesses invested 27% of their research expenditure in basic research, double the proportion in 2012. In the USA, the business sector funded 30% of basic research in 2017, up from 23% in 2010; in dollar terms, business spending on basic research has doubled since 2007 in the USA even as federal levels have remained stable (since 2011).**This trend may be partly a consequence of the avalanche of big data being generated through basic research which form an increasingly vital component of applied R&D.** Big data are at the heart of tech-based companies spanning fields as varied as social media, the automotive and aeronautics industries and pharmaceuticals.*" Both institutions stress the need for an intensive international co-operation on basic research and for promoting open science:

> "*Many global grand challenges do not present themselves in the same way as a pandemic. Global challenges like climate change and biodiversity loss are "slow-burning" crises that can only be tackled through* **international STI collaboration**. *This chapter has argued for a new paradigm of international STI co-operation. It has shown that elements of such a paradigm are already in place, but need to be consolidated and reinforced. In particular, governments need to work together on new financing and governance mechanisms, wherein business and private-finance actors work with multilateral and national development banks to co-finance STI solutions for global challenges and GPG problems. The rapid and unprecedented mobilisation of public and private R&D funding for COVAX has demonstrated that new innovative funding models can be deployed to address global challenges through international STI co-operation.*" (OECD, 2021a).
>
> "*Scientists now have an opportunity to share their research data, methods, protocols and code, laboratory notes and other materials by making them freely available online, under terms that enable this research to be re-used, reproduced, redistributed and credited. This approach is at the very heart of* **open science**. *In a break from our traditionally closed science systems, the open science movement has vowed to make the scientific process more transparent, more inclusive and more democratic. The culture of sharing, at the core of open science, nurtures synergies and avoids duplication of scientific effort, leading to research that is conducted more quickly and efficiently, easier to scrutinize and, therefore, of higher quality.*" (UNESCO, 2021).

Basic research and the challenges ahead

In the EU context, the need for a direct intervention by Governments in the definition of the ultimate goals of the public-funding R&D (including basic research) has emerged during the process of planning for a European innovation 2030 strategy (EC, 2017). The principle adopted in this exercise was that of defining a set of "missions" in order to be able to give priority to funding of some "mission-oriented" research (Mazzucato, 2018). Planning for research and innovation policies based on missions is nothing new (Kattel and Mazzucato, 2018) but the process of missions' identification as proposed in the EU experience features at least two original components: the full involvement of the whole society in the missions' selection process and the integration of all components of the R&D and innovation system in order to pursue such common goals. In this respect, Mazzucato (2018) argues for *"new conversations between fundamental and applied research."* Just for stressing the difference with the traditional mission-oriented approach, it is crucial to clarify that, in the new context:

> *"Missions are not about prioritising applied research and innovation over basic fundamental research, which will continue to be funded by instruments like the European Research Council. Rather they are a new way to frame the conversations between the two, galvanising new forms of collaboration. Missions are also a new way to think about the dynamic interactions between enabling horizontal policies (framework policies around e.g. education, skills, training, research and innovation) and more directed vertical policies (e.g. health, environment, energy). Instead of using vertical policies to 'pick' sectors or technologies, the vertical aspect of missions picks the problem. The solution is then reached by stimulating multiple sectors and multiple forms of cross-actor collaborations to work to address those problems using the entire research and innovation value chain, from fundamental research to applied research and cutting-edge innovation."* (Ibidem).

Outside Europe other interesting models of mission-oriented research policy have been adopted—from the highly decentralized model of U.S. Agencies to the planned Chinese R&D programs—and everywhere the issue of combining basic research and applied research in the pursuing of missions is at the core of the research policy (Arnold and Giarracca, 2012):

> *"Research and innovation policy spans the interest on the one hand of the scientific research community in pursuing its own agendas and on the other the needs of other societal stakeholders for knowledge to solve problems in innovation and more widely in society. These two communities often act—certainly when they lobby for resources—as 'two tribes' with different cultures, values and goals. Institutionally, we can see this in the traditional battle between education and industry ministries in most countries, which often boils down to a fight for budget. In policy debate, we see it in the frequent refusal of the scientific community to recognise any other criterion than 'excellence' by which to judge research."*

Either in the optimistic perspective of a common engagement by scientists and technologists to achieve socially-relevant goals, or by accepting that different communities of actors of the S&T system will keep fighting for resources and power, it can be easily understood that addressing challenges that are "bold, inspirational, with wide societal relevance" like climate change, oceans' cleaning or citizens' health protection will need, as Mazzucato (2018) highlights: (a) a clear direction: targeted, measurable and time-bound; (b) ambitious but realistic research & innovation actions; (c) multiple, bottom-up solutions; and—probably most important, (d) **cross-disciplinary, cross-sectoral and cross-actor innovation**.

The role of basic research to face the global challenges

The national efforts to deal with societal “Grand Challenges” have been channeled into a global process of co-operation starting with the Millennium Declaration in 2000 when the United Nations launched a development agenda built around a number of Millennium Development Goals. In order to reinforce the process of tackling such challenges and because of the emerging concerns for the overall sustainability of the current and future pathways, the Rio Conference in 2012 launched a process to develop a strong “Post-2015 Development Agenda” around the concept of sustainable development and universally applicable Sustainable Development Goals to be achieved by all countries in the world. Shortly, the new global goals cover more ground, with ambitions to address inequalities, economic growth, decent jobs, cities and human settlements, industrialization, oceans, ecosystems, energy, climate change, sustainable consumption and production, peace and justice. On 1 January 2016, 17 Sustainable Development Goals (SDGs) officially came into force.

Of course, the achievements of many SDGs will heavily depend on science, technology and innovation. Table 9.1 provide a summary of the role science, technology and innovation should play to support such global effort. Overall, this could imply a substantial re-orientation of R&D and innovation activities in most countries, redefining priorities and objectives with direct effects on the education system, as well.

Table 9.1. The role of science in SDGs achievement

1. Cross-cutting contributions	There is not a specific Goal to boost scientific research, but the SDGs recognize the need to mobilize science at multiple levels and across disciplines to gather or create the necessary knowledge and thus lay the foundations for practices, innovations and technologies needed to address global challenges today and in the future.
2. S&T featuring directly in the Goals	Two Goals are mainly influenced by the outcome of dedicated research projects: **Industry, innovation and infrastructure:** - upgrading infrastructures and retrofitting industries to make them more sustainable with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes); - enhancing scientific research, upgrading the technological capabilities of industrial sectors, mostly in developing countries; encouraging innovation and substantially increasing the number of R&D workers per 1 million people and public-private R&D spending. **Partnership for the Goals (Technology):** - promoting the development, transfer, dissemination and diffusion of environmentally-sound technologies; - fully operationalizing the technology bank and STI capacity-building mechanism for least developed countries and enhancing the use of enabling technology, in particular information and communications technology.
3. Implications for some goals	At least six goals could indirectly benefit of a contribute from scientific research. - **Clean water and sanitation:** improving water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally. - **Affordable and clean energy:** - enhancing international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology; - expanding infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries. **- Decent work and economic growth:** - achieving higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high value added and labor-intensive sectors; - promoting development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-small- and medium-sized enterprises, including through access to financial service. **- Climate action:** implementing the commitment undertaken by developed countries to mobilize jointly $100 billion annually address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund. **- Life below water:** preventing and significantly reducing marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. **- Life on land:** ensuring the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands.

4. Implementation of the goals	Adoption of a "Technology Facilitation Mechanism" to promote collaboration and coordination of the use of science, innovation and technology. Key targeted areas include agricultural research ("ending hunger"); R&D on vaccines and medicine ("ensuring healthy lives"); R&D infrastructure development ("establishing sustainable consumption and production patterns").
5. Translation and Monitoring	Scientists need to support all aspects of implementation, including ensuring that appropriate metrics, monitoring, evaluation, infrastructure and data are in place. Science is important in collecting, analyzing and making inference from data. Statistical methods and analyses are often used to communicate research findings and for making appropriate decisions.

Adapted from: https://www.ingsa.org/wp-content/uploads/2017/11/Science-and-the-SDGs-_UNESCO_November-2017-Final.pdf.

The issue of influencing the S&T systems to effectively contributing to achieve the SDGs has been already broadly discussed and some key points have emerged:

- The contributions by science have to be measurable as well as the actual progress in the achievement of single SDGs.
- Science policy should evolve by making national and global objectives compatible with the use of available R&D resources.
- Science has to primarily address "nexus challenges" by considering that many SDGs are intertwingled to each other.

In April 2015, an International Conference addressed the needs related to a detailed monitoring of SDGs progresses on the basis that measuring is a key component of the SDGs strategy and that science has to support such quantification effort (Schmalzbauer and Visbeck, 2016). Some recommendations emerged from the discussion: (a) the need for regular evaluations that provide continuous information to member states and other stakeholders on their progress toward reaching goals and targets; and (b) on-demand assessments that provide necessary feedback to member states and other stakeholders on key scientific issues concerning SDGs.

> *"Assessments need to be multi-level, integrated, transparent, participatory and consensual in the summaries they make; their guiding questions need to be jointly framed by policy and science communities. The methodology for carrying out these assessments is readily available from the scientific community. Assessments in support of SDGs need to "go the extra mile" by assessing interlinkages (positive or negative) embedded within the SDGs as well as policy options to transform possible trade-offs into synergies."* (Ibidem).

In terms of science policy, a key issue is that of the ownership of the outcome of R&D and innovation activities instrumental to the achievement of SDGs. In contrast with the current context where the appropriation of the research results is the standard and the free availability of them an exception (usually limited to fundamental research or to the output of the activities of researchers from the non-profit sector), SDGs-related research should make available its results to the international community for free, either keeping their ownership but without enforcing it, or transferring the ownership to international actors, or even allowing for the appropriation of such ownership by those local communities which could more benefitting of their application. Even if this new approach should be adopted only in selected areas—like agricultural technologies or vaccines development—its impact could be disruptive.

Not surprisingly, the process of SDGs implementation is far from being smooth and free from criticisms. The COVID-19 crisis has worsened the achievement levels by leading the UN program off-track (Nature, 2021). As *Nature* is arguing, researchers have a key role in making SDGs reporting and monitoring more frequent and to assure to keep momentum and improve inclusion of communities and NGOs. On the other hand, the program needs more resources than originally planned and this an issue to be addressed at the highest UN level.

An effective contribution to the SDGs by the scientific community cannot neglect a key feature of the SDGs program: that of a very complex interaction among most of its seventeen goals (ICSU, 2017). A study by ICSU, based on four SDGs[141]—those identified as the most synergic:

> *"…identified 316 target-level interactions overall, of which 238 are positive, 66 are negative, and 12 are neutral. This analysis found no fundamental incompatibilities between goals (i.e. where one target as defined in the 2030 Agenda would make it impossible to achieve another). However, it did identify a set of potential constraints and conditionalities that require coordinated policy interventions to shelter the most vulnerable groups, promote equitable access to services and development opportunities, and manage competing demands over natural resources to support economic and social development within environmental limits."* (Ibidem).

Such an approach, extended to all the SDGs, could provide:

> *"a basis for a science-policy dialogue on translating integrated science for the achievement of the SDGs. As a tool for policy coherence, it provides an understanding of the conflicts and synergies to be managed across government departments and sectors, understanding where the emphasis should be put for efficient and effective action, and identifies who needs to be brought to the table to achieve collective impacts across multiple interacting policy domains."* (Ibidem).

A similar, or even higher, level of interaction has been documented by a research by Nakamura et al. (2019) by using quantitative evidence extracted from bibliometric data (Web-of-Science of Clarivate Analytics). This makes clear that in parallel to the complex interaction among the SDGs' objectives, a multi-disciplinary research effort—probably developing new and unexplored interactions between scientific disciplines, will have to be undertaken. In Figure 9.1 the complexity of the interactions between research areas influenced by the SDGs can be appreciated. This analysis, based on a dataset of more than 10,000 scientific articles, gives additional insights on: the positioning of different countries as potential contributors to SDGs-related research, links between scientific areas and policy priorities (at either national and global level) and potential areas of collaboration between countries or even institutions (based on past experiences of co-authoring).

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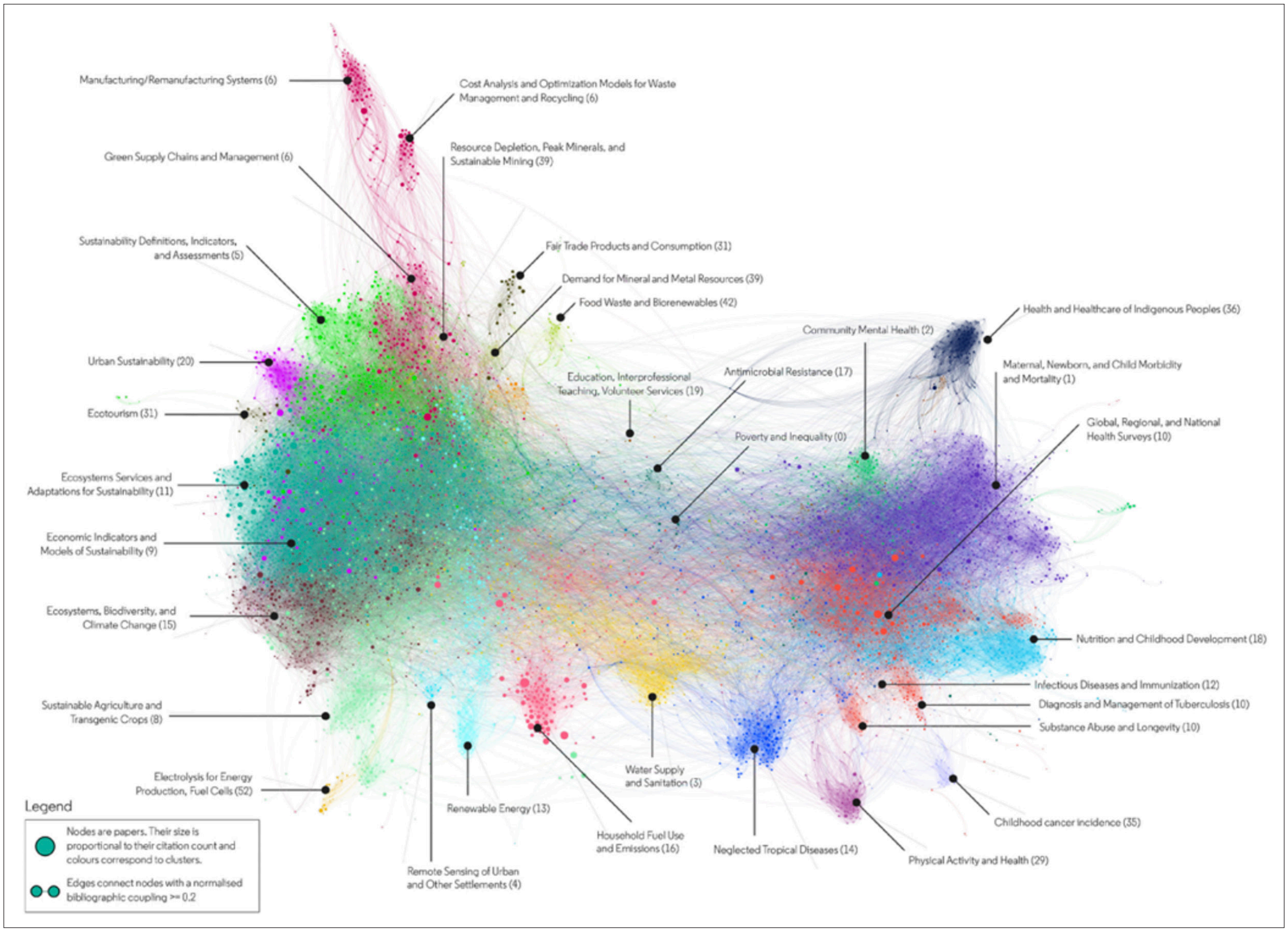
[141] SDG 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture; SDG 3. Ensure healthy lives and promote well-being for all at all ages; SDG 7. Ensure access to affordable, reliable, sustainable and modern energy for all; SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

Figure 9.1. Thematic map of research on Sustainable Development Goals



Source: Nakamura et al. (2019).

It could be said that the results of the study reveal where the research potential to address the challenges behind the SDGs is located, in terms of researchers, research teams, institutions and countries. How to mobilize them in the framework of a global research effort—but in coordination with national policies and institutions' strategies—is an additional, hard to address challenge.

What is the strategy of the UN in this context? And the specific role of basic research? UNESCO, as the UN Agency dealing with research, has launched an initiative—sponsored by 28 Nobel Prize winners—devoting the year 2022 to the support of *Basic Science for Sustainable Development*[142]. The aim is that of refocusing on basic science (or basic research) beyond the efforts already in place by the above-mentioned *Technology Facilitation Mechanism* and its annual Forum. The UNESCO purposes for the year 2022 are those often discussed about the effort to reinforce basic research in order to serve the SDGs needs: enhancing inclusive participation in science, strengthening education and scientific training, financing basic science and generalize open science. Of course,

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[142] https://www.iybssd2022.org/en/home/

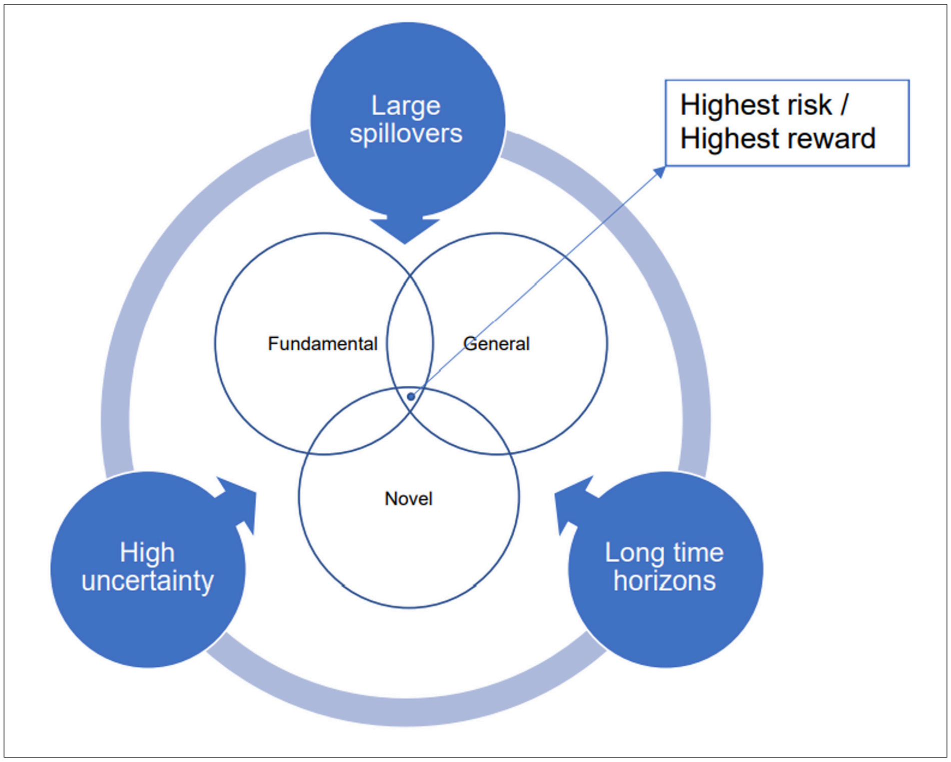
the real issue is that of reinforcing the commitment of UN countries to invest their research potential in the directions given by the SDGs program.

Basic research between risks and returns

The debate about potential and constrains of a public support to basic research includes many spurious arguments originated by ideological assumptions and deeply rooted interests. In a more objective perspective, it could be said that the orientation of research in terms of usefulness, or applicability of its potential results[143] is essentially that of a right balance between risks and expected returns. This is fully in line with the treatment of R&D in National Accounts (Ker and Galindo, 2017) where, since 2008, R&D is classified as an investment and, as such, contributing to the calculation of the national Gross Fixed Capital. Thus, like every investment, potential risks and returns have to estimated and used as a guide for decision whether getting involved or not in anew activity.

Basic research, in this respect, is a high risk/high reward (HRHR) activity and, as such, to be potentially assessed in a model. The OECD has recently carried out some analyses on the HR/HR approach by describing the evolution of the concept and different experiences at international level, but also proposing a conceptual framework and a set of metrics to evaluate its impact (OECD, 2021b; Machado, 2021).

Figure 9.2 HRHR knowledge characteristics and associate market failures



Source: Machado, 2021.

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[143] Often, even measured in terms of Technology readiness levels (TRL).

Figure 9.2 provides for an essential description of the HR/HR approach. Conditions (in blue) and characteristics (white) of HR/HR projects are described: shortly, it is expected that rewards—which could come far in the future and with a high level of uncertainty—will be sufficiently high (also in terms of spillovers) to remunerate the initial investment. This is an appropriate framework for the conceptualization of basic research.

As described in OECD (2021b), the current evidence is restricted to a few examples (in countries U.S., Germany, Japan, India, etc.) and it is premature to recommend this approach. Nevertheless, some practices could be taken into consideration to become standards—for instance, indicators of novelty, also based on the work by Machado (2021), by using bibliometric data—and some experiences of national HR/HR R&D funding programs could be seen as potential models.

Overall, this further development of the basic research concept still deserves to improve its empirical basis: There is a substantial work to do both on the implementation side (R&D funders and performers), and on the analytical side.

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United States

The Aspen Institute global project for basic science convened key stakeholders in a roundtable discussion to share expertise, experience, and perspectives around five main questions dealing with multiple aspects of basic science and fundamental research in the United States today.

How can we engage non-obvious stakeholder groups so that basic science becomes a priority for them?

One of the ways to do this is to advertise science and market it better, but also inspire people with it through the arts. There's a lot of evidence that the arts, television, radio, and movies have had big social influences. This is why, while maintaining scientifically accurate dimensions such as documentaries, it is important to reach out to a diversity of venues, which also includes television ads. Another possibility would be to directly reach out to Hollywood and get access to meetings with screenwriters. Connections with Hollywood and the entertainment industry aren't used enough in terms of their power to convince people of the value of basic research.

A second way is to build trust in science, because the non-obvious stakeholders often distrust science for various reasons. Creating and encouraging a specific set of guidelines could be a way to avoid distrust: how does the profession work and how those in the profession do the work they do and why.

It may seem like a more trivial aspect but another element to consider within the dimension of trust is: why should people trust science? It is important to explain this. Other aspects of building trust relate to having the right role models, using simpler language, tackling misconceptions, and not being afraid of controversial topics. Trust is also entrenched in diversity and inclusivity. For basic science to excel and for people to become interested in it, it is critical to have diversity of thought and inclusion. Many non-obvious stakeholders are often underrepresented groups, and often, they are marginalized from basic science. These groups do not see a welcoming environment or people they can relate to or share identities within positions of leadership. One key way to overcome this is to intentionally find ways of creating more diverse teams, especially at the leadership level. The question is: do our culture and our leadership really reflect the diversity that we have and want to see?

It is also fundamental to talk about inclusion separately from diversity but, at the same time, point out that they go hand in hand. In fact, having diversity without inclusion will exacerbate the problem. It is crucial to treat diversity, inclusion, and equity, as distinct ideas that must be worked on individually and integrated.

A big problem relating to the challenge of inclusion is the pipeline model, the notion that science is something you must decide to do at age 12 and take all the right classes and, if you've deviated from this and did not follow a very structured program, it is very difficult to get into the career. It is important, instead, to be thinking about ways in which we can have more flexible paths into research careers and whether that means establishing master's programs geared at science, enabling a more diverse group of people to become scientists, and drawing in underrepresented groups. And maybe one might consider it a path, rather than a pipeline: there shouldn't be one single way into science.

In the context of engaging stakeholders, it is essential to emphasize that each stakeholder group may have its own distinct sets of priorities, interests, sensitivities, and willingness, and this is why it is, in turn, fundamental to map a strategy to each particular stakeholder group. Another element to this is how to make science important to stakeholders. However, to achieve this, it might be useful to invert the question, and consider this: how we take what is already important to the stakeholders and show them how science connects to what they already care about. In this regard, the task is not elevating their willingness to be open and value science, but to demonstrate how science already connects to the things they cherish, value, and set priority on—which is this idea of meeting people where they already are, and it's easy for scientists and those who promote science to do this. Furthermore, it is a way to avoid an elitist approach and message, which most times is very off putting. In the same way, the language used is also key, as well as working together with and for communities, asking them what they want to know, how they can be served. This is what drives engagement.

This dimension also has to do with building trust and taking into account how to make a connection, how to reach everyone and specific communities, and how to integrate this approach with the notion of scale.

It is imperative to acknowledge and recognize the elitist processes and unconscious biases in basic science and work with institutions and within institutions toward concrete racial justice and diversity efforts. To this point, it may be relevant to not only to be attentive to inclusion but also to the way the profession is conducted in the popular press, for example, which has often not encouraged trust by the public.

Science needs to create a sense of urgency, because people respond to urgency, but conveying that urgency and finding a way to address it through basic research are a big challenge. In this respect, it is important to involve the media in the process right way, and it also means conditioning scientists to embrace a more divulgated approach, to write good popular books, it means getting economists to say that the engine of economic growth is basic science, it means getting articles in popular platforms, it means getting TV and radio people into this thinking, because that's how society changes. And how do we affect change? One way to do it is through urgency—and agency. It is, of course, it is difficult to sell urgency but it is important to find ways to do it.

Another important aspect to engage stakeholders is trying to convey the excitement of discovery, to inspire curiosity. And it goes beyond just talking about science, but actually providing input and viewpoints about fundamental science and about how it might affect society and people, it means looking at ethical implications which could engage people in a different way rather than just talking about pure science in itself. To do this it's increasingly important to engage scientists in direct conversation with other people, for example, faith leaders, judges, politicians, and journalists. This, then, goes back to trust and, particularly, to the following question: who is the person who can make that connection, who is the trusted messenger?

Basic research is often defined as something that an elite group does for their pure enjoyment, and that's something the ecosystem should be combating. It is not always effective to try to justify everything in terms of what it's going to practically yield because, consequently, that leads to a micromanaging of the science from the top, which doesn't allow for science curiosity and discovery and the freedom to pursue different avenues and research. There is less and less opportunity for this, while it is precisely this dimension which often leads to what we now see as the exciting science. At the same time, regarding education elements, what is taught in high school and college and informal and outreach education, it is extremely important to take into account what pulls people into basic science, to consider and explore what are the things that make it attractive. Some people may get pulled in by the practical aspects but many consider the "wow factor" of science and this aspect hasn't been played into very much in schools, whereas it is definitely one of the things that would engage students the most: basic science understood as a curiosity, as driving fundamental questions, as a starting point to understanding the world and, at the same time, the surprises of the world that we don't understand. The ecosystem is missing opportunities to get people excited about basic science and getting them excited about the methodology of science, to the extent that this would then, in turn, service very well in many of the other practical matters. Simply, taking into account the basic consideration that science is fun, and this is part of the reason why people pursue it, why people want to keep doing it.

While maintaining this approach, it is essential to deal with some of the problems, such as issues with the pipeline: some students complain that they came into science wanting to do discovery but they find that it's the applications, the intellectual property, the how they form ties to corporations and so on, that count for far more than whatever drew them there and, similarly, another is the very tight filtering of the pipeline, so that very few people end up getting academic jobs and when they do, it's gender-tilted. So, the final outcome is often that what they thought they were getting into the basic research for, is not the way the payout looks at the end.

This is why rewarding researchers is also crucial, and it is a real opportunity to link science communication, science education, and research. Many of the aspects not yet touched upon such as the exchange of young scientists, import of talent, and individual and team contributions to research and industry are also opportunities to shape a different, more inclusive, diverse, trusted, and constructive ecosystem. At the same time, these elements propel the United States to maintain its leadership. In particular, international partnerships have a large impact beyond science, and it includes stabilizing diplomatic relationships and world peace and cooperation on so many things.

What cross-sector partnerships do we need to support or create in order to bolster basic science?

Before exploring which cross-sector partnerships we need to support or create in order to bolster basic science, it is essential to recognize that they are fundamental to encourage and promote trust and integrity in science, and they can lead to exceptional endeavors that wouldn't and couldn't have been done otherwise.

But what is a partnership and what does it mean? To a certain extent, it means changing the culture of science, creating an ability for people to move from one sector to another seamlessly, creating opportunities, just like this one, and looking for entities that can work together, finding new and creative ways to knit partnerships together around basic science. In this context, it is also important to recognize that partnerships may be a potential avenue to build conviction and support for basic science, by working with those already engaged in any aspect of science, technology, research development, and application.

A big challenge here is creating proactive partnerships between universities and civil society. Many more partnerships are needed between industry and high schools. To this point, it's important to understand how to build bridges internally within universities so that civil society can solve issues by driving change from social sciences and humanities as well as basic science and questions on how natural systems work.

Another crucial challenge revolves around partnerships and funding. It is necessary to drive fundamental investments on basic sciences and research as well as technologies, to invest in longer term efforts, to find more allies for those investments in fundamental science, not only to pursue benefits and practical uses but also to support the discovery and curiosity that incarnate basic science.

Partnerships with the private sector are also worth consideration, and it is relevant to understand how a private business could really support basic research in its purest sense. One reason why these partnerships are important is that it creates a talent pool, and to capitalize on the talent production is an opportunity.

Another key way to create and support significant partnerships is to connect funders such as philanthropy and government agencies with educational institutions in a meaningful way.

A lot of the problems that have surfaced in the discussion have to do with an inefficient reward system and a funnel-shaped pipeline where there is a down selection for a particular profile. So, changing the reward system is very important, especially if people do education and outreach work or other kinds of work that reaches out to society, and it must be taken into account in the decision to hire someone or promote them.

Part of the difficulty with achieving successful partnerships has to do with funding, especially federal funding, where funders are very risk averse. And this means having a justification for why a particular kind of research is going on, which doesn't leave a lot of room for flexibility. It is important to have some element of research funding that is not risk averse, and philanthropy can surely play a role there; however, more federal funding is necessary as well. It may also be interesting to think about a metrics system with timing and investment criteria for funding. Congress should be given the metrics to use when overseeing different agencies, scientists, reporting, and grant writing. Right now, the agencies are in a position to make it harder and harder for scientists to do more open-ended creative thinking. In this context, it may be useful to come up with ways to convey to the government why it is that they have to generate a more open ecosystem for scientists.

Last but not least, partnerships with teachers and students in schools are key, because if you can inspire every person at that level, then they are the people who become the future inspired citizens, so it's necessary to make sure that that's where we start. High school science teachers are an essential part of strengthening the science program and a group that most of the university academic community, particularly the research community, is cut off from. In this regard, it is fundamental to think of ways in which to connect high school teachers with research scientists as it is something that will strengthen opportunities for the scientific community, students, and the teachers. It's worth pointing out that the Research Corporation for Science Advancement has done some great work in providing research training for high-school science teachers.

What can be done to increase global collaboration for basic science in the United States?

One thing that can be done is changing immigration policies, as the ecosystem is suffering enormously from the inability of bring international scientists and keep international scientists in the country. One of the ways to argue this with the public is to talk about innovation, because there is evidence that shows that the frequency of entrepreneurship is directly correlated with the number of immigrants.

Promoting open data, including open-access science publications to support citizen science and enable international connections, is also a key element to bolster international collaboration. In this context, it’s essential to emphasize the power of citizen science for engagement with the public, with Zooniverse, FoldIt or SciStarter as good examples. Another interesting proposal is to use the Paris Agreement as a model for a basic science global agreement, to support inclusive basic science around the world and in the United States.

It is fundamental to increase global collaboration, but the process in the U.S. does not allow it to do so in the most efficient and effective manner: the budgetary process is yearly and varies on the whims of political winds, so it’s harder for other nations to trust the country on commitments and projects.

There are different levels of collaboration that extend from individuals to large multinational facilities, but building collaboration at the individual level, almost the grassroots science level, pays huge long-term dividends, because those relationships blossom in many unexpected ways as people take on more senior positions and leadership roles. People exchanges, philanthropic organizations, and building trust are all crucial dimensions to strengthening collaboration between the U.S. and other countries. Basic science transcends borders, and, in this dimension, it is also important to mention that universities are extremely crucial.

Every nation positions itself to use science to gain comparative advantage in the world; however, the global good that science represents as a basis for multinational collaboration on basic science is a much harder sell. We have to acknowledge that we need to deal with this dynamic and that the processes which reinforce Americas’ competitive position are very different from what is, in fact, needed to succeed. Moments of crises like the pandemic have also given rise to the birth of new institutions and laboratories, and scientists can push grassroots efforts for change and consider that collaborating on science is, in fact, for a common good. Open source is also crucial to pave the way for partnerships in this sense, especially in sectors like computer code and genetics. And this process is bottom up and at the basis of collaborations between institutions.

At the same time, the understanding of science as an international endeavor has been lost. And it is one of the great attractive elements of science: it brings people all over the world in contact with each other in a shared collaborative goal. This is why it is important to increase collaboration among governments, rather than harmful competitiveness which undercuts how science should and can work.

A way to do this would be to fund international projects, especially by federal funding agencies and encourage international collaborations by helping to build trust and emphasize strengths. In this context, open borders seem to be the basis of all strengths—the ability to attract excellent scientists and researchers from all over the world, to value their talent and work and fund new partnerships. One also has to keep in mind what collaboration is for and who it is between.

International collaboration should not be based on competitiveness but at the same time it should recognize the political workings of governments and take into account party lines in regards to funding: which party is going to fund what and why. Once you do have the funding, it is important to use it to enable collaboration rather than exacerbate competitiveness.

In this regard, it may be useful to share the following anecdote from one of our participants: "I showed Senator D. a poster about cleaning nasty chemicals (PHAS) from water with an accelerator. He was very interested as this is a big, expensive environmental problem for the government. He said to the Secretary we need stories like this to convince his colleagues on appropriations why pure science is important. So even though he is one the biggest pure science supporters in Congress, he needs to explain to the non-pure science types why it is important to support our funding. To me, this sums up the challenge."

How can basic science be made more inclusive in the U.S.?

It is necessary to remove barriers so that people who actually want to become scientists and start on that career path don't encounter obstacles like harassment, aggression, discrimination, or biases. Consequently, it is also necessary to do concrete things in order to mitigate against a culture that could encourage this, ignore it, or simply be blind to it.

Usually what happens is that leadership focuses on what we can do to help minorities and underrepresented groups rather than what we can do to change our institutions to make them less racist and sexist. And this is not only a problem in science alone but in American society.

To this point, it is crucial to work on the demographics of leadership and doing so by considering that diversity without inclusion exacerbates the otherness. It is fundamental to treat diversity, equity, and inclusion as three independent pillars that all have to work together. Basic science in particular must change the rubric for what is valued: in addition to scientific outcomes, it can be more constructive to think about which characteristics of scientists need to be better valued, such as their ability to be inclusive, collaborative, collegial, their ability to have resilience, grit, their ability to adapt and to have a growth mindset. And capture all of these things when hiring. Inclusion is the glue that ties diversity and equity together.

At this point, it is important to oblige faculty to confront racism and sexism, and what it means for individual people, and to develop curricula that align with JEDI: justice, equity, diversity, and inclusion. Beyond this, in many institutions, the environment is not conducive to encouraging and transforming ideas and being able to contextualize them in a successful execution of research.

Another dynamic to avoid is to keep singling out individuals and only individuals for merits, incentives, and rewards. Science is a group effort, and this is often failed to be acknowledged; not all the contributions of people are often recognized. This must change, and in turn it will allow more people to connect to science.

It may be useful to come up with a set of best practices to implement based on those that are already being played out in different institutional settings and are successful. This can be a way of consolidating information and sharing approaches and evidence about what is already working and what is working better. This could be a real contribution to accelerating the process.

Another issue to address is lack of inclusivity for first-generation low-income students. It is essential to be able to support students that often come in at a disadvantage because of various reasons such as not having gone to elite schools, to provide financial support for the family, and to help them support their families. In this context, consider families as part of the equation and look for alternative pathways from schools that are elite institutions.

Another challenge is being attentive to criteria for the hiring process and promotion in the current university system. There has to be a real culture shift.

A key aspect of this is how to hear from young people in a more representative way. In a recent survey by *Nature*, young scientists today are happier with industry than academia, and so, although there's nothing wrong with that per se, it may be useful to try to understand why the situation has flipped from a few decades ago, for example.

How can we excite younger generations to pursue careers in basic science?

To excite younger generations to pursue careers in basic science, it's important to provide them with role models and success stories they can relate to, attract their attention, and then, of course, be mindful about how much time you have to keep their attention on platforms like social media, for example, to meet them where they are. Another way is to use different means, aside from social media, such as video games about science, which as opposed to merely instructing them about science, tries to create engagement. A further means that can prove effective today are podcasts.

To understand the dynamics which revolve around younger generations in the field, and in reference to the *Nature* survey mentioned earlier, it may be useful to look at ways young people are making choices about staying in the fields of science and what can be done about that.

At the basis, it's necessary to pay better and to be mindful of work-life balance for students, to applaud and recognize that this is important and to encourage this balance in order to keep youth in science. To this point, it's fundamental to recognize that many young people leave because science is not always an inclusive ecosystem, and many believe they don't belong, so the challenge comes back to creating that inclusivity and finding ways to keep the young people engaged and feel like it is worth it and that they can do their jobs and research without sacrifice.

In this regard, it is crucial to guarantee the life-work balance for scientists and students who want or have families, to understand the trajectory of somebody's career without compromising it in order to avoid dropouts or losing tremendous talent along the way.

It is also necessary to do a better job at teaching young people and teaching the world that science is a work in progress. In this sense, one must avoid the mindset that science is fixed in a textbook, as this is destructive in many ways and easy to undermine for anti-science or pseudoscience groups. Instead, it's paramount to emphasize the dynamism and exciting parts of science and avoid talking about science as merely fixed facts. To this point, it might also be useful to inform young people that there are many ways to participate in science, not just academia. To start with, this can be done by giving teachers in elementary school and in middle school the resources to excite curiosity in their students, teaching people that science is about curiosity and learning, and encouraging experiments, references, and associations that are relevant to the students and that they can relate to and encompass a wider variety of people.

It's also necessary to clarify what research actually is, because the notion during the pandemic has become confused. Consequently, it's important to teach people what are the ways to recognize high-quality expertise and how to distinguish it from claimed expertise.

Another way to look at it is to consider the message, the messenger, and the medium. It's important for the message to be exciting and that it can be thought of in many different ways to inspire more generations of young scientists.

Participants

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Harvey Fineberg	President, Gordon and Betty Moore Foundation
Cynthia Friend	President, Kavli Foundation
Darío Gil	Senior Vice President and Director of Research, IBM
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Jo Handelsman	Director, Wisconsin Institute for Discovery, University of Wisconsin-Madison
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Nigel Lockyer	Director, Fermi National Accelerator Laboratory
Marcia McNutt	President, National Academy of Sciences
Sethuraman Panchanathan	Director, National Science Foundation
Sudip Parikh	Chief Executive Officer, American Association for the Advancement of Science
Saul Perlmutter	Franklin W. and Karen Weber Dabby Professor of Physics, University of California, Berkeley; 2011 Nobel Laureate in Physics
Eric Schmidt	Founder, Schmidt Futures
Kartik Sheth	Assistant Director for Research Infrastructures & Science Equity, White House Office of Science and Technology Policy
David Spergel	President, Simons Foundation
Holden Thorp	Editor-in-Chief, *Science Magazine*

Japan

Aspen Japan sought the input of five experts on the topic of pure science:

Tateo **ARIMOTO** | Tatsuhiro **KAMISATO** | Yoichiro **MURAKAMI**
Tadashi **KOBAYASHI** | Masaki **NAKAMURA**

Tateo **ARIMOTO**

Professor and Deputy Director, Science, Technology and Innovation Policy Research Center at the National Graduate Institute for Policy Studies (GRIPS)
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1. Why is fostering "pure science" an essential value, specifically to realize a free, just, and equitable society?

(1) What is "pure science"? Who conducts pure science? Who supports pure science? Does the Nobel Prize serve as a model? The definition of pure science may vary in accordance with times and countries. Therefore, it is important to foster a culture and secure a place in society allowing people to discuss freely and continually about what is pure science and why pure science is so important?

(2) While there may be no end to discussing the definition of pure science, my understanding is as follows. Pure science is an activity to observe, think, and generate, synthesize, and evaluate knowledge in an original manner at the individual or group level without being bound by academic disciplines or social systems. It is fundamental to the survival and evolution of human beings and other living creatures; the appropriate state of human beings and society such as freedom and equality; and the building of a sustainable and resilient society.

(3) In conducting pure science, the management process of activities including setting themes is important. As its basis, regardless of whether the background is in humanities or sciences, it is important to foster the culture and abilities such as historical view, world view, nature

view, imagination and creativity, reason and sensitivity, aesthetic sense, judgment of right and wrong, justice and conscience, tolerance and humility, acceptance of diversity, and passion. These are not only acquired by the transfer of knowledge and experience through education, but also embedded in mind and memory physically through the places and opportunities of mutual exchange and inspiration.

Therefore, it is also important that the persons and organizations that design and manage such places and opportunities have good culture and abilities.

Notes

Many great scholars have left historical statements on pure science. Here, I would like to introduce the words of four philosophers and scientists who have been of high interest to the students in my lectures on the History of Science and Technology Policy. 1. “Galileo Galilei is at once a discovering and a concealing genius.” Edmund Husserl

From Part II, Section 9.§ h “The life-world as the forgotten meaning-fundament of natural science” in *The Crisis of European Sciences and Transcendental Phenomenology: An Introduction to Phenomenological Philosophy*

2. “The formulation of the problem is often more essential than its solution which may be merely a matter of mathematical or experimental skills.” Albert Einstein, Nobel laureate in physics

3. “The important thing in science is not so much to obtain new facts as to discover ways of thinking about them.” W. L. Bragg, Nobel Laureate in physics

4. “We think that it is the best scientists working in the frontier fields of science who are best able to judge what is good and what is bad—if any—in the application of their scientific research.” Kenichi Fukui, Nobel laureate in chemistry, from the speech at the Nobel Banquet, December 10, 1981

2. Why should we prioritize pure science, especially in this moment?

(1) In the present age when science for innovation is overemphasized, pure science needs to be distinguished from it and supported by independent systems for promotion, funding, evaluation, and reward. To this end, the role and responsibility of academies composed of so-called intellectuals who think and act beyond disciplines will be even more important, in addition to those of academic societies composed of researchers and groups of specific disciplines.

(2) Diversity is important in pure science. It is important to form a robust system with a sound mind that is not influenced by populism fluctuating in socioeconomic and political conditions.

3. How does pure science unify the world today?

(1) Pure science contains generalized knowledge, wisdom, and sensitivity that can be understood and shared by humanity across borders and overcoming the national and regional divisions caused by war, politics, economics, religion, culture, and other factors. This has been proven by the world's history of knowledge development, transfer, and exchange.

(2) On the other hand, pure science is vulnerable to the pressures of war, nationalism, and politics, and it is important to have robust mechanisms to maintain the integrity and quality of pure science, both nationally and internationally. Such mechanisms are, for example, national academies, the International Council for Science (ICSU), which has been reformed into the International Science Council (ISC), Pugwash Conferences, CERN, SESAMI, and the Global Climate Observing System.

(3) In the age of social networking and post-truth, we need to protect and sustain the spirit and systems of pure science. In the early 1990s, the late Dr. Hiroshi Inose made the following notable comments at a committee meeting of relevant ministries and agencies to discuss the introduction of Internet services in Japan. "The Internet will provide benefits to people, but it may also damage the authenticity of modern society and modern science." Thirty years have passed since the Internet was introduced to society. We need to always pay attention to the merits and demerits of the influence of the Internet and its derivative services on pure science.

4. How should pure science be guided to be more inclusive?

(1) Pure science has crossed various barriers (such as those related to existing disciplines, organizations, gender, socially vulnerable groups, generations, and countries) to open up the frontiers of human knowledge, and has accumulated common human knowledge and diverse local knowledge and experiences.

(2) As we enter a major transition period to the new world after COVID-19 in which sustainability, diversity, and inclusiveness are emphasized as values of the 21st century, it is important to review the definition, purpose, scope, and methods of pure science while maintaining its integrity and quality. To this end, it is important to focus on the roles and responsibilities of the humanities and social sciences, collaboration between the humanities and sciences, and support for such activities.

(3) As big data and artificial intelligence (AI) develop as important tools in pure science, there is a need for reasonable monitoring and correction on the limitations and biases as well ethics and reliability of these methods and tools, and developing and implementing favorable human-centered applications by using them.

(4) Distance learning and teleconferencing, established in the wake of the coronavirus pandemic, provide opportunities and new ways for pure science professionals and students to connect across time and space to mutually enlighten and empathize.

5. How can pure science be improved in your country?

(1) Pure science is attractive to young people. It also serves as leverage to increase the interest of people and society in science in general. However, I see that the sustainability of pure science is in danger in the current situation of Japan, with its strong nationwide atmosphere oriented toward innovation and short-term results.

(2) It is essential to form a free and tolerant forum to discuss the state of pure science, and to develop an environment for discussing what to research and for conducting research. Considerable effort is needed to deepen people's interest in, respect for, and tolerance of pure science as a whole or at the meta level, not the discipline-specific level. The method of narrative is important for communicating and empathizing with each sector of society.

(3) As for the formation of such activities and places as well as human resources and organizations that synthesize knowledge and tell narratives, the recognition of the importance is considerably poor in Japan. A results-oriented tendency in the history of modernization of science in Japan (just like neglecting the roots and soil of plants) are now looming as dark clouds in the Japanese scientific society. While a reform movement has gradually started especially among young people, it is essential to strengthen the support of people, goods, money, facilities, and networks for such fundamental activities.

(4) Specifically, for example, the Grant-in-Aid for Scientific Research (KAKENHI, Japan), which is said to be a public system to support pure science, should, in my opinion, be drastically redesigned to support small-scale activities. It is also necessary to correct the overwhelmingly uneven distribution of public research funding to a limited number of universities.

6. What do you think should be done to increase global cooperation / collaboration for pure science?

(1) Pure science is essential for preparing for human and global challenges, such as the climate change crisis, SDGs, and future pandemics. Global cooperation has become essential not only in sciences, but also in humanities and social sciences, in both of which such cooperation has been insufficient until now. For this purpose, it is important to secure resources such as people, goods, money, and information, and to establish systems (e.g., global science foundation, globally open facilities). It is also important for safety and security in Japan, to develop and secure human resources that enable this kind of activity and establish career paths for them.

(2) The issue of climate change, which is now a major problem even in the international political arena, is a typical example of how people around the world have shared a sense of crisis and moved international politics through the promotion of international cooperation and communication with politics and society in pure science simple activities since the 1960s (accumulation of observation data, modeling, etc. across various atmospheric and oceanic

fields). It is important to keep telling this narrative to people. It is a clear example of the importance of pure science and evidence-based policymaking.

(3) Currently, there are many international joint projects in science and engineering to study climate change. In addition to these, it is necessary to consider international joint projects in the humanities and social sciences as well as transdisciplinary co-creations. For example, the formation of a transdisciplinary co-creation research platform, the study of pure science and sustainability in the 21st century, and the joint production of a new encyclopedia of the 21st century would be possible.

(4) It is important for Japan to demonstrate leadership in these international activities and to train and secure the human resources to carry them out. This relates to the formation of Japan's soft power.

- In the past, Japan led internationally influential multilateral science programs such as the Human Frontier Science Program, the Budapest Declaration on Science and the Use of Scientific Knowledge for the 21st Century, the STS forum, and the Okinawa Institute of Science and Technology (OIST).

- Japan's international presence in such multilateral science programs has been waning in recent years. For instance, Japan's contribution was marginal when ICSU and ISSC merged to establish the International Science Council (ISC) in 2018. Although Japan made substantial contributions when the International Network for Government Science Advice (INGSA) and the Foreign Ministries Science & Technology Advice Network (FMSTAN) were established in around 2014, Japan's current contributions are marginal. The reasons for this include poor systematic for activities led by individual-level efforts; poor institutional systems and think-tank functions to sustain management; and a lack of human resources.

7. How can we excite younger generations to pursue careers in pure science?

(1) It is essential to create an environment where younger generations who are interested in pure science can enter this field with confidence as a lifetime career. For example, we can work on research positions, remuneration, human resource development evaluation systems, reform of research funding systems, publication of transdisciplinary research journals (other than the traditional peer review journals), and expansion of opportunities to participate in internal and external activities.

(2) To increase the interest of young people, it is necessary to construct a system, and collect, accumulate and publish research cases to convey the importance and attractiveness of pure science to them in the form of a narrative. We need to foster a culture in society so that pure science is accepted with respect and tolerance. A possible approach is to establish a STEAM education and research network for promoting education and research that combines reason and sensitivity and for sharing practical examples.

(3) Another idea is to produce a systematic chart of the world's historical development and deployment of humanity's pure science and knowledge, as well as a genealogical chart of scientists and scientific centers extending across time and space. JT Biohistory Research Hall in Takatsuki, Japan is a pioneering example of this. The Nobel Museum in Stockholm is also a precedent.

8. How could in-house labs of private companies be positioned?

(1) Until the 1980s, corporate central laboratories played a major role not only in industrial technology development but also in the promotion of basic research and human resource development. They contributed significantly to maintaining and strengthening Japan's industrial competitiveness, improving the international competitiveness of scientific research, and promoting industry-academia collaboration in basic research. Under present circumstances, it is difficult to revive this system. Not enough analytical research has been conducted and not enough experience has been accumulated as regards the impact of the economic friction between Japan and the United States in the 1980s on Japan's science and technology policy and industry academia collaboration systems, and as regards the downfall of corporate central laboratories. Such experiences must be passed on from generation to generation.

(2) A possible proposal at present is to build a place and facility where the industry, academia, governments, and citizens can discuss and practice themes, methods and others of science, technology, and innovation in a transdisciplinary co-creation manner, not only within universities and companies but also outside of them (off campus), through joint investment by the industry, academia, and government. It can be viewed as a training place where people are free to play in new styles. I expect that the humanities and social sciences will play a major role in this environment. (3) Such places, facilities, and investments should be recognized, encouraged, and expanded as a social system, and these efforts are already underway in some cases. This system should also be able to cope with the inevitable dual use of scientific research in the future.

9. Pure science could be applied to military purposes in a long run. Atomic or nuclear research was an example in the past. How could this aspect of pure science be handled?

(1) Even in pure science, the creation, accumulation, and synthesis of knowledge are inevitably subject to dual use over the years. The only way to put a stop to this is through institutions and dignity of science.

(2) First of all, it is necessary as a culture for scientists to be aware that the use of scientific knowledge has historically had both good and bad aspects for humanity and the earth.

(3) In this context, it is necessary to educate and train pupils and students from elementary, junior high, and high schools to universities and graduate schools on the thoughts and actions—both good and bad ones—that have been taken by scientists throughout history, by showing examples and telling narratives. The current problem of marine plastic pollution is a clear example of this. Plastics invented at the beginning of the 20th century should have been "good" for society, people, and the protection of forest resources during the 20th century. It is important for leading scientists to be aware that the reputation of plastics has now turned into "bad" in the 21st century.

(4) Persistent activities will continue to be essential for international deterrence systems such as the Treaty on the Prohibition of Nuclear Weapons and the Chemical Weapons Convention, although many are skeptical about their viability. It is necessary to establish and sustain international forums to share these discussions and incidents, and foster major trend. Examples include the Pugwash Conferences and the World Science Forum (Budapest Declaration). However, it should always be noted that the agenda of the talks and international mechanisms may change according to changing times and global politics.

(5) In examining the direction of science and its impact on socioeconomic life in the 21st century, in which the extent and speed of change are great, it is important to strengthen programs to develop and implement new methods of foresight and anticipation, and to develop relevant human resources.

10. Basic science is generally preferred to pure science in Japan among researchers. "Basic" naturally implies "applied" in the following phases. How would you evaluate basic science from this point of view?

(1) In Japan, it seems difficult to draw a boundary between pure science and basic research, define their scope, and differentiate their methods. Nevertheless, there are many examples of "academic pursuit without intended use" having had a great impact on the social economy, people's lives, or the military over the years. (2) It is the responsibility of a mature country like Japan to preserve "academic pursuit without intended use," that is pure science, as sources and bases of human knowledge and wisdom.

(3) In this context, I think the functions, roles, and responsibilities of academies, which are different from those of discipline-specific societies, are critical. Nowadays, the role and responsibility of academies are serious not only in promoting or lobbying for a specific field or a specific facility, but in discussing from various perspectives and formulating a comprehensive view on the state of academia in general, including the preservation of pure science, and spiraling up to a higher level through trustworthy dialog among politics, industry, academia, governments, and citizens. Redefining and reforming academies are urgent tasks as they are especially expected to respond to the rapidly changing times in present Japan.

(4) Problem-solving and mission-oriented public research programs are expanding recently. Seeds of pure research and ideas for new thinking frameworks are latent in such research activities. One idea for exploring them is to set aside about 10 to 20 percent of the budget of so-called problem-solving programs from the outset, introducing a system to support research on the discovery of knowledge frontier, wisdom, and challenges; ethical, legal and social implications (ELSI); social impact assessment and others.

(5) Using scientific knowledge, so-called "STI for SDGs" has been proposed at the STI Forum, a forum established by the United Nations to discuss how science, technology and innovation can contribute to the SDGs. This concept suggests that the SDGs are urging a major transformation of the values, systems, evaluation methods, and human resource careers of science, technology, and innovation nurtured by modern society in history. It is important that this concept includes the insight that new seeds and methods should be discovered in academia in the process of addressing the SDGs.

11. Research themes are often classified either as curiosity-driven or as mission-oriented ones. Is this dichotomization enough for classifications of research themes?

(1) Although researchers need to be aware of this traditional dichotomy as basic science, I think that the actual barrier between the two is getting lower today. That is, even in mission-oriented research activities, there are opportunities and motivations for researchers to be driven by curiosity if they are conscious of it. Without curiosity, researchers would be little more than data-producing machines. However, it is often harshly pointed out that under the current situation, many young researchers are engaged only in data production in narrow themed silos and are not in a situation to potentially drive their curiosity; rather, the current research environment and evaluation systems are nipping the buds of their curiosity. Comprehensive reform efforts are needed at the policy level, funding agencies, culture of actual research sites, and management, with regard to the provision of incentives for research, maintenance of the soundness and quality of research, evaluation methods, human resource development and careers, and exchanges with overseas countries. (2) Whether curiosity-driven or mission-oriented, the process of setting a theme in scientific research is very important. As an individual or a group, it is essential to cultivate the background and ability to think consciously and deeply about the historical transition, the position in the world, the background, and the limitations of the research theme intended to set, and to foster a research environment that makes this possible.

12. When you compare the current status of researches in Japan with that of other countries, how would you describe the current status of "basic science" in Japan?

I see a significant deterioration in the environment, institutional system, and culture in promoting basic research in Japan. Below are some of the challenges to be addressed.

(1) Increase the time available for researchers to contemplate and study. We need to free them from chores.

(2) Make a fundamental review of the funding systems, research support systems, and evaluation methods.

- For example, set aside 20 to 30 percent of the national public R&D budget as a basic research frame from the outset.
- Within the above budget frame, secure non-competitive research funds.
- The establishment and management of competitive basic research funds should be free from political and administrative intervention, independently evaluated by the scientific community, and dedicated to supporting mainly small-scale individual based research. The criteria for evaluation should include diversity (discipline, gender, generation, region, and international collaboration), originality, independence, and interdisciplinarity.

(3) Although there are many difficulties in realizing these challenges under Japan's current policies, systems, research environment/culture, and university management, given the limited time left to spare, it is essential that all sectors collaborate and take comprehensive action with the shared sense of crisis that Japan's research activities and systems are deteriorating.

(4) The responsibility and role for these efforts is great at the policy and funding levels. Meanwhile, it is necessary to check the abilities and qualities of instructors and research managers who manage research sites. It is impossible for universities alone to reform laboratory management, which now focuses on mass production of papers on fragmented topics. Scientific communities and academies are asked to share their awareness of the problem at a deep level and to implement reform. Although caution is required, I hope they have the ability to induce improvements in the culture and environment of research sites in conjunction with the reform of funding systems. That is, it is essential that institutional reform and cultural reform proceed in tandem.

13. Any constructive comments on budget allotment of the central government in light of its master plan of science and technology.

(1) As mentioned above, there is a proposal for a government decision to invest 20 to 30 percent of the public R&D investment in basic research on a stable and continual basis.
(2) It is also important to form a platform for dialog and trust-building among various stakeholders involved in policymaking, funding, research sites and others. (3) It is necessary to strategically address the following issues: continually support new types of research activities, such as research monitoring, impact evaluation, foresight, and ELSI that are different from conventional knowledge production and that aim at knowledge synthesis; and foster new ways of thinking and new types of scientists who engage in these activities and establish their social recognition and career paths.

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1. Why is fostering “pure science” an essential value, specifically to realize a free, just, and equitable society?

Modern times are built on various foundations, but I would dare say the most important are the democracy based on the principles of human rights and the scientific spirit focused on objectivity. And these two foundations have worked in tandem to build our times.

They are deeply intertwined with each other: In other words, “the will to preserve the future ourselves, regardless of who we are, as central players and as the core” and “the attitude to continue to pursue knowledge of the world in its true form, without fear,” are woven like warp and woof to create modern history.

But, if the attitude to pursue knowledge of the world in its true form should ever be abused by the ever-expanding commercialism or the short-sighted convenience of the political power of the time, it will bring about a disruption of one of the foundations of modern times.

In this sense, the most important science is probably pure science. In view of the infiltration of commercialism and capitalism, it seems too optimistic to think that all we need is proper functioning of applied science or that applied science is what makes people happy directly. Every system is built on foundations to maintain it and the foundations must be kept away as much as possible from the prejudice, egoism, and opportunism of people of those days. To enable this, we must maintain and foster pure science by keeping it a certain distance from politics and economy.

Otherwise, the key elements composing the philosophy of modern times—liberty, justice, and fairness—would be subject to ruin. Therefore, if we do not want the project of modernity to come to an end during our time, we must protect basic science.

2. Why should we prioritize pure science, especially in this moment?

Our society is undergoing a massive shift. No one can deny that the foundation of modernity, in other words, the belief that science and democracy will work to bring a better future for humanity, has been brought to question from various perspectives and in fact, has been collapsing.

This is evident from various aspects, such as the emergence of populism, the expanding view that science should be a tool for innovation, and the increase in the number of people who think it inevitable in times of digitalization for efficiency and convenience to be given priority over freedom and privacy. It can also be seen in the increasing number of people who live comfortably in filter bubbles made up of people with similar beliefs, who mistakenly regard the echoes reflected in this small chamber as socially just opinions.

The origins of populistic anti-intellectualism and innovationism differ but share similarities in terms of disrespect for the value of basic science. And, needless to say, resuming an academic tradition of any sort that once was disrupted requires significant cost and time. For this reason, as we do for other human activities, fostering "successors who will do science" for many years to come is of utmost importance. The absence of people fostering people means the end of science. It is too late when we notice the absence.

Now is therefore the time for us to protect basic science and the framework that supports it.

3. How does pure science unify the world today?

Our vision to observe the world is becoming distorted day by day due to business requests for innovation and politics driven by populism. Furthermore, though it looks as if digitalization contributed to an increase in the amount of information, what we are actually getting is more noise than data, leaving us more confused in determining what is important and what is not.

In such a world, where society has been digitized, populism has gained ground, and innovations have become excessive, pure science is an important yardstick to bring together humankind's perceptions which were once split onto a common platform.

After all, scientific spirit is the most universal "common yardstick" among the ideologies and practices that we humans have invented. We therefore must keep remembering that pure science always underpins our perceptions of things.

4. How should pure science be guided to be more inclusive?

Scientific activities are often subject to distortion from pressures to innovate and are belittled by anti-intellectualism. There is probably no way other than protecting these scientific activities from institutional and budgetary perspectives. But this is not easy by any means because these two trends, which are in progress around the world, are likely to continue for some time at least.

However, if science is properly understood, it is actually indispensable even to a group of innovation-oriented people or a group of anti-intellectualists. However, to be honest, I do not have any good ideas on how to persuade them into understanding the indispensability of science.

5. How can pure science be improved in your country?

Japan's R&D budget growth rate in the past quarter of a century has been stagnant compared to that of the E.U., the U.S., and China, and the ratio of pure science budget to total R&D budget has not changed much either. Furthermore, Japan remained stagnant in the number of scientific papers it produced and among industrialized countries, plunged in the rankings of scientific papers. There have been a number of Japanese Nobel Prize laureates in recent years, but all of their research results were achieved in the previous century when the foundation of pure science did not suffer as much damage as it has today. In other words, the Nobel Prize is merely glorifying the results of the past.

The first thing to do then is to stop the policy of "selection and concentration," which has prevailed in Japan over the past quarter of a century. Nobody, not even scientists, know what kind of research will prove to be important or will develop later on, let alone administrators in charge of science and technology policies, politicians, or business managers. The history of science clearly tells us that no one can predict a streak of new achievements in science. Of course, there may be areas with some apparent prospects of success over a short period of time but these areas will have already garnered attention and can naturally attract talents and funds.

Accordingly, what the government should do is at least invest talent and funds evenly and comprehensively in various series of research. It is silly to expect that innovation will take place simply by putting resources in some important research, and it is sillier to assume that excellent new scientific knowledge will be generated just by putting resources into excellent scientists chosen by the government.

There has recently been an odd widespread belief in Japan that, in order to develop scientific research, researchers should be made to compete with each other like race horses and consequently, the social status of researchers should be kept unstable so as to make them foster a competitive spirit to earn research funding. This belief, which perhaps was derived from a misunderstanding among administrators in financial authorities, has been handed over by successive governments, causing a complete decline in Japan's R&D system.

I would say that the biggest mistake ever made was the policy of reducing the budget for national universities at a constant rate each year regardless of their situation. As a result, national universities could no longer employ young people and even successors of retired faculty members could not be employed. There is also a growing disparity between affluent universities such as the University of Tokyo and local national universities that are not, which has led young people in Japan to regard academic work like science, studies, and research as economically challenging and toilsome professionally relative to other types of work.

Already in Japan, fewer students are enrolled in doctoral courses, and academic communities are suffering from a lack of members, resulting in, academism in various fields taking a natural course of decline. In addition, due to the low birthrate in Japan, there are fewer young people across all fields but the number of young people in the academic fields has been decreasing at a higher rate of acceleration. Given this, Japan should first drop the policy of reducing basic funds for R&D and university operations, and focus budgets on some specific fields. This policy has been applied to pure science and even to applied science in a similar manner.

Additionally, putting the argument over pure science aside, the private sector spends relatively more on R&D in Japan than in other countries. But it is important to point out that over the past quarter of a century, Japanese companies have reduced their R&D spending and in particular, have one after another, abolished or downscaled research organizations that engaged in research that sought to find seeds of research from a long-term perspective.

In summary, the rate of increase in research expenditures, for both basic and applied research as well as research funded by the private and public sector, has shrunk in Japan over the last quarter of a century, widening the gap between Japan and other countries. This coincides with the extreme decline in Japan's entire economic growth. Capitalism will not develop without investment and in recent years, Japan has failed to understand this obvious fact.

As such our problems are not easy to solve, but I can say that it is not a good idea for Japan to reduce its already limited expenditure on research and advanced education, and in particular should not cut down on basic expenditures. We must start by changing this policy. The government is launching a new 10 trillion yen endowment fund, but even this will basically be for competitive funding and is not thought to radically improve the situation that we face.

6. What do you think should be done to increase global cooperation / collaboration for pure science?

Global dialogue among scientists and networking between researchers of relevant fields have developed rapidly. However, the issue does not lie there. To begin with, people engaged in research and science are only a small part of humanity. In a sense, they are the privileged, a part of the global elite, and are people with a weaker sense of belonging to a particular nation.

When we look at China today, the nation has seemingly succeeded in combining nationalism and the elite, but this seems to me a temporary phenomenon. I believe there will be a divergence between the people and global elites sooner or later, which will likely cause a serious issue in China.

In the United States, I assume reflective reviews are underway as to why President Trump gained support. The findings and the cause that hinders the development of pure science will likely bear something intrinsically in common. In other words, the gap between people in general and elite researchers who are active on the global stage is the very essence that drives the problem.

It may sound paradoxical, but unless we start by learning what kind of life people in general lead in our country and what kind of issues they face, and enhance our ability to empathize on these matters, people will not approve of the need for global cooperation and collaboration. And if as a result, the circumstances turn bad, it will give rise to a storm of populism again and the storm will drown out the voices of the scientists who stress the importance of science.

As such my conclusion is as follows. If you wish to enhance global cooperation and collaboration, start by re-examining the settings around you. As a proverb goes, “slow and steady wins the race.”

7. How can we excite younger generations to pursue careers in pure science?

Many adults say knowingly that money attracts young people. But is this true? Remember when you were young. In making a big decision such as choosing a path in life, you must have weighed “requirements for development” against “requirements for restraint,” which means the process of decision making started from things such as whether you found the subject sincerely interesting or whether the subject was what you longed for. These are called “requirements for development.” There are other factors, on the other hand, that will discourage such positive feelings. These are called “requirements for restraint.” These will include for example, your economic outlook or your evaluation of your own abilities. In some cases, remarks from your parents, siblings, and friends may become a restraining factor.

The key point to note here is that “requirements for restraint” are no more than part of the problem you face, and youth tends to let you ignore such requirements. In short, youth is something that makes you careless in a good way and the world has developed and should develop based on this recklessness.

Consequently, what is most significant is to increase “requirements for development,” or in other words, increase opportunities to make you find pure science interesting and consider it as something to admire.

To that end, what is most important is to demonstrate how happily scientists immersed in pure science are leading their life. Of course, the world of research can be challenging and not always rewarding, but if a scientist can tell younger generations about something interesting that happened with a sparkle in their eyes, it will certainly be one of the most powerful means to attract them.

8. How could in-house labs of private companies be positioned?

As I mentioned earlier in question 5, Japan’s R&D investment was characterized by a comparatively greater investment by the private sector, but in the past quarter of a century, Japan’s rate of increase in investment has remained much lower than that of other countries and basic research divisions such as central research institutes were being abolished or downsized. As a result, fundamental factors supporting Japan’s science and technology in various ways have been declining. For example, the network of researchers belonging to corporate research institutes and universities has greatly contributed to maintaining the fundamental research ecosystem of engineering research by facilitating the liquidity of human resources and activities of academic conferences and associations as well as research activities themselves. But the current collapse of this system has disabled various buffer functions and continues to damage the fundamental capacities of research activities.

In general, private sector research institutes make comparatively large contributions to the fields of applied science, but they make a significant contribution to pure science as well. A good example is a researcher at Shimadzu Corporation who received a Nobel Prize.

It can be said that the overall current situation is that Japan's corporate research institutes are becoming less able to contribute to pure science.

9. Pure science could be applied to military purposes in a long run. Atomic or nuclear research was an example in the past. How could this aspect of pure science be handled?

Needless to say, the usefulness of any science or technology depends on how it is used. There are many cases where a strong nationalistic intent is hiding behind what looks to be a pure science activity, and in some cases, a technology itself or something built by the technology itself could come to assume political power. So, it does not mean much to try to discern between pure science and applied science in terms of dual use and it is probably difficult to draw a clear line between science that is politically driven and science that is not.

On the other hand, while scientists are nonchalantly immersed in their own specialties, their science and technology could be utilized for security and military purposes because the line between science for military purposes and science for civil use is ambiguous, turning the world into a suffocating space (although this may already be the case.)

As such there is little we can do in realistic terms, but we should firmly position the importance for researchers to care about just and fair research in the educational system at advanced educational institutions. To achieve this, I think that national academies of various countries, such as NAS (National Academy of Sciences) in the United States, will play an important role.

For example, all researchers must be careful about the kind of sponsors that are supporting individual scientific research activities. It is also necessary to raise their attention to activities such as the Pugwash Conferences, and the same can be said for other fields such as life science and information science. As is already known, these fields will come to bear a strong influence that could match or exceed the power of nuclear physics in years to come. Furthermore, it will be necessary to promote research areas, such as science and technology ethics and science, technology, and society that specialize in analyzing and introducing the structure and mechanism of dual-use technologies and other issues.

10. Basic science is generally preferred to pure science in Japan among researchers. "Basic" naturally implies "applied" in the following phases. How would you evaluate basic science from this point of view?

Though there are certainly some researchers in Japan who believe that dealing with basic problems is superior in terms of research work, Japan is fundamentally a country that highly appreciates people who have solved social issues with applied technology. As it were, there has been a strong tendency in Japan to support "science for the sake of technology," which is apparent from the fact that the quota of and budget for engineering students in national universities are larger in Japan compared with other countries. Furthermore, recent years saw a heavy promotion of "science for the sake of innovation," followed by various legal revisions. This means that Japan apparently places less emphasis on basic research, shifting to give more weight on applied research.

Basic research that is unable to contribute to applied research may certainly be considered meaningless, but once basic research turns slave to applied research or innovation, the achievements of science in aggregate terms may stray from the original mission of science which is "objective understanding." If this were to happen, we would be putting the cart before the horse.

11. When you compare the current status of researches in Japan with that of other countries, how would you describe the current status of "basic science" in Japan?

As I mentioned earlier, the academic foundation itself seems to be disintegrating in Japan. The gravest issue is that this industry has been regarded as an unattractive field by the next generation and this is attributable to the fact that many young researchers find themselves in lower economic and social positions than their peers with the same academic background who advanced to other fields.

Already, academia is losing its attractiveness as a work option in Japan and recovering the trust once lost is not easy. Even if we reflect on the past mistakes in policy and make changes, Japan's academic research system will likely undergo the dark ages presumably for the next twenty years, slowly disappearing from the global stage of research. As the world moves toward a knowledge society, Japan's decline in academic research will bring a deadly blow to the nation. Someday in the future, Japan may be remembered as a country that once flourished. However, if we look back at the history of the world, such ups and downs of nations is a not uncommon. Nevertheless, if there is still a possibility for recovery, I believe we should make a policy change immediately.

Tadashi **KOBAYASHI**

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1. Why is fostering "pure science" an essential value, specifically to realize a free, just, and equitable society?

In the latter half of the 19th century, science, excluding chemistry, did not demonstrate much social usefulness and the strategy scientists took to appeal to society was the perspective of a new culture distinguished from Oxbridge gentleman education, rather than its usefulness. This eventually became intellectual culture among rising industrial capitalists.

Science in such terms as a new culture can perform an educational function for society, or in other words, can put irrational customs and injustices right. Using terms from recent years, science would be referred to as an act of realizing critical thinking.

I would suggest that Mertonian norms (or CUDOS—communism, universalism, disinterestedness, and organized skepticism) describe these characters of science in a somewhat idealistic way. Actual science has not yet achieved the norms perfectly and this realization has not always been easy in recent years. But it does not mean that the norms have become less important.

And I believe that, when pure science is regarded as the science to realize CUDOS, the educational function as a new culture is essential in realizing a free, just, and equitable society.

2. Why should we prioritize pure science, especially in this moment?

There is a paragraph in the declaration released at the World Science Forum 2019 held in Budapest (https://worldscienceforum.org/contents/declaration-of-world-science-forum-2019): "In our societies transformed by the rise of new communication channels and social media, scientific knowledge is increasingly challenged in public discourse by opinions and beliefs based on distrust, insufficient engagement, poor science literacy, and inefficient communication of science to the public and policymakers. At a time of accelerating global change, it is particularly important that young people in all societies have access to scientific education."

As the paragraph says, despite society becoming more dependent on science and technology, there is a growing distrust of science itself or experts. Such distrust has also emerged during the ongoing COVID-19 pandemic.

One of the reasons is that too much emphasis on the usefulness of science from a short-term perspective facilitates a negative evaluation of the science that falls short of expectations.

Science must be evaluated not only based on results brought forth but also through the value of its process as expressed by the CUDOS norms.

This is the very reason why recovering the educational function held by pure science in the above-mentioned sense is critically important.

3. How does pure science unify the world today?

Pure science that is most difficult to justify in modern times is probably physics that uses a large-scale collider. The laboratory equipment and experimental costs are so large that it is difficult to justify covering the costs with public funds.

However, moderate-scale pure science should be actively promoted and evaluated. For example, the Ig Nobel Prize possesses and appreciates a primitive but essential spirit of pure science. It serves the function of providing intellectual entertainment as well as the educational function of pure science. Pure science that cannot or should not be justified from the perspective of usefulness is what society seeks as top-level intellectual entertainment that satisfies the intellectual appetite, a fundamental human desire.

The point to be noted here is that the promotion of such pure science could likely end up as a luxury for the rich. Countries faced with a large number of issues that require scientific solutions tend to be poor and lack enough educational capacities, and it is therefore important to address the issue of how to deal with the lack of researchers (see http://uis.unesco.org/apps/visualisations/research-and-development-spending/). In this situation, the educational function of pure science should be prioritized.

4. How should pure science be guided to be more inclusive?

Pure science

- Critical
- Open minded
- As inexpensive as possible
- Accessible for everyone (gender equality, young people, the poor)

It is important that the contents of pure science can be described in not only Western languages but also in the native languages of various countries. This has not been realized in many non-Western nations and it is essential to increase and facilitate access to pure science.

5. How can pure science be improved in your country?

Japan was the first country among developing countries in the world that accepted Western science. To resist the threat of Western military and industrial power in the latter half of the

19th century, Japan was strongly committed to accepting Western science and technology and therefore, did not invest heavily in pure science. Even in universities, there are more faculties of engineering that are oriented toward applied research and experimental development than faculties of science that prefer pure science. Use-inspired basic research, known as Pasteur's quadrant as referred to by Stokes, is also heavily conducted by faculties of engineering.

The issue here is pure science which is close in type to the Bohr's quadrant. As national finances get tighter, the sustainability for pure science projects that require enormous expenses, such as a large-scale collider, begins to be questioned. An investment of public funds requires accountability based on some level of social usefulness and such accountability will also be required for pure science.

As I mentioned earlier, from the perspective of the educational function and the function of providing intellectual entertainment, an investment of public funds can be justified to a certain extent, but the amount cannot be too large. It will therefore be necessary to conduct private or cloud funding efforts.

In Japan's case, however, the dire issue is the decrease in the amount of funds being provided to universities from the turn of the 21st century. Particularly, for universities responsible for basic science and pure science, reducing block funds while increasing competitive funds for mission-oriented research has led to the disruption of the foundation of pure science. We must be held responsible for undermining the foundation of pure science, and amend our policies.

To this end, we must analyze the reasons for strong results in the Ig Nobel Prize, and the increase in the number of Nobel Prize award recipients in the 21st century (not that all of them are related to pure science) and draw lessons from them.

6. What do you think should be done to increase global cooperation / collaboration for pure science?

We must promote international exchange among students and young researchers. We should learn from academic exchanges and global culture created by CERN. https://www.gradcracker.com/hub/759/cern/additional-content/1358/culture-and-values

Specifically, I would recommend building a base for pure science in China, for example, as it is an economically affluent nation, and gathering students and young researchers from around the world. The educational function of pure science will influence China's current science and technology policy, which has been inclined to practicality, and encourage China to play the role of supporter of pure science as an international public asset, thereby possibly helping to alleviate global tensions.

7. How can we excite younger generations to pursue careers in pure science?

They may and should excite themselves to pursue pure science in ways that are not ordered or designed by others. All we can do is to show our respect for pure science and enjoy it.

8. How could in-house labs of private companies be positioned?

As long as private companies are profit-seeking organizations, they may invest in basic science (based on applied research) but they are unlikely to invest in pure science except for social contribution activities.

In fact, during the 20th century, corporate research institutes invested heavily in use-inspired basic research of Stokes' quadrants, but this has decreased in the 21st century.

9. Pure science could be applied to military purposes in the long run. Atomic or nuclear research was an example in the past. How could this aspect of pure science be handled?

It is quite a tough question. Knowledge producers cannot control ways of appropriating one's product (knowledge) and this is, in a sense, the "creative process" of science. What we can do is show some historical examples of the "creative process" and their results in society and encourage researchers to continue to consider this issue.

10. Basic science is generally preferred to pure science in Japan among researchers. "Basic" naturally implies "applied" in the following phases. How would you evaluate basic science from this point of view?

I agree that basic science is a concept built on applied science. Presumably, basic science corresponds to the Pasteur type of research in Pasteur's Quadrant. Many engineering researchers in Japan associate their research style with Pasteur's quadrant (use-inspired basic research). On the other hand, science faculty researchers tend to claim that they belong to Bohr's quadrant (pure science). But with funding for research coming from public funds and the recent increase in mission-oriented competitive funds, it is becoming difficult to advocate pure science head-on.

11. Research themes are often classified either as curiosity-driven or as mission-oriented ones. Is this dichotomization sufficient for classifying research themes?

This dichotomization is a little crude.

First, researchers will not conduct any research that will not stimulate their intellectual curiosity. In this sense, the term "mission-oriented" gives an impression of an external party enforcing a mission on them while ignoring their intellectual curiosity or as if researchers were passive beings.

Second, there are various types of missions, such as development research centered on the creation of economic values, innovation-oriented research, research for achieving SDGs, research aimed to resolve global environmental issues, and military research.

12. When you compare the current status of researchers in Japan with that of other countries, how would you describe the current status of "basic science" in Japan?

Japan is following a course of decline. Japan is the only advanced country where the number of doctoral talents per population is decreasing in the 21st century. Young students have begun shying away from advancing to graduate school to earn a doctoral degree in basic science. This is because it is now considered a career risk to earn a doctoral degree. The central government has finally realized the imminence of this issue and have started addressing it, but I feel it is a little too late.

13. Any constructive comments on budget allotment of the central government in light of its master plan of science and technology.

We need to increase the number of doctoral talents as soon as possible. For that, we should create an environment that enables researchers to participate outside of academia and attracts young talents. Businesses must build a framework to actively utilize doctoral talents, universities must establish an educational system capable of both developing the excellence of doctoral talents and securing their employability (providing good job prospects), and the central government must provide funds to support these initiatives. Increasing the number of doctoral talents and their diversity will no doubt help enhance the number and quality of researchers engaging in basic science and pure science as well.

Yoichiro **MURAKAMI**

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Professor Emeritus, International Christian University

1. Why is fostering "pure science" an essential value, specifically to realize a free, just, and equitable society?

The fact that pure science is fostered in a society testifies the society is free, just and equitable. Because science is originally based on the free intention of individual members of society to elucidate unsolved problems in nature. Pure science is not the womb of a free, just and equitable society, but one of its fruits.

2. Why should we prioritize pure science, especially in this moment?

In a highly capitalistic society, everything proceeds on the commercial base, and science is not an exception. Consequently, the results of scientific research are easily exploited for producing societal values. As a result, for the want of research bankroll, scientists are induced to research themes which could directly produce the profitable results. This is the death of science in the original sense of the word, “science.”

3. How does pure science unify the world today?

I do not think that pure science can politically unify the world. It is indispensable for a scientific, particularly pure scientific field to organize a scientific community, and such a community is intrinsically formed beyond national borders. In that sense, it can unify the world today.

4. How should pure science be guided to be more inclusive?

Honestly, I cannot follow this question. Today, scientific fields are more and more specialized and compartmentalized and nobody can cover the phenomenon. It comes from the nature of scientific research itself.

If you want to change this institutional situation, you should bring along not pure scientists but some special resources which can be called “lay-experts.”

Let me tell you about a Japanese experience. Now several Japanese universities developed a graduate program for science-communicator or science interpreter, which is open to all graduate students of specific major programs as their sub-major. And finishing this program means that the researcher is expected to be an expert of his/her major scientific field and also to be a person who can have a much broader view which allows him/her to give social problems such as ELSI a careful consideration than usual proper scientists.

5. How can pure science be improved in your country?

Again, this question seems to me to be rather odd. Pure science is pure and that is all. There is no room for it to be changed, spoiled or improved. Of course, today there might be a problem that in a country pure science is almost neglected whereas only applied or mission-oriented science flourishes. In that case, the policy-makers of the country are strongly advised to refer to the classical report, “Science—the Endless Frontier,” written by Varnevar Bush, although, the basic attitude of this report is on the side of applied science.

6. What do you think should be done to increase global cooperation / collaboration for pure science?

As I said before, in the fields of pure science, scientists intrinsically and always are to go international. They do not care about their nationality, and are willing to cooperate and collaborate with researchers of every country. If not, simply they are not pure scientists.

7. How can we excite younger generations to pursue careers in pure science?

This is the hardest question to be answered, because today secular utilitarianism is quite popular especially among younger generations, and it is quite hard to let them choose careers of pure science, which rarely bring secular success to them. Of course, to get the Nobel Prize is considerably the best motivation for young pure scientists, but the possibility for them to reach the target is quite limited.

My answer is really humble. To let senior scientists tell enthusiastically the pleasure and soulful impact that they experienced when they elucidated, and opened the doors of the unknown in nature, this is only the suggestion that I could.

8. How could in-house labs of private companies be positioned?

Even in the mission-oriented program, we could have some pure scientific results from time to time. Let me give an example. Some big Japanese companies used to have two kinds of in-house labs, one of which was categorized as "basic," and the other "applied." A good example is Hitachi. Late Dr. Akira Tonomura was best known for his development of electron holography, and also experimental verification of Aharanov-Bohm effect, and these amazing accomplishments of physics were done when he worked for the Central Institute of Hitachi.

9. Pure science could be applied to military purposes in the long run. Atomic or nuclear research was an example in the past. How could this aspect of pure science be handled?

It is ideal for a scientist to decide to quit, by his own decision, his research when he realizes that his research results could be unwillingly exploited for military use. But that may be unrealistic. Then the third institution which can bridge the gap between the scientific community and other parts of society is badly needed.

10. Basic science is generally preferred to pure science in Japan among researchers. "Basic" naturally implies "applied" in the following phases. How would you evaluate basic science from this point of view?

The oldest modern university in Japan, the University of Tokyo, is known as the first university in the world that equipped an independent department for engineering education. Also, Japanese expression “Kagakugijutu”* tells that from the beginning of modernization Japanese people accepted science and technology as one, single concept, not as the combination of two different concepts. This shows that in Japan fundamentally the concept of pure science has been something quite inaccessible. That is why in Japan “basic” is rather preferable to “pure.”

*“Kagaku” is the Japanese word for “science,” whereas Gijutu is the word for technology.

11. Research themes are often classified either as curiosity-driven or as mission-oriented ones. Is this dichotomization enough for classifications of research themes?

Of course, in some mission-oriented projects, scientists can do pure scientific work, and vice versa. But this dichotomization is still useful, particularly the project is done by governmental aids.

12. When you compare the current status of researches in Japan with that of other countries, how would you describe the current status of “basic science” in Japan?

Unfortunately, today’s trend in Japan goes not toward pure science but just applied. One example is the application form of the governmental fund of pure science (Kaken-hi in Japanese). In the form there is an item requiring the applicant to fill in what kind of social profits can the applicant expect at the end of the proposed project. This did not appear in the past.

13. Any constructive comments on budget allotment of the central government in light of its master plan of science and technology.

It is a question too big to respond in a short space. The eligible allocation of the budget might differ from country to country. Only thing that I can say here is that at least a considerable part of the total budget for science and technology should go to pure science, and have a long view on the results.

Masaki **NAKAMURA**

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1. Why is fostering "pure science" an essential value, specifically to realize a free, just, and equitable society?

First, what is important for a "free, just and equitable society" is that knowledge is not monopolized by particular people and that access to knowledge is open to all.

Second, applied research is conducted by assuming specific values and visions for the future and pursuing their realization. On the other hand, "pure science" is driven by curiosity and does not assume a specific mission, and therefore it can embrace various possibilities for the future society. For example, just as the theory of relativity brought about major changes in the conception of time and space, pure science fundamentally overturns what we currently consider as the options available to us and opens up new possibilities far beyond our imagination. I expect that such potential of pure science will make a significant contribution to the realization of a "free, just and equitable society" by expanding the range of possibilities available for our future society.

2. Why should we prioritize pure science, especially in this moment?

First, humanity is currently facing unprecedented challenges, including the even more ongoing global warming and the resulting spate of natural disasters, as well as the declining birth rates and aging population in developed countries. To deal with such problems, it is obvious that development research and underlying applied research are important. However, in envisioning the future of society over a long-time span, the development of pure science will play an important role in making it possible to broaden the range of options for the future society, as mentioned in my answer to question 1.

Second, the coronavirus has sharpened the disparity between developed and developing countries in terms of vaccination status, for example, and there are social divisions over vaccination and other issues within developed countries. The social divisions may continue to deepen. I believe that pure science, whose activities transcend national and social boundaries, is capable of unifying the world that has been divided in such a way and therefore needs to be promoted.

3. How does pure science unify the world today?

Science is an activity that transcends borders, language, religion, gender, and communities, and this trait is most evident in pure science. This is because development research and applied research are aimed at realizing the objectives that a particular group of people endorse based on particular values, whereas pure science is (comparatively) free from such a context. For pure science bringing the world together, it is essential to place a focus once again on the philosophy of science, i.e., to be humble before scientific facts and to make decisions based only on the objective correctness of scientific statements, not on who made the statements.

From this perspective, citizen science, in which citizens are the actors of front-line scientific research, is extremely important. Professional researchers in universities and research institutes and citizens outside such institutions are essentially equal in the face of knowledge. I believe that knowledge should not be monopolized by professional researchers who belong to universities and research institutions, but should be extended to citizens at large, and that it is necessary to reaffirm the value of openness of knowledge.

4. How should pure science be guided to be more inclusive?

It is important to substantially guarantee access to science to a wide range of people. While science claims to be open, access to science is often substantially limited to a few people in many situations. Research facilities, resources such as research paper, and the funding required to conduct research are currently almost exclusively dominated by professional researchers. Women, people with disabilities, minorities, people in developing countries, and citizens working outside research institutions have limited access to science. In recent years, access to research results, as one aspect of research infrastructure, has been emphasized under the philosophy of open science. While the importance of promoting open science is obvious, it is also important to ensure that research funding, research facilities, and other infrastructures that support research are available to non-professional scientists, as well as to create systems that support nonprofessional people in conducting research. For example, public libraries could be staffed with personnel who provide research consultation, in addition to librarians. It may also be possible to introduce a system in which graduate students, like teaching assistants who support university classes, give advice for citizens on their own research and receive a certain amount of wages as compensation.

5. How can pure science be improved in your country?

It is important to guarantee the right to research to all citizens. To achieve this goal, it is important for elementary, junior high, and high school teachers and others involved in education to not only teach students the knowledge as given, but also enjoy for themselves the thrill of intellectual exploration. This requires expanding research funding and systems that support research conducted by non-university schoolteachers, as well as ensuring that they have enough time available to conduct research. The busy and poor working conditions of schoolteachers have often been raised as a problem in recent years. Such a situation is an obstacle to ensuring their right to research.

Second, the age of those who enter universities in Japan today is concentrated between 18 and 19. It is important to further strengthen the system to guarantee and support opportunities of studying at universities whenever people want to study while working in society. We need to create a society that attaches significance to the exploration of pure intellectual curiosity. To this end, it is important to improve the working environment and create a system that allows people to balance their work with their study and research. Universities and research institutions also need to further improve their systems to accept and support working adults.

6. What do you think should be done to increase global cooperation / collaboration for pure science?

It is important for young researchers, such as graduate students, to gain experience in global research exchange. In this context, it would be effective if young researchers independently plan and implement research exchange opportunities, rather than senior researchers planning such opportunities or letting young researchers participate in such opportunities that also involve senior researchers. For example, we could establish a system to fund opportunities for international research exchanges to be planned and organized by graduate students from multiple countries. It is important to create opportunities for practical international research exchange even on a small scale by, for example, having a few researchers who have had exchange opportunities at academic conferences or the like take the lead, or having foreign graduate students studying in Japan serve as a hub for such an event.

7. How can we excite younger generations to pursue careers in pure science?

First, in order to foster an interest in pure science, it is important that adults who closely relate to children enjoy the real thrill of research. To this end, it would be effective to expand citizen science, which allows anyone to be involved in research, and to create a system to support elementary and junior high school teachers in conducting research.

Second, it is also important to eliminate factors that may prevent young people who are interested in pure science from pursuing their own interests. For example, it is not uncommon in Japan for a female student who wants to pursue science at university to have parents who oppose her, resulting in changing her course. It is also not uncommon for university students who wish to continue their research at university to give up a career in research due to uncertainty about their future. The former relates to gender bias, and the latter to future economic insecurity. Such factors are expected to vary according to the country and each person's attributes and family environment. It is important to specifically identify such factors and address them one by one.

8. How could in-house labs of private companies be positioned?

In order to guarantee access to research to as many people as possible and guarantee diversity in research, it is important that places where scientific research is conducted are not limited to universities and research institutes. In-house company laboratories play an important role in ensuring research diversity and in mediating between development research conducted in companies and research conducted in universities. Research conducted in company laboratories is also diverse, ranging from development research to applied research, and even basic research in some cases. The diversity of research is important in fostering pure science, and having a variety of actors involved in research in various settings and ways has, in principle, a positive effect.

In reality, however, research conducted in companies is likely to lean toward applied research. Narrowing the diversity of research means that companies may lose the possibility of creating seeds for future breakthroughs. I therefore propose that researchers in company laboratories be allowed to spend, for example, one day a week (or 20% of their time) for independent research, so that they can freely pursue their own research themes, and also propose that the necessary funds and facilities be provided to a certain extent. In addition, tax incentives may be applied to companies that introduce such a system. This is expected to have a significant effect on companies in securing excellent human resources and in terms of investing in the future by conducting various research activities including pure science.

9. Pure science could be applied to military purposes in a long run. Atomic or nuclear research was an example in the past. How could this aspect of pure science be handled?

The possibility of military use in future is not limited to pure science, but is true of all human activities. The same argument applies to the fact that it is often difficult to foresee military use in advance. Therefore, what is important is to respond appropriately when the possibility of use for military or other purposes becomes foreseeable and to foresee such possibilities as soon as possible. Due to the specialized nature of scientific knowledge, especially in the early development stages, it is difficult for all but a few scientists to foresee the technical possibilities of military use. This is particularly true in pure science. It is the social responsibility of scientists, who are capable to do so, to foresee the possibility of pure science for military use or misuse at an early stage.

However, what exactly constitutes an “undesirable military action” or “misuse” differs from person to person and group to group. On the other hand, there are some acts that are to a large extent shared by all as being problematic, as demonstrated by the Treaty on the Prohibition of Nuclear Weapons. For issues that are expected, to some extent, to raise concerns in society or that are irreversible, scientists are expected to focus their efforts on preventing undesirable uses, both individually and as an academic community. For the other issues, it is the social responsibility of scientists to actively participate in discussions, on the premise that they rely on consensus building in society.

10. Basic science is generally preferred to pure science in Japan among researchers. “Basic” naturally implies “applied” in the following phases. How would you evaluate basic science from this point of view?

I think that people prefer to use the term “basic science” for justifying the practice of pure science, which is not oriented toward direct application, to society, government, and politics. The logic here is that pure science is not conducted for the self-gratification of researchers, but is important as a foundation for future applied research, and therefore it is necessary to invest in pure science. While this will be effective in eliciting various types of support, including investment in pure science, there is a concern that it will lead to the discrimination of areas that have a high return on investment from those that do not. This logic is therefore ambivalent and insecure. It is necessary to appeal to the significance and importance of pure science itself more directly, instead of assuming the possibility of future application.

I also feel that in many cases, the application of basic science is perceived in a too narrow concept. The application of basic science should not be limited to technological application, but should be viewed in a broader way, including making people's lives more mentally fulfilling.

11. Research themes are often classified either as curiosity-driven or as mission-oriented ones. Is this dichotomization enough for classifications of research themes?

The issue is how to position the research that lies at the boundary between curiosity driven research and mission-oriented research. The discussion of “oriented” basic research and “use-inspired” basic research mentioned in the report appears to stem from such concerns. What is of interest here is the content of research that is funded in the name of mission-oriented research. There is, of course, a group of research conducted with the attainment of a mission clearly in mind. On the other hand, there appears to be many cases in which researchers apply for research funds associated with a mission in order to obtain a budget, but actually conduct ordinary curiosity-driven research without much awareness of the mission in their daily research activities. It is a matter of separating the significance of research assumed by the researcher from the explanation (official stance) given to obtain research funds. Maintaining such a situation, which can be viewed as duplicity, is not healthy, and it may be perceived as a problem from the perspective of investment in research. Nevertheless, from the perspective of investment in basic research, it is also true that sometimes the progress of research in a field is strongly expected to serve as a basis for applied research, even if the researchers themselves have no or little awareness of the mission.

Given this backdrop, I propose the following four categories for the description of curiosity-driven research and mission-oriented research from the perspective of researchers' awareness and the position of research in policy. What I think is important is how we perceive and position basic research (1) and basic research (2) given in the table.

Categorization of research	“Pure” curiosity-driven research	Basic research (1)	Basic research (2)	Mission-oriented research
Researchers’ awareness	Curiosity-driven No awareness of mission	Curiosity-driven Mission is only for external explanation. Low awareness of mission.	Basic research, with awareness of and orientation toward mission	Conducted as mission-oriented research
Position in policy	Curiosity-driven There is possibility of forming a basis for future applications, but its outline is unclear.	It is expected to form a basis for specific mission-oriented research in the future.		Conducted by setting and implementing a specific mission

12. When you compare the current status of research in Japan with that of other countries, how would you describe the current status of “basic science” in Japan?

The policy of reducing the basic funds for research (operating expense subsidies) and increasing the ratio of competitive funds has been unsatisfactory, resulting in an extremely distorted research environment. This severely hinders the development of basic science having diversity. Particularly at regional national universities, it is said that due to the reduction of operating expense subsidies, the research funds allocated to each researcher have fallen far below the level necessary to conduct minimum research and educational activities. It is a good idea to expand competitive funding to stimulate research activities, but as a precondition, it is urgent to establish a system ensuring that individual researchers receive a stable minimum amount of research funding that enables them to generate seeds for research.

13. Any constructive comments on budget allotment of the central government in light of its master plan of science and technology.

First, the promotion of citizen science has been included in the basic plan. I propose establishing a mechanism to promote grass-roots basic science conducted by citizens, such as providing research funds, research facilities, and research advice to support it.

Second, many people involved in universities have criticized the policy-driven shift from basic funds to competitive funding. In order to empirically clarify what kind of fund allocation will lead to the strengthening of research capabilities, a system could be introduced, as a social experiment, in which a certain amount of research funds is stably allocated to researchers affiliated with a particular regional national university for, say, 10 years to verify the effect of the system.

United Kingdom

The Aspen Institute U.K. convened participants in a roundtable discussion to share expertise, experience and perspectives around four main questions dealing with multiple aspects of basic science and fundamental research in the United Kingdom today.

Which stakeholders do we need to engage to promote basic science?

Aside from the obvious stakeholders involved in basic science, the public is probably a key stakeholder. The pandemic has been a great example where public trust in science is extremely important for public policy to function. For this reason, amongst others, it is important to encourage participation in basic science, to have an understanding for the motivations for fundamental science and a basic level of knowledge in science.

But how do you engage the public?

Most of the time, when talking about public engagement and support, the argument is made in the context of applied science or applied research. This is a real opportunity to engage with the public in the very early stages of basic research, focusing on appreciating the elegance of answering questions and solving problems, for example, and the value of knowledge in itself.

It seems that we are now in a more sophisticated place, where the public understands uncertainty. Scientists and researchers have been doing science in real time, in front of the public, and there's been a far greater degree of understanding of how all of it happens. The U.K. is in a more mature position relating to public debate, and, although there is still some level of polarization and disinformation, the scenario has improved overall.

The relationship between scientists, the public and educational contexts is also worth noting. On one hand it is important for scientists to interact with students in the universities and with the wider public to ensure the next generation of scientists are trained efficiently and to ensure that the citizens have enough knowledge to be able to participate in democratic decisions about energy, health or environment, for example. On the other hand, it is important for scientists to be able to work on long-term projects and, at the moment, the opportunity for long term research has diminished in British universities. In this regard, there is a tension between long-term uninterrupted research projects and interacting with the wider public and the students.

Policymakers, including civil servants and those who are involved in the policy development process, are also important stakeholders. Once we understand the values and the culture and the needs of the stakeholders, then we can get better at telling the stories of what fundamental and basic science delivers. It is crucial, in this context, to consider the language and the format for different stakeholders in order to implement effective policies.

Another important stakeholder is the industry. There is an underrated interaction between some of the activities of basic science and industry whereas, often, to understand science we require tools that are sourced by the industry. Therefore, it is essential to improve their capabilities. To this point, it is interesting to note that basic science can be considered a driver of commercial capability. And, in turn, it certainly helps the process to have industries that will advocate for the importance of basic science because they understand what that means for their commercial capabilities.

Some stakeholders seem to not to be valued enough—science communicators and those involved in science communication, for example. Facilitating them in communicating scientific concepts, methods and facts to people in a way that makes them accessible and relatable is essential to prioritize basic science.

Philanthropists and charitable funders are also potential stakeholders. Similarly to the public, many of them tend to be more closely related to applied research. This also means that they often fund applied research rather than fundamental research. In this sense, to what extent can they be brought around the conversation on basic research?

Furthermore, it is relevant to note that basic research can happen in the private sector as well as the public one, so it's an important piece of the puzzle in the discussion of stakeholders.

In this context, timing as well as scale are both of significant importance. However, some stakeholders, including politicians, do not always have a clear understanding of scale, which is, in fact, essential when it comes to international collaboration. Furthermore, unless there is a clear understanding of scale, some stakeholders may be lost along the way.

One of the main issues with stakeholders in the U.K. revolves around the link between politicians and scientists, so that there is a lack of scientists in government and many politicians lack a solid understanding of how science works which, in turn, is counterproductive and not constructive within the policy making and democratic processes. This is particularly problematic during times of crisis or national and global emergencies, such as the pandemic.

What cross sector partnerships do we need to support or create in order to bolster basic science?

In the U.K., a very important role is played by the public research sector and labs. Agencies are also important, as they talk to one another regularly and on a multilateral basis, which is an essential part of the picture to bolster basic science. Within this ecosystem, it is necessary to have small-, medium- and large-sized groups that can work together toward solution-oriented projects and research endeavors.

It is equally important to recognize the value of peer review in terms of partnerships. Peer reviews are powerful processes to ensure high quality research and, at the same time, still leave some room for innovation.

Partnerships are closely linked to collaboration, which is required in order to do science in the context of both individual research and group research or cross sector research. However, it is often an underappreciated, undervalued and under-recognized quality.

In terms of partnerships, the question can also be what is that “flow”, whether it’s data, ideas, or actually people, that drives interesting work and discoveries and pushes the frontier forward.

This is relevant also because partnerships can be crucial in a context where it is not always about having an impact, but more about thinking which outcome actually drives the basic research.

Furthermore, partnerships across disciplines are increasingly important. However, it must be noted that the incentives system, from funding through publication and career pathways, don’t always facilitate this. Now more than ever multidisciplinary journals, such as *Nature*, have a key role to play. The multidisciplinary dimension involves a sum of many disciplinary approaches as opposed to approaches that borrow from across disciplines. Some of the young generations of scientists in certain research sectors do not identify with any discipline at all but this is rare as the education systems tend to reinforce discipline boundaries. At the same time, it is necessary to emphasize the fact that research and science have no borders, as such it might be necessary to consider drawing a clear distinction between politics and political dynamics and research itself, as all the more often there is a damaging spillover in this sense.

It is paramount to ensure that young people and young researchers who are coming into the field see this as a valuable career, where not only they can grow as individuals, but they can contribute back to society in an effective way. This goes beyond partnerships, but in the context of collaboration it is relevant to bringing together organizations in order to incentivize individuals to have a long-term career—this is one important element of partnership. Another is giving credit to organizations as well as individuals within the context of collaboration, which is something to highlight and encourage.

One of the issues is, to this point, whether science and academia remain attractive careers for students and young professionals. Ensuring that academia does not become an unattractive career remains a key challenge. In this context, funding to universities doing research is incredibly important to guarantee the pipeline in basic research. Whereas universities, compared to research institutes in the U.K., tend to "lose out" and are, often, unable to maintain a level of funding that allows students and researchers to do their work.

How can basic science be made more inclusive in the U.K.?

It is crucial to think about inclusivity across different axes, as it is related to diversity and age as well as racial issues. It is also necessary to consider the whole research ecosystem in the U.K. as being more permeable and more friendly to movement between sectors as this would make the whole system more diverse, and the different sectors would learn a lot from it.

To have a truly diverse research ecosystem, which is based on age, gender and ethnic-related diversity, it is important to be more flexible with different individuals and groups coming to research and being productive at different times. An example of this may be individuals who wish to take time out for family reasons. There are different paths to making a contribution and it is important to reflect on what the expectations in terms of contributions from individuals are by a certain biological age—it might be relevant to note in this context that this does not relate to women only. Tied to this, the lack of attention to mid-career must also be addressed.

It is necessary to encourage and ensure general awareness in science, in order to make it less elitist and give people the chance of understanding that there are many ways in which one can contribute to science, many different avenues. It's not only about how to do research or how to implement the act of conducting fundamental research, but also how to handle different notions of contributing to the scientific endeavor in multiple manners.

Moreover, to guarantee further inclusivity, higher education in the U.K. needs to become more flexible. In this context, there is a need for a greater variety in higher education and lifelong learning.

It is an obvious consideration to say that by doing things in the same way, you end up with the same outcome but changing things, processes, mechanisms is truly crucial to guaranteeing inclusivity and diversity. This is why it is necessary to demystify systems of access and dismantle structural barriers.

The pandemic is a huge opportunity to embrace new ways to interact with each other. Sometimes, these ways can facilitate combating biases and discrimination. Zoom calls are the perfect example for this: the ability for people to list their pronouns in Zoom usernames has also been very helpful, for example, or the chance to speak and get one's voice heard irrespective of the perception of physical characteristics such as height. In this respect, it is also relevant to make further considerations on the relationship between professionals within the basic science field. It is important to be kind and embracing of the other, as this also helps to open up the creative process. It is equally essential to make an effort to understand people's boundaries and how to respect those boundaries. This also helps to build trust between individuals and build up systems at a local, national or international level. Science is intrinsically competitive in its own right, but we need to be competing about the ideas or competing to find solutions to the pandemic, for example, not competing between each other or hurting one another.

A big problem in academia is that appointments, promotions and honors are given on the basis of integrated achievement, which means that someone who starts late or has an interrupted career will end up with a lifelong professional handicap. This is also why it's been so hard to obtain gender balance among professors in universities, for example, because the criterion for appointment is unjust. Another big issue is that underrepresented ethnic groups and minorities often do not have access to basic science, so it is fundamental to learn about these barriers and understand how to effectively remove them. This is relevant for many reasons, including the fact that having a more inclusive and diverse set of people also produces better science. Playing with what the incentives are, then, becomes an effective pathway. When you have a targeted set of incentives you end up with a targeted set of people who all look the same professionally and are all doing the same things to hit that target. And that is not a constructive way to achieve inclusivity.

What can be done to increase global collaboration for basic science in the U.K.?

One of the most recognized elements to the importance of global collaboration for basic science is the exchange of people, particularly at an early stage. An example of this is scientists who go to other countries and build relationships. This process builds trust and an irreplaceable understanding to achieve international collaboration and success. Unfortunately, the pandemic has been incredibly damaging to this dynamic. And while safety must be the priority, it is also important not to lose the exchange dimension and to encourage all students and Ph.D.s to have an experience abroad when possible. This process is critical to the extent that it must be encouraged and facilitated in two ways, both in receiving talent and sending talent abroad.

Global collaboration also has to do with scale. What is the right scale to address different challenges on the national and global level? Both before and after COP 26 we've seen many joint international initiatives arising, and this is especially significant in the areas around vaccines and vaccine coordination, for example.

Some scientific collaborations in particular may become increasingly important in the context of diplomatic relations, for example the U.K. and Russia. Because of the U.K.'s political situation after Brexit, it is important to consider the different pressures around economy, politics and sovereignty. Many sectors will continue to benefit from being involved with horizon Europe. Especially since there is an objective lesson in how scale is crucial in the involvement with Europe, which is comparable in many aspects to the United States and, as a whole, can fully match what the country is doing.

Brexit also means that the visa system is harder to navigate. The issue doesn't have anything to do with a lack of talent or under-subscription but rather with funding, which is higher for domestic applicants, making the choice limited, and more expensive, in relation to bringing people in from abroad.

Ultimately, another crucial consideration is what can be done to facilitate the things that science needs. The U.K. is a role model in many areas, particularly around data. So, there is an important role to play in facilitating the resources and setting up protocols and processes that will allow other nations and organizations to contribute and make the most of the U.K.'s resources.

Moreover, collaboration needs to be more international, particularly on grand challenges such as health or climate change, which no country can do on its own.

Participants

Professor Sir John Aston	Harding Professor for Statistics in Public Life, University of Cambridge
Dr Pushmeet Kohli	Head of Research (AI for Science, Robustness and Reliability), DeepMind
Professor Carole Mundell	Hiroko Chair in Extragalactic Astronomy, Head of Astrophysics. President, The Science Council
Professor Anna Philpott	Head of the School of the Biological Sciences & Professor of Cancer and Developmental Biology
Professor Lord Martin Rees	Astronomer Royal, Fellow (formerly Master) of Trinity College, Cambridge
Professor Sheila Rowan	Chair of Natural Philosophy and Director of the Institute for Gravitational Research
Professor Hetan Shah	Chief Executive, The British Academy
Dr Magdalena Skipper	Editor-in-chief, *Nature*
Dr Mike Short	Department for International Trade Chief Scientific Adviser

Germany

The Aspen Institute Germany held a workshop with key experts in the field of pure science, including scientists, science communicators, and business leaders.

Introduction

The past year and a half have been both a challenging and an exciting time for science. COVID-19 revealed how vulnerable a globalized world is to pandemics, yet also demonstrated successful international cooperation in the search for a vaccine. A key factor in the development of the COVID-19 vaccine was prior investment in pure science research projects. If not for efforts to explore new immunotherapies for cancer, the mRNA-based vaccines could not have been developed as quickly as they were. This shows that a larger pure science pipeline provides our global society more agency to act in times of crises, such as the COVID-19 pandemic but also the climate crisis. Basic research is the basis for excellent applied science and signifies scientific breakthroughs and thus needs to be 1) properly funded and for that 2) its advantages properly communicated to the public, private companies, and politics.

This year, the Aspen Institute U.S. reached out to all its international partners to join a project to assess the status of, and opportunities for, pure science research around the world. It was a priority for Aspen Institute Germany to put together a diverse panel encompassing not only scientists who conduct pure science research but to include the voices of science communicators and businesses which build on scientific findings. The event was designed as a panel discussion followed by breakout sessions. This hybrid model workshop was chosen to invite the audience to participate actively in the discussion. Based on this premise, Aspen Germany's expert panel comprised of:

Hannah Helmke, Founder and CEO, *right. based on science*

Prof. Dr. Monika Stoll, Vice-Rector for Research, *University of Münster*

Markus Weißkopf, Managing Director, *Wissenschaft im Dialog*

The panel discussion was moderated by **Dr. Stormy-Annika Mildner**, *Executive Director of Aspen Germany.*

A total of 37 individuals participated in the 90-minute-long discussion. Similar to the panel, the participants were made up of scientists from universities and research institutes, science communicators, and entrepreneurs with an interest in basic research. This report captures the key questions, themes, and discussions on basic research in Germany addressed by the experts and the attendees.

This discussion was held under Chatham House Rules to allow for an open and honest dialogue between all participants. As a result, nobody may be quoted by name in any publications and all the participants have been anonymized.

1. What Is Pure Science / Basic Research?

The essence of basic research consists of the goal to simply advance knowledge. Pure science does not seek economic and/or social benefits, nor is its aim to apply its result to practical issues. Hence, the participants put a strong focus on curiosity as the leading motivation to pursue pure science research. In this context, a very prevalent theme was the description of pure science as "blue-sky research," meaning a creative, open approach to scientific theory, methods, and results. However, Prof. Stoll pointed out that in reality the line between pure science and applied science is much more blurred. She stated that the step from finding out principles to realizing their importance in, for example, the medical field, to then applying these principles happens very quickly. The participants recognized that this transfer should be encouraged and rather highlighted the intention and approach of basic research as what makes it unique.

1.1 How Is The Overall Health Status Of Pure Science In Germany?

The group assessed the health of German basic research with regard to three major aspects: 1. the level of freedom in scientific work, 2. funding opportunities, 3. public perception and acceptance of basic research.

1. Freedom in scientific work: Following a question by the Aspen Institute Science & Society Program Director Dr. Aaron Mertz, both the panelists and scientist participants insisted that science in Germany was free and independent. This applied both to research done at universities as well as at research institutions. A professor from the Technical University of Berlin (TU) quoted article 5 of the German *Grundgesetz* (Basic Law for the Federal Republic of Germany), which states: "Arts and sciences, research and teaching shall be free." This paragraph is an answer to the Nazi crimes in science, more precisely: the close connection of academic research, rational planning, and research funding in the service of the National Socialist policy of conquest and extermination. In the everyday work of scientists, this (political) independence is proven by the fact that they are free to set their own research priorities and preferred methods irrespective of the university's direction. The TU professor commented on this: "The directorate can tell me what research they would like me to do, but they cannot force me to do anything."

2. Funding opportunities: The financial resources for basic research in Germany are generally stable and enable scientists to plan ahead. Group consensus was that the funding opportunities were better at research institutes, such as Max Planck Society or Helmholtz Association, than at universities (more on this in Chapter 1.3). At the same time, the experts agreed that when measured against a) Germany's economic power and b) the volume of basic research output in Germany, the overall amount of funding available was rather small. Here, Prof. Stoll criticized the political dependency: whether basic research in general or specific projects in the realm of basic research received adequate funding ultimately depended on whether the government considered the topic to be important to society. As an example, she recalled how funding for genetic research suddenly ceased after the change of government in North Rhine-Westphalia in 2012. For this reason, basic researchers in (politicized) scientific fields were increasingly turning to their international network to secure funding.

More information: https://www.dfg.de/pub/generalplan/downloads/dfg_wissenschaft_planung_vertreibung_katalog.pdf

3. Public perception and acceptance of basic research: Based on results of the *Science Barometer,* Markus Weißkopf stated that the majority of Germans supported the conduction of pure science. The level of support had remained stable and comparatively high throughout the years. During the pandemic, trust rose even higher. However, it is important to emphasize that this high level of trust is only granted to scientists working in universities or public research institutions. Much less trust is placed by the public in scientists working in private companies. This is due to the three pillars of trust in science: expertise, integrity, and benevolence. Scientists are perceived to have the expertise and mostly also the integrity, but benevolence seems to play the most important role in the eyes of the public. The more conflict of interest, the more involvement of companies or politics, the more people seem to lose trust in the process. The share of third-party funding from companies is increasing and the public believes that business interests are driving the research, if it is funded by the private sector. In the end, scientists in Germany are confronted with the discrepancy between the expectations which are voiced by the public and the politicians and what realistically can be achieved with the funding opportunities researchers are provided with.

1.2 Who Decides What Is Worth Researching And What Isn't?

Scientific practice in Germany is free. As such, the decision for or against a subject, theory, method, or project lies with the scientist. A researcher from the Max Planck Society stated that researchers can change research fields and often switch from pure science to applied science depending on what their interest is in. Prof. Stoll seconded the statement but pointed out that it is harder for scientists at universities as they have to worry more about their funding, if they wanted to change directions. Since funding at universities is comparatively lower, most researchers submit a research proposal to the *Deutsche Forschungsgemeinschaft*—DFG (German Research Foundation), which then is peer-reviewed. The TU professor coming out of this system could result in a disadvantage for novel pure science. If the research proposal included an alternative approach to existing scientific practice—“blue-sky research” so to say—it could be extremely difficult to find peers who would deem the project worth investing in.

1.3 Who Is Paying For Pure Science And Who Should Be Paying For It?

Germany’s research funding system: To a large extent, basic research in Germany is publicly funded. Like the state itself, the public funding of German basic research is organized in a federalist manner: In other words, the *Bund* (Federal Government) and the 16 *Länder* (states) share the responsibility of financing science and research. For this, they collaborate through joint bodies and, in some cases, through joint initiatives. The most prominent examples for this pooled funding of non-university research institutions are the Max Planck Society, the Helmholtz Association, and the Fraunhofer Society. The largest organization granting financial support to individuals and their research projects is the *Deutsche Forschungsgemeinschaft*. Generally, these research institutions have more financial resources than universities, which get funded by the *Länder*. In both cases, the budget is decided on by the respective federal or state parliament.

In addition to this, there are (private) foundations that support science and research as well as companies that are involved in basic research. The European Union (EU) also funds pure science through the program Horizon Europe, one of the largest research funding programs in the world.

The political component: While research funding itself is described as stable, basic researchers, especially those from universities, complain that the budget is not sufficient. Prof. Stoll attributed the lack of funding to the fact that the federal and state governments prioritize applied science over pure science. Multiple participants pointed out that pure science had not been included in the party programs for this year’s German federal election, which could be an indicator that it does not get sufficient recognition. However, the professor from TU Berlin also emphasized “You can’t win elections with research”: Basic research was a long-term investment, so it usually first took much more money than it made, he pointed out. As a result, there was growing pressure on university researchers to acquire third-party funding, which, in addition to their teaching responsibilities, meant further workload. Basic scientists at non-university research institutions did not struggle with this to the same extent as was confirmed by the researcher from the Max Planck Society. However, they pointed out that since the Max Planck Society, as well as Helmholtz Association, Fraunhofer Society, and Leibniz Association are of “national interest” the researchers must work on a topic which the government deems to be of national interest. In this way, the political component of public funding also has an impact on basic research in non-university research institutions. In addition, funding can be hard to obtain if the research theory, methods, or results are perceived to have a political connotation. As an example, Prof. Stoll pointed out how challenging it was to receive funding for research on genetics in Germany.

Public versus private funding: With regard to the question of who should pay for basic research in Germany, the workshop group was split. At the heart of this division stood the perception (of the public) about how credible and trustworthy the theory, methodology, and results of basic research are, based on either public or private funding. As governments prioritize applied science, university researchers are turning to the private sector for third-party funding. In this context, Markus Weißkopf highlighted the public's mistrust of mixing science and business. Prof. Stoll agreed with him and added that in Germany there was a lot of mistrust on the part of scientists to work together with private companies—even though she has had positive experiences with such cooperation. Multiple participants were able to name successful cooperation between basic researchers and private companies.

A participant from a life-science consulting firm explained that the reputation of basic research in the private sector had been very low, but had now become a highly attractive investment project, especially with the success of BioNTech. This was further supported by Hannah Helmke from *right. based on science*, who has seen an increased interest from the private sector to invest in climate technologies as companies recognized the need to meet the 1.5-degree target. However, transparency and active communication was needed to counter the public mistrust in company's influence in research.

1.4 How Do We Communicate Scientific Content To A Non-Scientific Audience?

The workshop group distinguished between three non-scientific groups in society: 1. those who generally place a high degree of trust in science and are open toward the results of its work, 2. those undecided 30-40 percent who remain unsure whether they can trust science or what scientific content they can trust, and 3. the minority, which Markus Weißkopf estimated at 10-15 percent, who mistrust science. Based on this distinction, the panelists and participants each discussed different approaches to science communication.

Groups 1 and 2 can be engaged in different ways: starting from the scientist's side, Markus Weißkopf once again emphasized the three pillars of trust in science. It was the responsibility of academia to pay attention to these three factors and to communicate its work accordingly. According to him, the pillar of "benevolence," in particular, had to be conveyed through transparency and open communication to counter the public mistrust in companies' influence in research. Individuals are less likely to trust science if they believe that the public good is no longer at the heart of the matter. Most people think of basic research conducted by businesses first in terms of profit, while research from universities tends to be viewed more positively. If companies are conducting basic research, they must put extra effort into communicating their theories, methods, ambitions, and results to the public.

Furthermore, the panelists and participants stated that demonstrating to the non-scientific public how scientific results are relevant to their everyday lives is of fundamental importance. Too often, science is perceived as a closed elitist community that produces its content primarily for itself and for politicians.

This perception must be changed by showcasing how science works in the interest of society. In this case, COVID-19 was viewed as an opportunity to demonstrate how science can help overcome the pandemic. Additionally, the undecided group must be actively approached, something the panel and the participants unanimously agreed on. One participant provided an example of a campaign by the Charité: the outreach platform *SoapboxScience* aimed to transform public spaces into an arena for public learning and scientific debate. As part of their Berlin initiative, *SoapboxScience* put up information booths in U-Bahn stations all over the city and were able to engage with a large number of non-scientific passers-by, who reacted overwhelmingly positively to the initiative. Said participant emphasized that this campaign served the sociological effect of demonstrating that scientists were not an elitist, closed group, but met the public at eye level and were interested in getting feedback from the public.

With regard to those who do not trust science, Hannah Helmke and Markus Weißkopf assigned less significance to the group as they are determined to maintain their opinion that science isn’t trustworthy.

Summary

The workshop showed that basic research in Germany enjoys a high level of health; in a European comparison, Germany is a front-runner in generating basic research. The German public assigns both high importance and a high degree of trust to basic research. The scientists are free in their choice of research theory and methodology. Likewise, results can be published freely without the risk of negative consequences for the scientist. Although the funding situation varies from *Land* to *Land* and also between universities and non-university research institutions, scientists are nevertheless offered stable public funding options. By international standards, Germany is skeptical about private research funding, but is slowly opening up to this option through positive examples such as BioNTech. Hope was expressed that current global crises, such as the COVID-19 pandemic, have highlighted the relevance of basic research to the extent that policymakers and businesses will fund it in the same way as they finance applied science.

France

THE ASPEN INSTITUTE
FRANCE

The Aspen Institute France received input from four external experts on the topic basic science research.

Main Questions:

1. What is the difference between basic and applied research?
2. What actions would enable the mobilization of all stakeholders to motivate and support research (both applied and basic)?
3. How to make young people want to pursue careers in research?

Identified problems:

Lack of research ecosystem, disconnection between the public and private sectors, lack of funding.

Planned improvements:

Trust, Training, Simplification.

Contributors:

Sophie ACHARD	Director of the "Mathematics, Science and Information and Communication Technologies" (MSTIC) division at the Université Grenoble-Âlpes (UGA)
Marc BONNEVILLE	Scientific and Medical Director, Institut Mérieux
Thierry COULHON	President of the College of the High Council for the Evaluation of Research and Higher Education (Hcéres), former Education, Higher Education, Research and Innovation Advisor to the President of the Republic
Arnold MIGUS	Honorary Senior Advisor to the Cour des Comptes, former managing Director of the CNRS

1. What is the difference between basic and applied research?

The difference between the two is primarily cultural. In the United States, there is no real difference between academic/fundamental research and industrial research, and this is reflected in the guidance provided by the Aspen Institute when the terms are used interchangeably. **The American system is based on the recognition that the former is never truly “pure” but is instead always imbued with an element of practice or application to reality.** Moreover, the Americans have understood that applied/industrial research can only progress by relying on very high-quality basic research. Thus, the major applied research campuses are above all major basic research centers.

In France, on the other hand, there is a difference related to the very purpose of research: **the Academy of Sciences defines basic research as research that does not have an application in mind.** But this vision is very far from reality. In fact, there is a total continuity or absence of barriers between the two types of research.

The issue is therefore not to discuss the distinction between basic and industrial research, but **to question the absence and feasibility of creating a favorable ecosystem that would simultaneously:** 1) motivate basic research in a more global and interconnected context that would allow practical applications to be created from basic research; and 2) an issue related to the means of strengthening research activities in France. In the United States, it is possible to mobilize industrial investors to fund academic research programs that are economically or strategically attractive to industry. In France, industrial investors do not understand how academic campuses operate. It is therefore necessary to reinforce the acculturation between the public and private sectors to encourage industrialists to invest in research. This is the main source of the research funding deficit in France.

2. What actions would enable the mobilization of all stakeholders to motivate and support research (both applied and basic)?

Internationally, France specializes in certain fields of excellence such as the study of the human past, the sciences of the universe, mathematics, and certain biological disciplines such as immunology or infectiology. In these fields, **it is essentially through a phenomenon described metaphorically as percolation that French excellence in fundamental fields has been transmitted to other industrial fields.** The typical example is the trickle of skills from the field of mathematics to that of artificial intelligence and data science. These observations confirm the importance of a favorable ecosystem for fundamental research that would create a situation where France can perform well in the pursuit of fundamental studies (mathematics, computer science, etc.) and reproduce this excellence in related industrial fields.

However, this percolation is not reproduced elsewhere: education in general remains two-thirds publicly funded, notably because of the persistent perception of a disconnection between basic and industrial research. This disconnection is embodied in the freedom that researchers enjoy in their work: being able to undertake long-term projects is conceivable in an academic setting but is more difficult in an economically motivated industrial context. In France, the culture of risk among investors is not as well developed as elsewhere in the world. Some industrialists are willing to sacrifice time for the benefit of long-term projects, but this mindset is not yet widespread. **A public-private acculturation is therefore essential for the industrial sector to become familiar with the operating logics of the academic world and to accept certain funding that is initially at a loss but necessary and profitable in the long term.**

There are therefore three areas of improvement to consider:

1. Simplification and fluidity. Develop public-private links and the internationalization of its scope by creating clusters that bring together private investors and university researchers. To do this, it is necessary to: a) give more autonomy and authority to the presidents of universities and Grandes Ecoles so that they can manage their laboratories and direct the organization of their network themselves; b) maintain a "culture of risk" that is strong enough to motivate private investment, for the common good of research; c) also maintain a "culture of belonging" for industrialists on the campus where they are located, and a sense of reciprocity between private funding and sustained academic research efforts.

2. Alignment of actors. Do not mix or merge the existing large public and private actors but align and coordinate their activities and interests. Restrict the excessive importance of competition between actors in favor of cooperation.

3. Training. Ensure the succession of current researchers by balancing the autonomy of higher education institutions with state supervision of the training of the next generation of researchers.

3. How to make young people want to pursue careers in research?

As far as the capacity of universities is concerned, the situation is deteriorating in part because of an overload of work for teacher-researchers and a lack of funding. A visible solution at the local level is the process of CNRS or CRCT delegations that allow teacher-researchers to be relieved of their teaching activities for a given period of time to devote themselves to their research. **These leaves of absence must be made more regular and accompanied, in particular the phase of reintegration of teacher-researchers into teaching after the research period.**

At the same time, **it is necessary to reduce the workload, which is increased by a problem of non-delegation of administrative tasks associated with teaching activities.** This habit is rooted both institutionally and in the mentality of the teaching staff. A revision of the work model is necessary.

The failure to restrict university intake rates has also played a role in creating this overload. Some universities have begun to restrict their enrollment rates, but to continue on this path requires a change in the position of the rectorate on this issue and a transformation of the "accept all" mentality that permeates the faculty. This reduction implies the creation of new professional training programs, which are costly and call into question the French educational system.

The comparison with other countries shows that **too few responsibilities** are given to young people in France. More than an increase in salary, an increase in the freedom and means to carry out research programs, combined with a reduction in the administrative effort linked to teaching activities, should allow the image of research to be revalued among young people. The frequency of reporting to the funding authorities should also be more spaced out, ideally 3 to 5 years, to give researchers the opportunity to develop their work. However, this breathing space implies stricter criteria for access to these teaching and research positions, and a revaluation of the doctorate.

Italy

Aspen Institute Italia

Aspen Institute Italia convened two brainstorming sessions and one webinar on the topic of pure science. Presentation of the project and summaries of the meetings held are below.

1. Introduction

“Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress.”

Vannevar Bush, *Letter to President of the United States Franklin D. Roosevelt, in Science, The Endless Frontier,* 25 July 1945

1.2 Goal

The project’s main purpose is to impress on civil societies everywhere the strategic importance of pure science, not only in terms of scientific study in general but also of its fundamental significance for all of humanity. Its actions and instruments aim to make possible the involvement not only of leaders within the global scientific community, but also of the wider public. **Our goal is to generate discussion and form a consolidated approach to the message we intend to transmit.**

1.3 Instruments

Aspen Institute Italia planned three encounters: two brainstorming sessions featuring, respectively, scientists and businesspersons from the Aspen Italia network, whose purpose was to gather ideas and proposals; a webinar followed the brainstorming sessions, and aimed to discuss ideas and proposals, produced during the preceding two sessions with institutional figures competent in the subject areas.

The **first** brainstorming session was held with the community of scientists of the Aspen network on November 26, 2021.

The **second** was held with the business representatives associated with our network on February 1, 2022.

The **webinar** with the Italian institutions was held on February 21, 2022.

Following are summaries of the issues and proposals that emerged from the three meetings.

2. Summary of the brainstorming session with Aspen Institute Italia scientists and experts

The working group acknowledged the importance of pure science research and set the goal of raising awareness of that importance among the society at large. A series of questions were posed with a view to framing and focusing a discussion in which each participant would be able to contribute based on their own direct experience in the field.

The key words that ultimately emerged were **Education, Inclusiveness, Business, Financing, and Communication.**

Education: society's idea of science is an antiquated one that needs to be changed. A good point of departure would be the earliest school grades, where science in all its glory should be presented as a game that awakens curiosity. The approach of teachers, who are essential and indispensable to changing the way knowledge is imparted in our country (and not only ours), should foreground not only curiosity but also creativity and critical thinking. A better grounding in science would, among other things, help prevent the diffidence toward science that has proliferated in reaction to anti-COVID-19 vaccines.

Governments should also be made to understand how the various sciences are interconnected, with research in one sector often affecting a multitude of others. Needed then are policies capable of attracting researchers to pure science, since this is currently incapable of offering guarantees to young people. Instead, they are more likely to be lured by the high earnings and stability promised by corporate sectors working in applied research. Consequently, the training of young researchers requires qualified teachers selected strictly according to merit, since theirs is a critical role that requires careful direction, especially in the case of STEM subjects.

The concept of science education naturally extends to the education and sensitizing of public opinion through efforts both to silence disinformation and to channel the apolitical message that pure science can reveal significant phenomena. These discoveries can lead to concrete applications that successfully confront and contain these phenomena for the good of humanity as a whole (once again, the recent experience with COVID-19 and vaccines is a perfect example). This could well be an incentive to young researchers anxious to see their efforts bear fruit, and heighten public awareness of the dividends that such investments in pure science can yield.

Inclusiveness: science research has to be inclusive, i.e. offer young people and women equal opportunities, thereby motivating young people to follow this path and giving women access to the same funding as male researchers. The role of women in science and in the scientific community is an important issue because of the benefits they bring to the research itself. Furthermore, inclusiveness is the concern not of any single country within itself, but also of each nation in its relations with others.

Another important point regards international cooperation, which creates synergies for exchanges of experiences and knowledge that, in turn, lead to progress. The fact that networks also need further developing prompts reflection on the role of bureaucracy, where streamlining would only expedite collaboration.

Business: the role of business is fundamental to our investigation. Involving managers and industrialists, the likely end-users of the fruits of pure research, would help to encourage institutional financing. The approach should certainly change to one that ensures investments in pure science are no longer viewed solely from an economic standpoint, since the parameters for measuring them must necessarily be more flexible. It has to be acknowledged that, since pure science has a medium/long-term timeframe, immediate returns on investment cannot be expected, and that this kind of investment is riskier given the impossibility of immediate or predictable results. Nevertheless, there is no avoiding the fact that in certain situations—and the pandemic is a perfect example—*not* investing in research can result in the loss of more than a few percentage points of GDP. In any case, despite everything, vaccines have been made available to the whole of humanity in a relatively brief span of time.

Financing: a word that links naturally to the above key concepts. Institutions should be made aware that investing in research must go beyond the conceivably ineffective approach of merely shifting resources from one sector to another, and be seen instead as an effective instrument for incentivizing business. This is the awareness that basic science should be understood as a public asset on which to focus a positive rather than polemic policy debate. That would help to channel investments into research and ensure sufficient resources for managing the problems humanity is now and will be facing in the future (pandemics but also other pathologies, climate change, and so forth).

Another useful consideration would be to increase support for research centers and enhance their relationship with the business world, as happens in other countries where the private sector contributes up to as much as 50% of funding. Examples are Germany's Fraunhofer and Max Planck centers.

Communication: the discussions on pure science and the issue of how to raise awareness among political and economic decision makers and the wider society (both public opinion and citizens in general) converged on an underlying problem: a correct dissemination of information is fundamental to understanding the utility of science. Yet, the current spread of misinformation and untruths about science has been more about garnering consensus than transparency, and has hindered ordinary people's confidence in science. Such politically motivated manipulations of science will only obstruct efforts to rebuild that trust in science that has given way to convictions devoid of any scientific foundation. Thus, the language has to be clear and transparent and experimentation must not cease because these are the only way to ensure a better future. The scientific community considers this the proper message to convey.

Proposals

The debate produced the following two proposals:

- ***Preparation of a "Manifesto"*** by the scientific community to be signed by major Italian industrialists and submitted to policy-makers. The decision was made to engage industrialists since they are the ultimate end-users of the results of scientific research—first pure and then applied.

- ***Advocacy actions*** for the precise purpose of raising awareness among political and economic decision makers and public opinion of the pivotal role that pure science plays. The pandemic, like other disruptive events in the past, offers us an opportunity to enhance the importance of research in and of itself as a driver of progress in medicine and of development in general. Actions should be undertaken at various levels, and include the involvement of the country's industrial fabric.

3. Summary of the brainstorming session with Aspen Institute Italia business members

In recognition of the importance of scientific research, the working group developed a series of questions and reflections on some critical concerns regarding the Italian scenario, calling upon institutional and political spheres to provide clear and coherent guidance.

The issues that emerged were grouped as follows:

1) Size of enterprise: Although Italy has some large-scale industry, the entrepreneurial fabric consists mainly of small and medium-sized enterprises (SMEs) whose small size is a deterrent to investing in pure research. This results in a greater concentration of resources going to applied research, which ensures an immediate return on investments thanks to the industrialization and consequent marketing of the outcome of the research itself.

A combination of bureaucratic barriers to access, the limited number of available financial instruments and the difficulty to find non-public external funding sources constitutes another reason companies tend not to invest in pure research.

2) Investments: When a firm is limited in size its need for an immediate return on investment is directly linked with its survival. Added to that is an insufficient transfer of skills from the major players to small businesses that effectively impedes SMEs' ability to upgrade scientific and technological competences.

3) Strategies: Other issues on the table included the role of policy-makers and medium- or long-term vision. Yet, policies aimed at boosting investments in research remain a generic request if they do not first answer the question “What is the purpose of pure scientific research?” In other words, what are its goals and how can they be achieved? Consequently, clarity in the planning of goals, actions, and necessary instruments is indispensable.

4) Education: Industry’s shortfall in adequate skills points to a crucial problem in the educational preparation (technical schools and universities) of young people. The absence of consistency is also reflected in an inability to understand problems and how to correct them among policy-makers at multiple levels (national, regional, and local). Finally, resolving the two-fold dilemma of attracting and retaining brainpower is also strategic to generating a different approach to the way companies invest.

These being the critical points foregrounded by the world of industry, which clearly tie in with some very specific key concepts, a series of proposals were made for how to spin what seems to be a blind alley into a virtuous cycle. The common factor is an institutional demand for practical solutions associated with three simple concepts: convergence of views, concentration of resources and energies, and collaboration on a territorial scale between (diversified) business spheres and institutions that are therefore central to the process of achieving this objective.

Proposals

The debate produced the following proposals for possible solutions to the issues identified:

1) Strike a new balance in the public-private partnership.

- In as much as it is “free” and not aimed at the direct production of an asset, pure research is a high-cost item, especially for small and medium-sized firms, despite their clear awareness of its strategic importance. Therefore, cognizant that the public sector is not always able to satisfy requests, and that in any case timeframes for receiving funds are generally long, the proposal was made to **facilitate and increase public-private cooperation in order to allow for different forms of financing**. Italian firms could also be made more attractive to foreign capital.
- The **creation/reinforcement of basic industrial research hubs** with a view to boosting collaboration between academia and industry.
- The **creation of consortia of businesses** to support pure research in order to share the benefits.

2) Taxation

Tax-exemptions for investments in research and **tax simplification** are both sensitive topics. It should be pointed out that some instruments already exist, such as the “patent box” (a tax bonus on income from the use of some intangible assets). These, however, needs improvement given its scarce effectiveness to date. All these elements, if well organized and developed, would facilitate the flow of resources to research and development.

3) Financing

Firms are willing to invest, but in order to survive, and because of their size, they are obliged to seek returns on investment. A series of proposals for resolving this dilemma emerged:

- make risk/venture capital more easily accessible in order to render alternative forms of financing effective;
- improve the administrative efficiency of public funding;
- promote and strengthen the role of banking foundations operating across the country.

Another topic discussed was the attractiveness of the country’s economy and, therefore, of capital; referring back to the concept of “open innovation,” consideration must go to the possibility of developing plans for external communication, i.e. with the creation of networks involving public-private, academic/industrial, and government programs, in particular, those at European and global levels. Our country could be made more attractive with a well defined set of rules and coherent objectives and instruments in a comprehensive end-to-end process.

4) Education

- The current lack of multidisciplinary education could be addressed in part by offering university degree courses that combine diverse and transversal fields of study.
- Institutions must launch and/or intensify all efforts aimed at attracting talent, as happens in other European countries or the United States. At the same time, it is necessary to make a proactive effort to keep young graduates in Italy so as not to waste a potential and fundamental source of wealth, facilitating access to education and employment (continuous cooperation of industry with school systems/universities/research centers).
- Given that the education of national, regional, and local level decision makers is also to be considered an integral part of the problem, it was proposed that institutional representatives be adequately trained so as to best understand the needs of companies and help establish strategies that best tap potential.

5) Territorial mapping and institution/business and business/business cooperation

Consideration of the peculiarities of the Italian industrial fabric and of individual regions, and the need to identify the specific demands of industry, led to the following proposal:

- *a mapping of individual sectors on the basis of location* and the creation of opportunities for contact between industry and institutions (e.g. through the local offices of the Italian manufacturers association Confindustria) for each specific area.
- *Form/reinforce a virtuous chain connecting large scale and small and medium-sized* enterprises aimed at stimulating SMEs to be innovative by "guaranteeing" returns on investment, even though this would initially be limited to the domestic market (as a prime target market).

Conclusions

With a focus on what goals to pursue in order to promote the economic importance of pure research, and departing from the supposition that pure research is an investment in future wealth, **recommendations** would include the following:

1) increased public spending on research, with guaranteed benefits to private enterprise;

2) promotion of public-private partnerships, to be extended to small and medium sized enterprises and foreign capital;

3) generating synergy in place of the conflict between public and private research but that, nevertheless, ensures the public sector does its part;

4) creation of a virtuous circle with businesses for the purpose of deciding together where and how to invest.

4. Summary of the webinar with the Italian institutions

Funding being the most sensitive issue, it was emphasized that Europe has long had framework programs to which Italy has contributed, although investment in research remains among the lowest at 1% compared with other countries' average of 2.5%. Nevertheless, the pandemic has accelerated debt sharing, and this facilitates investments in key sectors. For the European Union and Italy as well, the Next Generation EU plan represents an essential step toward increased investments in basic research. Yet, those investments' main goal is output, which means they hinge on the production of concrete and demonstrable results. Their focus is basic research involving national research centers, research infrastructures, and extended partnerships, and the opportunity they create is one not to be missed.

The Italian government earmarks 250 million euro annually to permanent and individual grants through the Italian Science Fund for basic research in line with the model of the

European Research Council. Additionally, the Italian Fund for Applied Science is dedicated to innovation in spheres such as industrial and experimental development research. Moreover, within the month of March 2022, additional researchers will be assigned to industry in an effort to stimulate an exchange of skills. Public and private spheres will have to cooperate directly and transparently in processes and relations for the purpose of transferring results. Finally, a call for tenders for research partnerships is expected to be announced in the near future aimed at creating a value chain linking academies, research centers, and industry.

The government will probably have to focus on who is effectively capable of handling funds rather than on the firms themselves. If, as a “social affair,” science becomes a process, generating effective and efficient interaction with all the actors involved along the way will mark a true turning point.

It was observed that the government interface with the private sector must employ innovative means, facilitating tax credits, deductions, and various systems for universities in order to stimulate enterprise. The importance was also underlined of creating new academic streams and adequate training for all operators, with the focus, above all, on young people and STEM studies. To that end, international cooperation is essential since it facilitates the generation of supranational networks and skill and knowledge exchanges. However, such complex forms of collaboration need streamlining, especially when it comes to regulation. In any case, some progress has been made at the European level and governments are increasingly promoting what has been defined as “scientific diplomacy.”

The debate’s foremost theme, however, was the prevailing perception of a dichotomy between pure and applied science: pure science at the service of the common good; applied science focused on immediate returns on investment. The two concepts appear distant from one another, yet cultural change aimed at resolving that dichotomy does seem possible. Indeed, funding for a pure science spurred by “curiosity” and the urge to understand phenomena could conceivably dovetail with value chain-related research. Aggregating universities, research centers, and industry within a framework of collaboration would facilitate the birth of start-ups and spin-offs, making dialogue between academic and industrial spheres easier, fostering innovation, and exerting a positive influence on the country’s socio-economic development.

A Proposal by Aspen Institute Italia

Introduction

European actions in support of research and development

The funds earmarked by individual European Member States for research and development projects have long been used for independent, non-homogeneous undertakings. Over time, each Member has outlined its own model for intervening in support of research based on its particular industrial policy requirements and conditioned by respective budgetary constraints/limitations.

The sector is one that continues to generate strong competition among Members eager to attract researchers, research centers, facilities, and funding.

Some of the main options offered by national policies in this regard include tax incentives, depreciation, subsidized loans, and direct financing.

Instead of separately, more often than not these instruments are used in some combination, and this makes for a considerable variety of typologies. The multitude of incentives offered by a wide range of sources has led to the need for simplification so as to avoid recipients and sources having to bear the heavy burden of needless bureaucratic duplications and overlaps.

The fiscal incentives adopted by the majority of European countries are predominantly in the form of tax credits aimed at encouraging investments in the acquisition of new technologies, machinery, and new business assets, including intangible ones.

In its classic form, the tax credit is equal to a percentage of all documented expenses. Essentially, these are differentiated both in reference to the maximum amount admissible in a single fiscal year, and in reference to the base on which that credit is determined (often incremental expenses incurred over a previous period of time) and deductible expenses (personnel and purchase of material goods or know-how).

Clearly, the more complex the model the greater the bureaucratic burden in terms of reporting and controls.

Models based on investment depreciation consist of raising amounts and/or accelerating depreciation over time, in accordance with the law in effect, for the purchase of machinery or other deductible expenses. These too, therefore, contribute to lightening the recipient’s tax load.

Less complex are the systems based on subsidized loans granted by the banking system and at times guaranteed by government entities. These measures are often used to nurture innovative startups.

The direct financing model is especially developed in Germany and implemented through a stable research and development system, which is divided into the various phases of planning, financing, monitoring, and control; application to individual projects is mainly entrusted to major research centers and universities.

This model is often adopted in other European countries and appears well suited to encouraging the development of public-private partnerships.

Conclusions

The effectiveness of the overall European system for funding research and development is undeniable, given the excellent results produced in a range of significant sectors. Nevertheless, it would appear essential in the current phase to outline two different and separate recommendations. On the one hand, increase and improve inter-country collaboration and coordination in order to avoid dangerous duplications and harmful competition and, on the other, simplify procedures for granting and disbursing benefits.

Certainly, there should be a direct link between the various benefits assignable to a research project. Where, for example, an investment can take advantage of tax benefits based on verification by a competent authority, additional public financing could be granted automatically without further bureaucratic process.

Similar non-repetitive procedures could be implemented in the case of monitoring both how funds are used and research results.

Italy: Ideas And Proposals For Italy

1.1 Europe and Italy

European support for research has developed according to three main schemes: a) tax incentives, often consisting of tax credits variously applicable to expenses incurred; b) raising amounts and/or acceleration of depreciation over time for the purchase of machinery or other admissible expenses, something that also go toward lightening the recipient's tax burden; c) direct financing often associated with public-private partnerships.

1.2 Incentives in Italy: best practices

Italy has primarily chosen the route of tax incentives, and continues to refer to the first Tremonti law (d.l n. 357/1994), duplicated in various forms in the years that followed, which, for the first time in our fiscal history, used the tax lever to boost the economy by encouraging investments in new businesses. It should be noted that application of this law was eventually extended to intangibles, such as patents.

Another example of best practices is the Industry 4.0 incentive (introduced by then-Minister of Economic Development Carlo Calenda with the 2017 budget law and later abrogated). The measure reduced taxes by increasing the share of depreciation of the undertaking, yet procedures for demonstrating eligibility for this benefit, which was awarded to highly sophisticated investments, proved overly complicated (it required, for example, qualified preliminary analysis, etc.).

1.3 The current Italian scenario: problems

Current legislation provides for tax credits for a variety of admissible expenses associated with investments in fundamental research, industrial research, and experimental development in science and technology. These must, nevertheless, be accurately reported and certified by authorized legal auditors; moreover, businesses must submit a technical report on the aims, content, and results of all admissible activities.

Direct public financing for research can be granted in addition to tax credits, subject, however, to authorization (*ex ante*) and assessment (*ex post*) procedures. The bureaucratic process required to perform these controls therefore substantially conditions the effectiveness of the specific instruments.

2. Ideas and proposals by Aspen Institute Italia

One way to encourage investments in research and simplify access to the resources available could be to **create a direct link between the tax incentives already envisaged by law and additional direct public financing.**

Since an investment in research already presupposes the use of tax incentives, it could be arranged that additional public financing be disbursed on the sole presupposition of that incentive investment without further bureaucratic requirements. This is because if the presupposed tax incentive exists, it is automatically presumed that additional public financing will follow, thus rendering further bureaucratic controls unnecessary.

Furthermore, the so-called “5x1000” that taxpayers can already elect to earmark for various social purposes (including research) could be raised to “10x1000” for scientific research. It should be pointed out that this is an extremely simple instrument that has never been abused and that has the added advantage of being capable of increasing public participation and/or interest in scientific research.

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Spain

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The Aspen Institute Spain received input from three external experts on the topic of basic research in Spain.

Emilio **LUQUE**

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What is the state of basic or fundamental research in Spain?

All science and research in Spain have traditionally been quite anemic, and that goes all the more for basic research. Privately funded research is quite weak in Spain, hovering at around half of the total. Among other long-standing causes, this is connected to the prevalence of small business and the relative strength of non-industrial concerns. Public funding since 2018 is finally greater in nominal terms than it was in 2007, but as a share of GDP it has still not quite recovered from the 2008 misguided austerity budgetary decisions in this field (apart from the statistical effects of the pandemic crisis). Very low patent production is a good indicator for this.

Policy decisions are strongly biased toward applied research, in a purely translational mindset, as the 2020 "shock plan" shows. This indicates a poor understanding of the fluidity and complexity of successful science and technology ecosystems, where the definitions of basic, fundamental, oriented, pure, and applied science and technology are intrinsically blurred by the unpredictable trajectories of researchers, discoveries, knowledge, and applications.

The role of media in depicting and focusing (or ignoring) basic research should not be overlooked. Media do not exert, to a large extent, a counterbalancing, "watchdog" role regarding bad governance practices in R&D, nor do they keep scientists accountable to societal concerns.

What can be done in order to promote basic research in Spain?

Although it is not a novel proposal, it must nonetheless be stated that an across-the-aisle, stable, consensual policy agenda is of the essence. This new social contract should effectively (not merely cosmetically) conceive of science, technology, and innovation as core components of sustainable, inclusive growth policies, and even more so in the case of fundamental and basic research. The level of sustained increase in public budgetary allocations, but also of improved governance of the science and technology domain, should reach the levels obtained in the 2001-2007 period. This investment should encompass longer than annual periods.

An often-overlooked factor in fundamental research promotion is the investment in the capabilities of governing agencies and public institutions that play a crucial role in both the fundamental and applied research ecosystem. It is here that the bottlenecks that prevent ideas, projects, alliances, and funding from consolidating and flowing are often located. Spain has unfortunately proved quite unsuccessful at effectively spending available funds of different sources, due in large part to bureaucratic barriers and lack of genuine research-promoting agencies. Fundamental science must of course be managed, but this cannot be done effectively unless bureaucratic structures are agile and have a greater knowledge of the matter and processes they are managing. A greater role of the scientific community in this regard, with its already high connectivity levels, could drive this improved governance of basic research and its projects, while allowing for mainly *ex post* accountability.

How does Spanish public opinion value basic research?

Unfortunately, the main source of information on public opinion on R&D in Spain, the FECyT (Spanish Foundation for Science and Technology) Social Perception of Science and Technology biannual survey, with a considerable 8,000-strong sample, does not differentiate between kinds of science or research. It is plain that science in general is clearly well valued, with 84 percent of respondents favoring greater state funding for it, but it is not a topic of public interest to the same extent as in our European counterparts (citizens access media content on R&D half as frequently as the European average).

However, we can infer that the prevalent and somewhat contradictory model of science in the mind of Spanish citizens is that of a heroic researcher, guided by an inner vocation, as popularized by media through their depiction of famous scientists such as Ramón y Cajal. While almost half of respondents considered a scientific career as attractive for young people, and 59 percent deemed it personally fulfilling, two thirds of them thought it is badly compensated economically, and the same proportion considered it to have scant social recognition..

A recent and valuable contribution to this topic is the Public Dialogue with Spanish Civil Society, organized in September 2021 by the Barcelona-based Centre for Genomic Regulation. This process attempted to provide a forum where citizens, scientists, funders, and other relevant actors could exchange and reflect deeply on science and research.

After this sustained dialogue, in a deliberative framework, we see that an informed general public understands and considers knowledge for knowledge’s sake extremely relevant and supports funding basic research projects. The pandemic crisis has made basic research more relevant in the eyes of citizens, as a base on which to build medium and long-term discoveries. Basic and applied research, in their fundamental and oriented versions, are hard for both practitioners and citizens to tell apart. For the latter, basic research is envisaged as *previous* research. Also, basic research is conceived to be guided by its importance to society.

Scientists are strongly trusted in this and other respects. As the recent 516 Special Eurobarometer shows, they are considered by Spanish respondents rather more intelligent, reliable, collaborative, and honest than the European average, but it is 20 points higher in considering that scientists know best what is good for people. However, this must be taken with a grain of salt, since it may be chalked up to a poorer knowledge of the issues involved: citizen's engagement with science and technology (watching documentaries, reading related magazines or books, visiting museums, etc.) is consistently lower than in other countries.

What can be done to promote diversity and inclusivity in the face of all differences in fundamental research?

Gender imbalances have long plagued the Spanish R&D system, and they are likely the main barrier to diversity and inclusivity in this sector. A number of measures can be put forward to address this issue and promote diversity. They are likely to be even more relevant as regards fundamental science and research.

- Flexibility must be built into mobility and fellowships, including additional funding for children when researchers are also caregivers, and making remote postdoc fellowships more widely available.
- When allocating research funds, evaluation processes could be enhanced by including anonymization protocols in multi-step review processes, in order to prevent unconscious or implicit biases.
- Mandate transparency in all research reporting and statistics regarding allocation of funding by gender.
- Avoid the "Matilda effect" by recognizing and publicizing women scientists' contributions in educational materials and mass media, so that they can be role models for girls and young women in their intellectual and career development.

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State Of Pure Research In Spain

In 2018, Spanish investment in basic research was approximately 0.2% of GDP. This low figure is due, among other things, to the lack of conviction on the part of the public-private sectors of the importance of pure research and of guaranteeing its continuity.

In our country, investment in research has decreased and, in 2018, was at values lower than those of 2009: from 1.35% to 1.24% of the GDP. In this sense, we have lost both public investment from 0.65 to 0.54% of GDP (European average is 0.69) and private investment, which has fallen from 0.73 to 0.64% of GDP (European average is 1.41).

How Public Opinion Values Pure Research

Basic research has always been in a weak position because the authorities and public opinion do not understand that it is an area that must be unequivocally supported; if there is no basic knowledge, there is no possible application. It's like trying to run without knowing how to walk. Let's take several examples. If it had not been discovered that a gas consumes heat when it expands, the refrigerator would not exist. Without the previous discoveries about Hertzian waves, there would be no radio. Without the basic studies that helped discover the structure of DNA, biotechnology would not exist.

The struggle to value the importance of basic science was already evident in the 1930s in high-impact journals such as *Nature* (Hickman, 1930, *Nature* 126:11). It is also important to bear in mind that if you want the authorities and public opinion to truly value the importance of the investigation, you have to be active in convincing. In an interesting supplement (*New York Times Magazine* 2021 May, 23, The Health Issue) on health, examples are given on basic research and the importance of scaling the product after its basic development.

In his book *La utilidad de lo inútil. Manifiesto (The Utility of the Useless. Manifesto)*, Nuccio Ordine reflects on the idea of the usefulness of that knowledge whose essential value is totally alien to any utilitarian purpose. Considering knowledge that does not produce a direct benefit as useful is a serious error that condemns basic science. This does not have a utilitarian purpose or an express intention of applying the knowledge that is generated through it. However, thanks to it, the foundations for understanding the phenomena that occur around us and the observable facts are laid.

We live in a country that turns its back on science, both in the civil and the political spheres. According to the latest Encuesta de Percepción Social de la Ciencia y la Tecnología en España (Survey of Social Perception of Science and Technology in Spain) (2020), published by the Fundación Española para la Ciencia y la Tecnología (Spanish Foundation for Science and Technology), 14% of Spaniards state that they are interested in science and technology, compared to 25% who do not (https://goo.gl/ZZBDcD). The rest (61%) have no opinion.

What To Do To Promote The Growth Of Pure Research In Spain

1. Increase public and private financing and consolidate a basic structural financing system at the national level.

2. Increase the hiring of research personnel and guarantee their job stability.

3. Incorporate figures of non-teaching researchers in universities.

How To Make Pure Research More Inclusive

1. Promote scientific vocations, not exclusive, in early stages of life.

2. Promote the reconciliation of paternity/maternity in the workplace (nurseries, flexible start times, remote work, etc.).

3. Study why in certain areas of knowledge like STEM (science, technology, engineering, and mathematics) the number of women studying these areas is lower than that of men. It is most striking in the area of mathematics.

Laura **PADRÓN**

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1. State of basic research in Spain.

Spanish scientific formation is good. Students now have the opportunity to pursue scientific studies with a Ph.D. in excellent scientific research centers all around the country. But still students are told to go abroad to complete their formation. Not as an incentive or as a formative experience, but as an obligation. As if science would be better overseas. What usually happens then is that scientists start comparing their labor conditions and most often they end up concluding that they don’t want or can’t come back to Spain, often because work positions. Because work positions in science abroad are easier to obtain and conditions are better too. There is an important brain drain of well-formed Spanish scientists who will then publish articles and do basic science out of their country of origin.

In Spain, many basic researchers don't have a permanent position even after 15-20 years of hard work and good scientific publications in peer reviewed journals. They still work with 5-year contracts, at most. They also need to allocate a lot of time and energy to apply for funding that will allow them to cover their research costs, their salary, and part of their working group. All these conditions generate a very unstable situation to work and live in.

2. How does the public opinion evaluate basic research.

Nowadays, our society is more and more based on immediacy and usefulness. On top of this, Spanish society is very materialistic. Basic research is on the opposite side of these characteristics. This is because it takes time to make science, to collect results and knowledge and because basic research is by essence abstract.

I think most people do not see the utility of pure science; because it's not applied, they cannot see a direct effect on their lives. Furthermore, they don't see that without pure science there's no applied research. As indicated in the *Aspen Institute for Pure Science Project* report, "fundamental and applied research describe the two symbiotic faces of research that cannot live without each other."

Since the COVID-19 pandemic situation, science has gained a lot of popularity. But, once more, people have focused on the application of science: the vaccine. They have not considered that without many years of pure science around viruses, coronaviruses, RNA, etc., the vaccine wouldn't have been available so quickly. Probably more scientific diffusion is needed, so public opinion would know better.

Last week I heard on the radio a debate between Iñigo Alfonso (RNE1) and Antonio Garamendi (president of the Spanish Confederation of Business Organizations, CEOE) about the way out of the actual economic crisis. Garamendi said that "it is incredible to think that it is the vaccine (against SARS-CoV-2) that has taken us out from the crisis." I must say I was surprised by this thought. Why would this be incredible? When has science stopped being an economical engine for a country?!

3. What can be done to foster basic research growth in Spain.

To foster basic research in Spain, we need to increase funding in pure science and maintain it over time. Most of the countries have put in place an extraordinary investment plan after the COVID-19 pandemic situation in 2020, lasting around 10 years. This report indicates that Spain has also put in place such a program with a huge amount of money but unfortunately, this effort will only last two years. Moreover, basic research is barely included in this investment.

Basic research paves the way to innovation that will lead to scientific applications. Patenting applications will allow a return on investment.

To foster pure science in Spain, we also need to really trust our own science. We must be proud of the science we do, the good scientifics we form, and the excellent research centers we have in Spain. But we need to have competitive salaries, stable positions, and available support for researchers applying for funding. Fostering cooperation and collaboration between private and public sectors in research would also help to promote basic research. This has been largely promoted during COVID-19 pandemic situation and has given very good results.

4. How to make basic research more inclusive of all kinds of differences.

The most important scientific journals require researchers to pay if they want to publish their research. Some are very expensive. Open Science could fix this problem and allows science to be more collaborative, as it should be.

One of the most important discriminations in basic science in Spain is the very low number of women in management positions, a situation which is not only relevant to basic science but more generally to all kinds of scientific professions. A transversal way to promote women and basic science at the same time would be to advertise the past history of successful women researchers and how their scientific discoveries gave rise to innovative solutions, going from basic science to final application.

Czech Republic

The Aspen Institute Central Europe sought the input of two esteemed individuals and one major company on the topic of basic science research in the Czech Republic.

Jakub **HLÁVKA**

Research Assistant Professor of Health Policy and Management
University of Southern California, U.S.A.
Co-Founder, Initiative for Effective Healthcare, Czech Republic

Can the Czech Republic produce more world-class research?

Recent analysis shows that the Czech Republic is in the middle of the pack across fundamental research indicators among 14 “Aspen” countries. The report cites a relatively small high-tech sector, challenges in the governance of public research, weak public-private linkages, and limited access to funding as some of the barriers to world-class research. However, these statistics hide some promising developments in the country in the last decade, and an even greater promise for the future.

To start with, national data hide many outliers (good and bad), of which the top performers are the most interesting. Czech scientists have an excellent reputation in areas such as particle physics (consider the leading Czech role in the Pierre Auger Observatory, a project studying the mysterious origins of rare particles with extremely high energies), biochemistry (the world-class research of the Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences has drawn funding from world’s largest biotechnology companies), or research in artificial intelligence and computer science (spearheaded by the Artificial Intelligence Center of the Czech Technical University in Prague and other research groups in the country).

The Czech government can do more to make such world-class projects and teams find the country more attractive, in addition to its other advantages: highly equitable access to secondary and tertiary education, high quality of life in most parts of the country, and the international linkages of the country with the rest of Europe and the world. To ensure sustainable innovation (rather than the departure of the brightest minds for better pastures in the West), **Czech universities should be willing and able to offer internationally competitive salaries to their**

faculty and students (a strategy pursued by China in the past, for instance), **increase the quality and dynamism of the grant award process by making it more international and less susceptible to favoritism, and by investing in collaborative projects that introduce Czech scientists to the world, and vice-versa.**

All of this will require greater funding and **removal of red tape**, but as the many Czech success stories have shown, the return on investment on knowledge and innovation is one of the highest one can make in the world today.

Jan **KULIK**

Department of Research
Development and Innovation
Ministry of Industry and Trade of the Czech Republic

For the Ministry of Industry and Trade, the issue of basic research is relatively far removed from its competences and policy-making. Of course, we are also aware of its fundamental importance for breakthrough discoveries and for the development of the whole of human society. For me personally, the contribution in the form of fundamental discoveries/basic research is, unlike the later stages of the research and innovation process, more of a global issue. Nevertheless, basic research must also be seen in a national context, simply because there is no clear line between basic and applied research. I consider it as matter-of-course that basic research is carried out on a larger scale especially by developed countries that “can afford it” and in which it has historically had a strong background. Without wanting to embark on evaluation and international comparison, I would like to believe that especially in the form of the Academy of Sciences of the Czech Republic we have a traditional and sufficiently high quality base for a wide range of disciplines, and that its individual institutes have created conditions for achieving international excellence and that we will see fundamental world discoveries and benefits at the level of the work of Otto Wichterle, among others the inventor of soft contact lenses.

Most personally, rather than the level of citations or the number of patents, I consider the national differences in the link between basic research (or “pure science”) and the application phases of research, development, and innovation as an interesting point. While in most of the presented statistics and characteristics I think the Czech Republic occupies a level corresponding to its overall social and economic level, it lags behind especially in the cooperation of the research and application sphere and in the use of research results in practice. This is clearly illustrated, for example, by sources of funding, according to which it seems that basic research is not of interest to Czech entrepreneurs and other potential applicators (in contrast to a large number of innovatively advanced economies.) There are many reasons for not always good cooperation, inefficient outputs or not achieving excellence, and we know about a number of barriers—**unmodern education systems, rigid or complex regulations, specific economic structure, different goals and ideas, difficult or on the other hand too easy access to finance,**

lack of motivation, and many others. In some areas, we are working effectively to improve, in others we lack the will, the courage, or the need to change the societal climate, and that is work for decades. Nevertheless, we are at least talking about and writing about these challenges, and even that in itself, I believe, contributes to positive change.

ŠKODA AUTO

Science, Research and Development

The automotive industry is key to Europe's prosperity, providing direct and indirect jobs to 13.8 million Europeans, representing 6.1% of total employment in the EU. At the same time, the sector is the largest private investor in research and development (R&D). In 2019 alone, €62 billion went to science and research, twice as much as the second in line which is the Pharmaceuticals and Biotechnology sector. The situation is no different in the Czech Republic, where the automotive industry is the backbone of the economy, directly employs 180,000 people (500,000 including related industries), accounts for 10% of GDP, and accounts for 30% of industrial investment in R&D.

ŠKODA AUTO has repeatedly become the largest private investor in R&D in the Czech Republic and at the same time the entity with the highest number of patent applications. Technical development has been associated with the ŠKODA brand since its inception more than 120 years ago, and the responsibility for developing the global MQB-A0 platform for the entire Volkswagen Group has been added to the long tradition of engine or transmission development. Based on its research, the group's brands will develop new entry models for regions with high growth potential, such as India, Russia, Africa, as well as ASEAN and Latin America.

Since 1991, when ŠKODA AUTO became part of the Volkswagen Group, it has already invested more than 377 billion CZK in the modernization of production and plant development, and another more than 210 billion CZK in science, research, and innovation. Even in 2020, affected by unprecedented production outages caused by the COVID-19 pandemic, 18.5 billion CZK were released for technical development. It is the investment in science, research, and innovation that will be crucial in successfully managing the green and digital transformation and maintaining ŠKODA AUTO's competitiveness in world markets.

Romania

Aspen Institute Romania held a public panel discussion with scientific experts and commissioned an analysis of pure science in Romania from Roxana Voicu-Dorobanțu, Associate Professor of International Business and Risk Management at the Bucharest University of Economic Studies.

The Shifting Sands of the Quest for Pure Science in Romania

A few remarks about the context

The shifting geography of the human capital driven by the accelerating pace of technological, demographic, and socio-economic disruption is transforming industries and business models.

Automation, a shrinking labor supply, migration, climate-change-driven innovation, a global pandemic, a shifting aging workforce—all significantly affect the social contract by focusing on the need for convergence between short-term economic growth and long-term resilient value for the society in its entirety. Their coexistence in a volatile global environment highlights the relevance of accessible life-long education and the need for agility in developing skills.

Although years of conversations on the topic of the "good society" in the global Aspen Institutes community have shown no common list for its characteristics, values-based leadership has emerged as a proxy. A better future cannot be achieved in an individualistic mindset (as proven by the current pandemic). Still, it needs a fair amount of peaceful conflicting values for progress by focusing on the overarching societal values and not the differences. Thus, one may say that a good society is resilient, competitive economically, fair societally, inclusive, just, antifragile, … Nonetheless, a good society assumes the involvement of all constituencies. This involvement cannot be hindered by a volatile environment surrounding the gap between current education, future skills, present and future challenges.

The states of fragility (as described by the OECD) are pervasive and evident in a global society that is not resilient; the pandemic has revealed an enhanced interconnectedness and complexity, increasing the degree of fragility and bringing an opportunity for a positive disruption toward a future good society.

The elements that affect society at large bring vulnerabilities and opportunities for the business world, gather into the conversation cities and rural areas, agile start-ups, and monolithic corporations, all facing the same storm. A community of workers lacking critical thinking skills represents a risk for democracy as well as competitiveness. A city that is not environmentally friendly may be left behind, thus shrinking, by the human capital focused on their and their families' well-being.

The conversation related to the skills for the future good society is more than a focus on STEM, more than the perspective of upskilling. It talks about the same elements brought to the table by the values-based leadership started in 1951 in the Colorado Mountains: permeability of the values fostered by leaders in society's entirety toward a common goal. It creates a setting to navigate this complexity by balancing how we educate with what we educate.

One may wonder why we start from the values of the Aspen community when talking about the status of pure science in Romania. Primarily, the reason stems from the purpose of having pure science in a border country of the European Union when other Member states are better positioned to bring in competitive results. It boils down to the resilience and good society values within a national state. Harsh inter-national competitiveness and extreme specialization have reached their limits as proven by the pandemic and its stark spotlight on vulnerabilities. Without the possibility of a peaceful, open setting, in which communication and mobility are fundamental, nations find themselves in the position to prove their agility. This agility, however, is not innate in a society that relies for high-level innovation on other countries. Even if the contribution to worldwide innovation is small, the skills and processes developed to this particular purpose, boosted by the linkage and collaboration in international consortia, have their obvious benefits[1].

Lastly, one objective to be reached by increasing the visibility and attractiveness factor in pure science is the increase in higher education enrollments. The Romanian education system is failing at providing a mass enrollment in science for students, with roughly 46% of high schoolers enrolled in vocational and technical training instead of theoretical education.

The status quo—a complex landscape

It is rather complicated to express the situation of pure science in Romania in a nutshell. A more detailed overview may be found in a report from the European Commission from November 2021, mapping the performance of the ecosystem[2].

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[1] See more about these benefits in this research on the increased visibility of Estonian research due to consortia: Hirv, T. (2019). Research consortia determine a significant part of the bibliometric visibility of Estonian science. Trames, 23(3), 287-308.

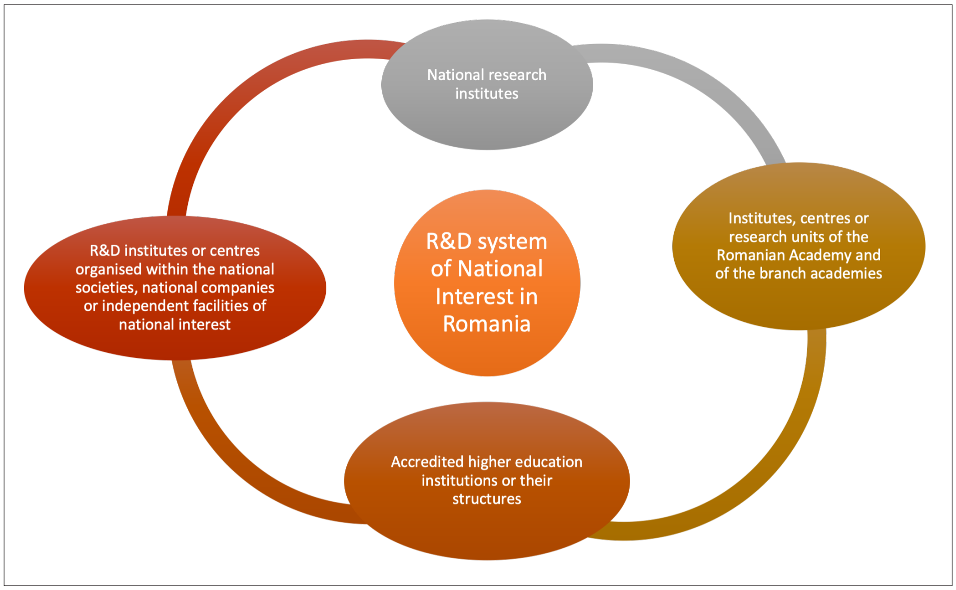
See also benefits in the framework of a center-periphery perspective: Feld, A., & Kreimer, P. (2019). Scientific co-operation and centre-periphery relations: attitudes and interests of European and Latin American scientists. *Tapuya: Latin American Science, Technology and Society*, 2(1), 149-175.

A more critical approach to international consortia in Kosmützky, A. (2018). A two-sided medal: On the complexity of international comparative and collaborative team research. *Higher Education Quarterly*, 72(4), 314-331.

[2] European Commission, Directorate-General for Research and Innovation, Pupinis, M., Serbanica, C., PSF review of the Romanian R&I system : background report, Publications Office, 2021, https://data.europa.eu/doi/10.2777/38334

Information is in various sources, pure research often gets lumped in with innovation, research is presented as a monolithic entity, following a hybrid understanding of development which tries to evolve from the Communist legacy of "science making" to the innovation scope of the EU. Nonetheless, there are a few elements to consider:

- The number of research units decreased from 1166 in 2011 to 621 in 2020 (latest data), mainly due to a reduction in the research units located in the private sector (see Figure 1 for more information).



- The official platform Brainmap.ro, "The online community of researchers, innovators, technicians and entrepreneurs," lists 49.787 accounts, a number that does not match the official statistics. The latter mention some 28.000 registered researchers, leading to the conclusion that the term is either misunderstood or appropriated by Ph.D. students or teaching staff.

Figure 1. Age of researchers in Romania 2011 compared to 2020 (latest data)

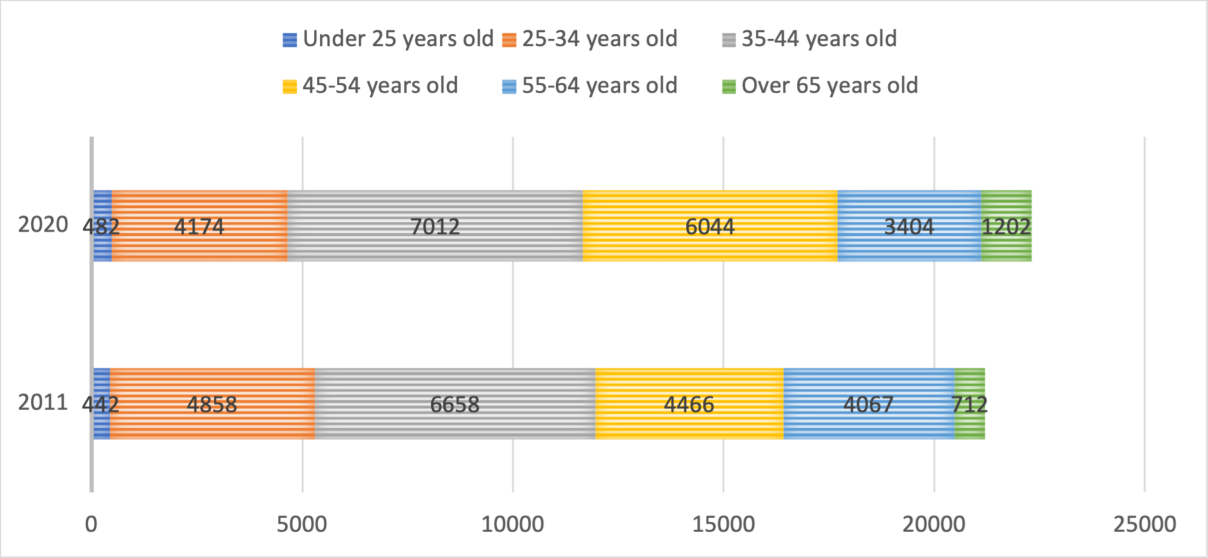
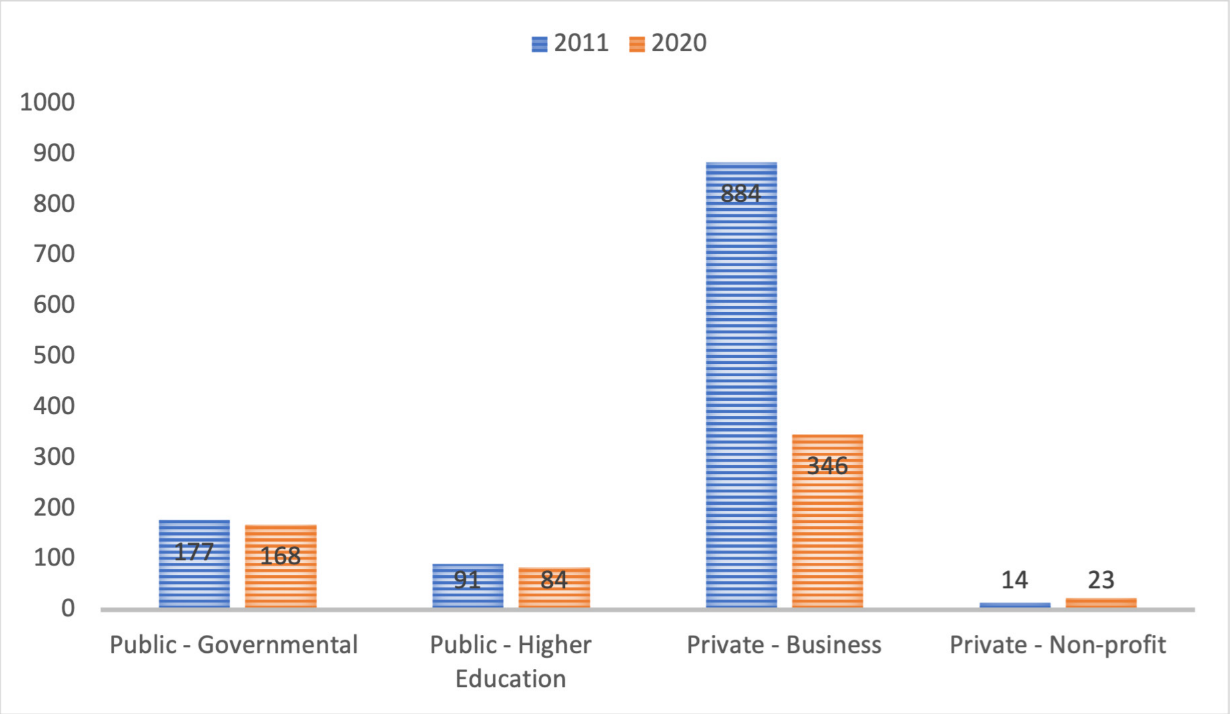


Figure 2. Number of research units in Romania 2011 compared to 2020 (latest data)



Source: Romanian National Statistics Institute, www.insse.ro—Data source> TEMPO_CDP102H & 101B

- As noticeable from Figure 1, although the number of researchers increased with some 3000 in 9 years, the ages are clustered between 35 and 55 with just a few youth attracted toward the specific profession. This follows the trend of the decline in STEM education with more and more pupils being registered in vocational schools.
- Although by number of research units, higher education institutions have a small share, they host most of the research personnel, if we are to consider the Ph.D. researchers as well. The top 20 universities in Romania (as shown in Figure 3) show a small percentage of their alumni following master or doctoral programmes (according to the Bologna Process) [3]. Most of these universities are general (such as Babes Bolyai University from Cluj, University of Bucharest, Al I Cuza University from Iasi, University of Craiova, Transilvania of Brasov, Ovidius of Constanta, West University of Timisoara, Lucian Blaga of Sibiu, Dunarea de Jos of Galati, Stefan cel Mare of Suceava), few are medicine schools (UMF Carol Davila, UMF Gr T Popa Iasi, UMFST Tirgu Mures), one is specialized in economics (ASE Bucharest), one in agronomy and veterinary medicine (USAMV) and the rest are technical (Politehnica, Technical University of Cluj, Technical University Gh Asachi of Iasi, Politehnica from Timisoara). They each have aresearch ecosystem around, usually in dedicated research centres, most of them connected to delivering tech transfer to partner companies.

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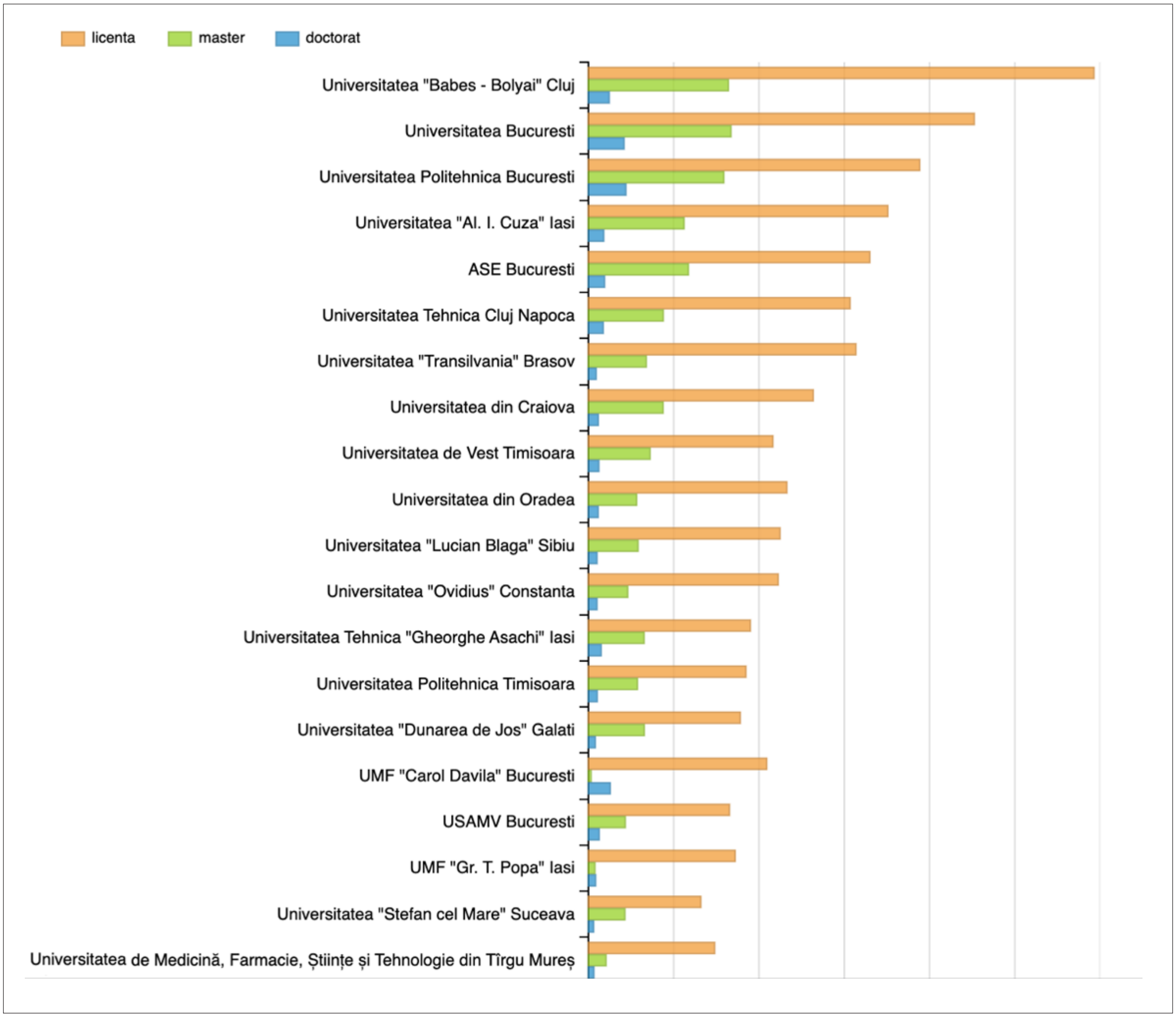
[3] Within the Bologna Process, the Romanian educational system considers 3 years for undergraduate studies, 2 years for master studies and 3 years for Ph.D. (with a maximum extension of extra 2 years). https://education.ec.europa.eu/education-levels/higher-education/inclusive-and-connected-higher-education/bologna-process#:~:text=Under%20the%20Bologna%20Process%2C%20European,a%20European%20Higher%20Education%20Area.

- There are seven national official entities funding research projects in Romania, with different budgetary allocations, depending on the year: UEFISCDI (The Executive Unit for the Financing of Higher Education, Research, Development and Innovation), IFA (the Institute of Atomic Physics), ROSA (Romanian Space Agency), OIC-POC (The Intermediate Research Body—in charge with European non-refundable funds for research under the Ministry of Research, Innovation and Digitization), the Ministry of Research, Innovation and Digitization, the Ministry of Regional Development and Public Administration (usually via Regional Development Agencies), the Ministry of Education. Add to these the direct funding researchers may obtain from the European Commission via the Horizon programmes, as well as other research boosting funding lines provided by the European Union.

Figure 3. Number of students in Romania's Top 20 universities in 2020 (latest data)



Source: REI - https://rei.gov.ro/ (accessed June 2022)

- UEFISCDI is the main source of funding for research, with four pillars, to which they add the funding from EEA & Norway Grants. The four pillars are: P1—The development of the national research and development ecosystem, P2—The increase of the national competitiveness through research, development, innovation, P3—European and International Cooperation and P4—Fundamental and frontier research. The latter is the one mainly dedicated to pure science, however projects which
- P4 from UEFISCDI lists three types of possible projects: Exploratory research projects (PCE), Complex Border Research Projects (PCCF), "ERC - like" (ERC) research projects.
- The National Research and Development and Innovation strategy is the overarching policy document on the topic, with a demonstrated (albeit modest) positive impact, despite the very limited budget allocated.
- In terms of R&D intensity (% of R&D in GDP), Romania has the lowest score in the EU (0.5%)[4], with the added comment that the EU itself is failing to achieve its 3% target, being in 2020 (latest data) at just 2.3%.[5]
- One of the most difficult aspects of the Romanian R&I system is financial (and governmental) support for R&D. Another limitative aspect is the widespread absence of regular reporting, monitoring, and evaluations of the effectiveness of R&D expenditures.
- Even if the national distribution of students is somewhat heterogeneous (with academic hubs, such as Cluj, Iasi or Timisoara, spread throughout the country), the R&D expenditure is mostly concentrated in the capital region—Bucharest Ilfov.

A little less pure science, a little more applied research

Following the massive restructuring after 1990, from centralized economy (and research) to market-led economy, research in Romania became crystalized either in universities (albeit with limited capacity), in struggling research institutes or in companies.

In a struggle to boost Romania's competitiveness, most research funds are directed toward close-to-market innovations and technology transfer, with a limited amount dedicated to pure science. The National R&D&I Strategy is focused on Smart Specialization [6] and each of the Romanian regions has its own strategy on the topic with an implementation (and financing) tool defined specifically as Promoting Technological Transfer.

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[4] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20211129-2#:~:text=The%20R%26D%20intensity%2C%20i.e.%20R%26D,compared%20with%202.2%25%20in%202019

[5] Rakic, R. et al. (2021) "Fostering R&D intensity in the European Union: Policy experiences and lessons learned," Case study contribution to the OECD TIP project on R&D intensity, available at: https://community.oecd.org/community/cstp/tip/rdintensity

[6] Smart specialization areas as defined by the National R&D&I Strategy: bioeconomy, ICT/space and security, energy & environment, advanced materials & eco nano-technologies and health.

Figure 4. Specific objectives (SO) of the Romanian National R&D&I Strategy

SO1: Creating an enabling environment for the private sector initiative, through instruments that support entrepreneurship and the commercialization of R&D results.

SO2: Supporting smart specialisation, by concentrating R&I resources in areas with economic relevance and demonstrated R&D potential, through public-public partnerships leading to concentration, efficiency and effectiveness.

SO3: Concentration of an important part of R&D&I activities on societal issues, to support the development of the capacity of the public R&D&I sector to respond to the global challenges of importance for Romania;

SO4: Supporting the aspiration to excellence in frontier research, through the internationalisation of Romanian research, use of international evaluations, increase of the attractiveness of the Romanian R&D&I system;

SO5: (By 2020) Reaching out a critical mass of researchers to transform R&D&I in a driver for economic growth, by ensuring the rapid and sustainable increase of human resources in R&D&I;

SO6: Development of successful research organisations, able to operate regionally and globally, by stimulating the defragmentation of the R&D&I system, concentrating resources and prioritising allocations, encouraging public-private partnerships, funding science and assessing the impacts, introducing new funding models to spur innovation.

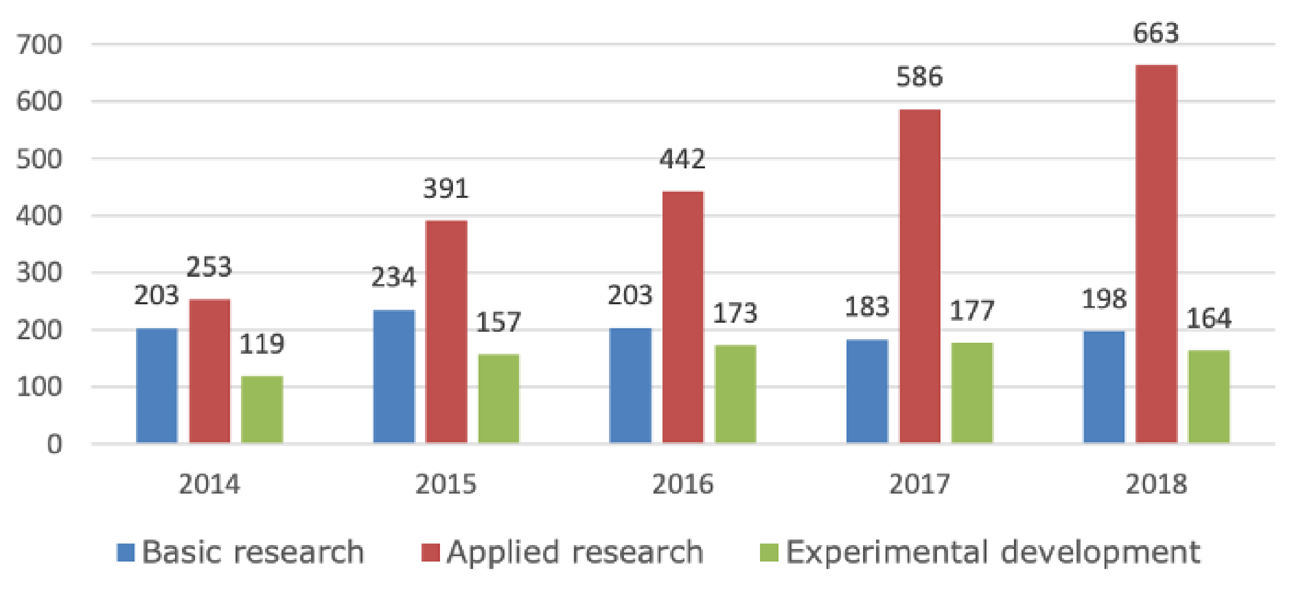
Source: Romanian Government

It is easily noticeable from the Specific objectives of the National R&D&I Strategy that the focus (with 5 out of 6 objectives) is on the private sector and on its capacity to deliver economic growth and competitiveness, with just SO4 aimed at frontier research.

This status quo is also linked to the fact that the private sector was the primary donor to research and development in Romania (47.95%), similar to the EU13 average. However, in the most research-intensive Member States, R&I financing from the business sector is over 60%. When compared to the commercial for-profit sector and the public sector, higher education's investment in research and development (R&D) remains very small.

From Figure 5, it is evident that applied research (mostly funded by companies) has increased in expenditure and budget allocated to the detriment of pure science (or basic research). Linking this aspect to the quest of competitiveness and to the initial conversation on the values promoted by the ecosystem, one cannot fail to notice a lack of interest of the leadership in developing research, not just as a quick win, but as a long-term strategy for improving the resilience of the economy in its entirety. The structural changes are still affecting prominently the economy, which, although growing at roughly 3.5% yearly, has a limited performance and productivity and relies heavily on low knowledge intensive and low value-added services and manufacturing.

Figure 5. Gross domestic expenditure on R&D (GERD) at national level in Romania on R&D activities between 2014 and 2018 (latest data)



Source: European Commission, 2021[7]

In this context of scarce funding, the research performance of the ecosystem is limited.

The Adjusted Research Excellence Index 2020 (AREI) places Romania in last place [8]. The AREI's normalized score is about three times lower than the EU average, except for the MSCA indicator, where Romania's score is about half of the EU28 average. This is even though the compound annual average growth rate for the AREI score from 2013-2018 is positive and higher than the EU average. When compared to European norms, scientific performance is subpar in terms of most-cited articles and PCT patent applications. Scientific publications have recently displayed improved performance, but patent activity has not. In terms of PCT patent applications relative to GDP, Romania ranks worst in the EU, and a considerable proportion of patents are applied for domestically and not abroad.

The research institutes (which may be considered a key actor in the development of pure science) have focused as well on commercialization of solutions (tech transfer) as their main financial instrument, the CORE programme is insufficient and mainly directed at a limited number of organizations. However, their lack of competitiveness in delivering close to market solutions even in a market-led ecosystem is evident, as the percentage of funding of institutes from private sources is under 20%. More than half of the CORE Programme's 2016-2018 budget

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[7] https://op.europa.eu/en/publication-detail/-/publication/460eb95a-4e6b-11ec-91ac-01aa75ed71a1

[8] The AREI is based on four metrics: share of top 10% most highly cities publications per total population, Patent Cooperation Treaty (PCT) patent applications per population, participation in Marie Sklodowska-Curie Actions (MSCA) and European Research Council (ERC) grants per public R&D initiative.

was allocated to just seven (of 47) national R&D institutes[9]. Similarly, more than half of the 2016-2018 budget for investments in INCDs' infrastructure went to nine national R&D institutes.

Although the Romanian Academy is one of the richest institutions in Romania (in terms of assets) and has its own budget allocation line, its impact regarding pure science is yet to be determined. Moreover, the aging pool of researchers and the topics chosen for research do not reflect an increase in its relevance at European level.

Instead of conclusions - A glimmer of hope

The shift from centralized research in state-owned institutes to R&D in companies has led to a significant number of reorganizations and institutional changes that ultimately affected the quality of the governance of the ecosystem. Public science is done either in (national) R&D Institutes and Academies of Sciences institutes and in public higher education institutions. However, for the latter, there is no direct institutional financing for R&D.

Lumping up research with education in one mandate and with digitalization in another has created a public perception of "left-over" in which this activity, crucial for a well-developed society, is marginalized. The advisory organization[10] that was supposed to monitor the development of the entire national R&D&I system has never been fully operational, regardless of the format and affiliation (either under the Prime Minister or a ministry). The large number of ministries in charge with aspects of the research ecosystem has more often than not failed to coordinate and synchronize on national or regional goals. The governance of the National R&D&I strategy has not been operationalized (regardless the amount of paperwork involved[11]) and there is no multi-year budgeting planning or financial stability with a dedicated, fixed amount of GDP allocated (regardless how small).

Human resources is one of the weaker aspects of the ecosystem in Romania, with the smallest R&D and science workforce in the European Union. This workforce is not growing, and the brain drain has a significant effect on the human resource pool, as it has on all industries and activities in the country. Romania has more than 4 million inhabitants living and working abroad, a number that is challenged just by states under war (such as Iran and, lately, Ukraine).

Retaining researchers is challenging since research professions are unappealing (low wages, poor working conditions etc.). Different HR support measures are in place, including the income tax

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[9] The most important recipients of Core Programme allocations were the "Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH Bucharest), the National Institute for Laser, Plasma and Radiation Physics (INFLPR Bucharest), and the National Institute for Aerospace Research "Elie Carafoli."

[10] National Council for Science, Technology and Innovation Policy (CNPSTI)

[11] Just as a idea of the massive amount of documentation, an Appendix issued by the Ministry of Research, Innovation And Digitalization in 2021- Summary Document on Medium-Term Budgetary Policies and Programs of The Ministry of Research, Innovation and Digitalization for the Year 2021 and the 2022-2024 Perspective has 93 pages.

exemption for R&D personnel, the "Human resources" programme within the National R&D&I Plan, a dedicated action within the OP Competitiveness for "Attracting highly-skilled researchers from abroad," the scholarships offered to PhD and post-doc students via the OP "Human resources," etc.[12].

Lastly the glimmer of hope, coming from a significant upgrade in Romania's research infrastructures (although their potential remains untapped).

The flag-ship project, intended as a nodus mundi for the Romanian research ecosystem, the ELI-NP Extreme Light Infrastructure-Nuclear Physics[13], may be considered a success for pure science at European level, but it nonetheless failed to catalyze the growth of the local ecosystem. ELI-NP is hosted by an institute, auspiciously placed on the outskirts of the capital city of Bucharest, in Măgurele, and is considered by the European Science Foundation and its Nuclear Physics Collaboration Committee (NuPECC) and a NuPEC facility in the Nuclear Physics Long Range Plan. This is one of the three major international R&I infrastructures funded in Romania, alongside Danubius-RI[14] and ALFRED (Advanced Lead Fast Reactor European Demonstrator)[15].

The project is still struggling to launch as a full blown catalyst for the ecosystem, particularly since the European Consortium ELI-ERIC[16] (which was created to manage the ELI facilities) does not include Romania.

However, one must consider in conjunction with the National Resilience and Recovery Plan and its desire to reform the R&D&I system and the research career.

It is not evident as of now how this reform shall focus on the values for a good society, but, if one looks at the specific objective of the National R&D&I Strategy targeting grand societal issues, affordable solutions and reducing disparities, these values act as permanent background. It is hoped that it will infuse the ecosystem with the needed amount of "coolness" to attract young researchers from Romania and abroad. However, the question about growing children to be curious and challenge themselves to see the world through new eyes is still a quest on shifting sands. The depreciation of the research career as such, but also the sheer availability of information as brought by the digitalization, added to the widespread poverty and degree of functional illiteracy have systematically affected the children's thirst for knowledge.

As some may say, the ecosystem just needs to hope that the laser is cool enough, even though they are aware that the "coolness" factor must be supported by effective policies and funding.

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12 The Romanian researchers are among the least mobile in the European Union; 42% of experienced researchers engaged in a short-term mobility program (highest share in the EU)

13 The institute hosts the most powerful laser in the world (a collaboration with Thales) and is currently conducting its first experiments. https://www.eli-np.ro/

14 https://www.danubius-ri.eu/

15 http://infoeuropa.ro/sites/default/files/file/anul_2018/alfred_research_infrastructure-for_mae_en_fin.pdf

16 https://eli-laser.eu/

New Zealand

The Aspen Institute New Zealand held an online discussion with ten scientific experts to explore pure science research in New Zealand.

Introduction

The following is a summary of the key points from the online discussion held with ten New Zealand experts moderated by Aaron Mertz, Director of the Science & Society Program, and Christine Maiden Sharp, CEO of Aspen NZ.

The purpose is to provide current insights into the state and future of pure research in New Zealand for inclusion in the Aspen Global Basic Research Report.

Please note that the summary does not necessarily reflect any one person's opinion or beliefs but is an aggregate of the views that were expressed during our roundtable discussion.

Participants

Name	Title	Organisation
Prof Troy Baisden	President	New Zealand Association of Scientists
Prof David Bilkey	Department of Psychology	University of Otago
Prof Richard Blaikie	Deputy Vice Chancellor, Research and Enterprise	University of Otago
Prof Paul Brunton	Pro VC Division of Health Sciences	University of Otago
Prof Giselle Byrnes	Provost	Massey University
Prof Gary Evans	Chief Science Advisor MBIE (secondment)	Victoria University of Wellington/ Ferrier Research Institute
Dr Jemma Geoghegan	Senior Lecturer	University of Otago
Prof Sir Peter Gluckman	Director	Koi Tū - Centre for Informed Futures, Auckland University, President International Science Council
Dr William Rolleston	Director	South Pacific Sera Ltd
Prof Tim Naish	Antarctic Research Centre	Victoria University of Wellington

Moderators

Dr Aaron Mertz	Director, Science & Society Program	The Aspen Institute
Christine Maiden Sharp	Founder, CEO	Aspen Institute New Zealand

Aspen New Zealand

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Summary

Q1. What is the commonly understood definition of pure science in NZ and is it helpful?

- *Like other countries, there remains disagreement on the definition or understanding of 'pure' science. There is, however, total agreement on the importance of aspects of science.*
- *Value in having consensus on the definition to keep track of international and domestic metrics of funding.*
- *Agreement that New Zealand underspends and undervalues science & research.*
- *Ongoing discussions on incorporating Matauranga (Māori science).*

Q2. Should we and why prioritise pure science now?

- *Strong support for prioritising pure science for NZ to remain economically competitive.*
- *Need to do more to recover and engage internationally, such as how overheads are allocated for research students, measuring outputs, payment of PhD students and career path for scientists.*
- *Plus, ability to respond to international opportunities in a timely matter with adequate funding.*
- *Increasing interest in recognising that social science has a basic science component.*
- *Important to have a resilient research system.*

Q3. How should pure science be guided to be more inclusive with Māori, women, and younger generations?

- *Science needs to be more inclusive and relevant, to increase trust and impact.*
- *Challenging issue—the position of science has changed and continues to evolve in society.*
- *Universities play an important role. In the U.K. focus is on the system, versus on the individual in NZ.*
- *Need to appeal to youth before age of 14.*

Q4. What do you think should be done to increase global cooperation/collaboration for pure science?

- *NZ scientists are actively engaged in world of science, but aren't necessarily supported by society (politically, business).*
- *Debate on how should NZ participate—lead or follow? Play to our strengths and focus on niche expertise, such as agriculture and climate change.*
- *Questionable if NZ really wants to be a 'knowledge' economy, as evidenced by the lack of research funding.*
- *Need to be more strategic and recognise the opportunity costs of pursuing ad hoc, short term, low cost, and low risk returns.*
- *Good to consider the systemic issues, involve the business community more.*

Q5. How can we excite younger generations to pursue careers in pure science?

- *Invest in schools (and teachers) from the first years to unlock curious minds, make science cool.*
- *Have scientists actively engage with the community and mentor diverse range of students.*

Responses

Q1. What is the commonly understood definition of pure science in NZ and is it helpful?

- *Like other countries, there remains disagreement on the definition or understanding of 'pure' science. There is however total agreement on the importance of aspects of science.*
    - o One person's basic science is one person's applied science.
    - o Excellence in research from government (MBIE). Simple answer—avoid, where possible the use of the word 'science' as a metaphor for much wider and necessary group of knowledge systems.
    - o NZ uses Blue Skies terminology. 'It's really what we do on a good day when we can afford it'. NZ may not understand the interpretation of basic science and where it comes from.
    - o Not too fussed about definitions though policy-makers need some framework … important to look strategically at aspects of science that can contribute to capability. Risk looking at applied end, start to lose capability. Maintaining capability should be aim. Need to have broad range of research to springboard from.
    - o Boundaries of definitions fuzzy. The Marsden fund is set up to fund investigator led science but much of what comes through has an applied aspect. We don't have a definition of basic or pure science in Marsden, but it must have scholarly impact.

- *Value in having consensus on the definition to keep track of international and domestic metrics of funding.*
    - Like to see metrics. Accept things change and trans-disciplinary. Some definition is useful and help in arguing with Government to get more funding and how we are trending.
- *Agreement that New Zealand underspends and undervalues science & research.*
    - Support knowledge and human capital. Should we invest in pure science? See CSR taskforce.
    - Agree with scepticism. University research is valuable and some institutions in our societies where pure research is supported and valued.
- *Ongoing discussions over incorporating Matauranga (Māori science)—different paradigms in looking at knowledge systems.*
    - We are moving into a different space in NZ around impact and benefit—we have a challenge around how to incorporate Matauranga (Māori knowledge).

Q2. Should we and why prioritise pure science now?

- *Strong support for prioritising pure science for NZ to remain economically competitive.*
    - NZ has a population of 5 million, in a world with 10 million scientists. Some aspects of fundamental science are more important to us e.g., methane production in cows—science or trade protection? Failure to invest in the international network of science and has been left to universities in an ad hoc way. If NZ is to remain competitive in international science, needs to invest more—not just a 'goodie' but the only way NZ will remain competitive.
    - We are part of international community.
- *Need to do more recover and engage internationally, such as how overheads are allocated for research students, measuring outputs, payment of PhD students and career path for scientists.*
    - NZ science system has a lot of recovery to do. Getting there requires us to do a few things such as engage internationally. But we don't invest in capitals—our ways are incompatible internationally e.g. Overheads based on FTEs but doesn't work well in collaborative space and investment have trouble in tracking in statistics. E.g. if Massey University was going to get rid of scientists and asked auditor general, how do we know input measures of $$ in research and output measures $$, how do we know they are accurate? Over time investment has ended up PhD scholarships have been international—scholarships have dropped compared to the minimum wage. Should our PhD students in pure science cohort be paid living wage? Universities are good at

  investing in basic research. But not so much in applied. Foster investment in science scholars but is this investment suitable for them into work force?

  - Usually, dependent upon importing labour from overseas … over half PhDs from overseas and over last 20 years PhD scholarships have dropped below minimum wage. Shouldn't our PhD students and pure science funding body be paid a living wage??

- *Plus, ability to respond to international opportunities in a timely matter with adequate funding.*
  - We are small country and benefit from leveraging international bodies. Benefits are not just funding and capability, but also science diplomacy. NZ seen as good honest broker e.g., Sir Peter is head of international science council and NZers hold many other international leadership roles. One of the frustrations is being able to play internationally and take advantage of opportunities. Funding systems are not aligned correctly. How do we respond to opportunities quickly?
  - There are aspects of pure science we must do that are different to other countries—e.g. methane production, is it basic science or about trade protection? We have failed to invest in the international network of science—left to universities. International collaboration is the only way NZ is going to be competitive in many areas of science—this is the issue beyond the quantum.
- *Increasing interest in recognising that social science has a basic science component.*
  - Deeper issue emerged in the science council of not recognising that social science has a basic science aspect to it. NZ has been minimal investor. "Unleashing Science" report. e.g. Covid issues are now about social science, communication, and behaviour to sustain behaviours etc. Weakness in social science. Need to change attitude in government and funding systems. Social science should be better represented.
  - Support comments about social science research e.g. climate change has huge social impacts/behavioural science. Plus, supporting basic science for early career scientists—challenge underfunding. Scholarships running under min wage.
  - We are a small country—'I'm someone who has benefited from the ability to leverage on international collaborations when resources of one nation can't do the job.' The benefits are not just leveraging of funding but also science diplomacy where NZ is a good honest broker
- *Important to have a resilient research system.*
  - This is where pure research is very important—have a wide range of people doing lots of things to build resilience, knowledge, and expertise for the future

Q3. How should pure science be guided to be more inclusive with Māori, women, and younger generations?

- *Science needs to be more inclusive and relevant, to increase trust and impact.*
    - Matauranga is developing, and the narrative is evolving with public discussions between Matauranga and western science. Not an either or, but an indigenous world perspective of benefits. NZ support for the Matauranga system will not set NZ behind—will still allow us to contribute internationally. Some indigenous groups have low trust in current systems.
    - The more inclusive, the more likely to get findings more relevant to all in society.
    - Few women in science … often I am the only woman in panels and discussions. A lot more needs to be done in gender diversity like mentoring women in science … to be open and honest about gender equity and funding … I benefited from having a mentor.
    - Basis science can unify because it is collaborative. At the other end, commercial advantage takes hold. Opportunity to have a better relationship with Māori. Risk of having western science and Matauranga as two separate systems, when they're not.
- *Challenging issue—the position of science has changed and continues to evolve in society.*
    - Science is not a good word—Wissenscshaft, used in German has a broader meaning. Deeper issue is position of science in society has changed a lot in last 70 years. How does fundamental and discovery science fit into more embedded model? System is changing. To confuse the picture for those at fundamental end of knowledge their career path not well developed and good career schemes are no longer available. We have undermined basic principles of how to sustain science system.
- *Community-led, community-based participatory research leads to good basic science.*
- *Universities play an important role. In the U.K. focus is on the system, versus on the individual in NZ.*
    - Pipeline development and pathways are critical for Māori engagement in research and science and for welcoming women … put simply, our current system settings are not as welcoming, encouraging, and supportive as they could be. Part of the University is to build capability for the future that is more inclusive … must change way we (Government, Universities, and private sector) recruit, reward, sponsor progression. Need to have hard conversations.
    - In the U.K., Universities are important. While it's early days in review of U.K. system, the focus isn't on individual researcher but more on system, focus on what are the input drivers that Universities control and how they are behaving. In NZ we have performance metrics based on individual rather than institution.

- *Need to appeal to youth before age of 14.*
    - Most interesting data from Ireland. Kids decided around 10—14 years of age—determined by parents' attitudes and peer attitudes. Unlocking curious minds—under invested in. Deal with equity issues by putting digital coding into schools with high minority numbers. Often teach science in boring way.

Q4. What do you think should be done to increase global cooperation/collaboration for pure science?

- *NZ scientists are actively engaged in world of science but aren't necessarily supported by society (locally/politically).*
    - The issue is not that NZ scientists don't take part in world of science for global good, it's that they should be empowered to do it without the constraints of political bias.
    - NZers stand out in lead roles around the world but are doing it in ways not supported by the state and often not paid.
    - It's about knowledge—sometimes science gets in the way of politics and as a result marginalises some of the research sector.
    - NZ should become an Associated Country in Horizon Europe, which has the potential to become a true global research investment platform with a focus on global issues such as climate change.
    - Undervaluing of research by government has a long history in NZ, rooted in our longstanding scepticism of intellectualism and picking winners. We need to get over this.
- *Debate on how should NZ participate—lead or follow? Play to our strengths and focus on niche expertise, such as agriculture and climate change*
    - It used to be said in a small country—why should we do science that other countries are better set up to do? In terms of NZ's role in international science—it's a niche thing—we are super important because of niche skills, we must play to our strengths because of the limited investment in international science.
    - We must value things if they are valuable to NZ.
- *Questionable if NZ really wants to be a 'knowledge' economy, as evidenced by the lack of research funding.*
    - To come to grips with what kind of country it is. Is it a knowledge economy?
    - 40 year running debate because of treasury philosophy—issues are very, very deep. Had the knowledge wave and lots of discussion on this, but every statement says we will increase R&D when fiscal conditions allow … that's not the way you invest … knowledge development takes a long time to achieve. Sectors of economy that need to support science research, often don't.

  - One of the problems—we don't currently know what economic value basic research might have. e.g. genome sequencing could save Auckland from more lockdowns. We don't know until there is a disaster when we can use it in a more applied way and the economic savings come afterwards. We don't know until its realised.

- *Need to be more strategic and recognise the opportunity costs of pursuing ad hoc, short term, low cost, and low risk returns.*
  - Farming sector does reflect conversation on short termism. Govt only invest in short term as they get a better bang for buck. We have good strategy in biology but it's not a short-term endeavour. Real focus away from long term and basic science has this problem. E.g. Dairy NZ and Beef and Lamb—used to invest in science and now only 10-15 % of budget goes toward it. Limited investing in capability.
  - Pakehas are short term in their thinking—Māori are not. NZ has had a low-risk approach. More fundamental research is always high risk about how it will be applied. E.g. Rocket Lab—low risk approach and how they got started and couldn't get funding.
  - We are not that strategic, we are ad hoc—a minister will see something overseas and will put money into the pot, rather than stepping back and being strategic. Need that invest capabilities.

- *Good to consider the systemic issues, involve the business community*
  - The systemic issues in NZ, way the science system is set up, leads to duplication, low efficiencies … counterproductive when looking at long-term thinking for NZ. Do we need to deinstitutionalise science in NZ?
  - The business community needs to get far more involved—they have taken advantage of Universities and CRIs, but not really responded to push government to put more money into R&D.
  - Investment in R&D has tended not to get votes even though NZ science is highly trusted
  - We don't have advocacy groups like Research America—the ones here seen as self-interested advocates.

Q5. How can we excite younger generations to pursue careers in pure science?

- *Invest in schools (and teachers) from the first years to unlock curious minds, make science cool.*
  - When a child chooses their direction of travel—14 years of age—determined by parents and peer attitudes. Peer attitudes about what's nerdy and not and easy, parents by their own perspective of things.

  - Unlocking curious minds—report massively underinvested in. If we want to deal with issues in school e.g. digital coding in schools with high minority numbers, it’s currently just in private schools. Children are interested at 8 or 9 and lost at 13 or 14—we need to think about late primary years where we start to turn kids off. We teach science at that age by people who don’t understand it and teach in a boring way.
  - The Jesuits had it right—should listen to them occasionally.
  - Look at the quality of teaching—what impact does it have on people's choices?
  - Issue of teaching is very real—average primary teacher is an Arts graduate, have less than 12 hours of training on how to teach science.

- *Have scientists actively engage with the community and mentor diverse range of students.*
  - Engagement—important scientists are engaged with the community, citizen science programmes.
  - As young people are thinking about research careers that they can see a pipeline and career—need to engage to get young people onto the career pathway.
  - Survey—values and attitudes—NZers would be happier if a NZer won Nobel prize than the Americas Cup—need to get the public behind it, to get policy-makers to shift.
  - We only spend $1.8 m a year on science experience programmes—e.g. Fisher and Paykel invest in South Auckland—their communities are going to be their workers in the future. Had their staff tutoring and involved in programmes. There are great examples but need more.

The Ananta Aspen Centre co-organized a discussion with eminent experts about research and development in India.

India’s R&D Ambitions: Challenges and Imperatives

Summary notes from roundtable discussion

Background

The Ananta Aspen Centre and the Centre for Technology, Innovation and Economic Research (CTIER) organised a round table discussion on **India’s R&D ambitions: Challenges and Imperatives** on the 29th of September 2021. The closed-door virtual round table discussion saw the participation of an eminent group of academics, policy-makers and industry professionals.

The discussion was based on a preliminary report that has been prepared as part of the Aspen Institute for Pure Science Project that looks at the relevance of basic research in R&D, and also does a comparative analysis of India with other select countries with respect to Basic Research being performed.

Part of what motivated the Aspen Institute for Pure Science Project was looking back at places like Bell Labs in the United States that produced at least half a dozen Nobel Prizes in the past. As companies focused increasingly on efficiency, cost cutting, they cut blue skies research. Bell Labs for instance will perhaps never produce the kind of basic research it once did, for example the transistor, that is such an essential piece of our technologies today.

There is increasing pressure on the scientific establishment in many countries for science to be more relevant, for science to be more capturable and appropriate in terms of its benefits for humanity, but also for companies and individuals. At the same time, there is also a sense that science is somehow best done as an open subject where the results of science are published and available to all—So, how does that then mix with incentives and appropriability, with people who fund science—and with regard to where the benefits are supposed to flow?

Inclusion and equity are an essential part of science—where science by its very nature should be unbiased and devoid of any prejudice. In thinking of mission-oriented research, or addressing issues around sustainable development goals, there is a better chance at making good progress if one is more inclusive and equitable, both in terms of gender as well as geography.

In trying to address and understand the research canvas in India, a presentation by CTIER provided an overview of India's R&D and innovation landscape—of public and private research, scientific and technological research within public R&D, and where the research is currently being done. The presentation also provided an overview of India's STEM workforce, the geographical diversity of state innovation systems and key public funded initiatives to support scientific and technological research. The data also considered schemes that have been introduced by various major scientific ministries and departments targeting the SDGs.

The overarching points from the discussion that followed are captured in the following sections.

Structure of Public R&D in India

- A majority of the research undertaken in India is through the Public (Government) sector. The research is being conducted by public sector institutions—autonomous labs or universities, which are owned by the state or run by the state. The public sector in India funds and does its own R&D, and the private sector in India funds and does its own R&D.
- When the U.S. does defense R&D, the bulk of it is funded by the Department of Defense, but it is done in private firms. When India does Defense R&D, it is funded by the government, but it is done at DRDO. The same holds for the Department of Space, the Department of Atomic Energy. Between those three agencies of the Union government (DRDO, DoS, DAE), they account for over half of total Union government funding of R&D and that's over a quarter of total national R&D which is largely technological research and not scientific research, and it is done in our own government laboratories.
- The R&D investment amounts for India, Israel and Taiwan are not very dissimilar at U.S.D 18-19 billion. The difference in a sense is footprint. The share in universities is not hugely different either—for India it is 7 percent, 10 percent for Israel and 9 percent for Taiwan. In India, 52 percent of total national R&D is funded by the state and done in autonomous labs and 7 percent funded by the state and is done in the higher education system. The share of national R&D done and funded by the state is much higher in India than the others, and over 85 percent of it is done in autonomous labs—if one looks at the share funded by the state and done in the university system in Taiwan and Israel, a significant portion of the public funded R&D would be done in the university system. Even in the U.S., where a large part of research is being done in universities, a significant portion of funding comes from the government.

From Basic research to translation and commercialisation

- Economic growth, social equity and environmental sustainability are going to be very critical elements for the human race to survive in the future. The pursuit of science and technology has to be driven by these three important forces. It is now time to focus not only on national issues but also on global crises like climate change, and the role of basic science in this context is now more important. Basic science research is important as it allows one to deal with the unknown. We need to figure out a way by which we can have all of the basic science and this dynamic connectedness for dealing with problems.

- The basic versus applied sciences sort of dichotomy appears to be more of the past—it should be seen as a continuum. In the past it was a dichotomy because of the time taken to understand something. Nowadays it is much faster, in terms of the knowledge created with the help of basic sciences which is used for technological development.

- Nevertheless it is evident from the distribution of gross expenditure on R&D that India hardly spends around 20 percent on basic research.

- If one considers vaccine research, for a country that should have done exceedingly well in this area, one can see that because of the lack of basic research it has not been possible for India to come out with new innovative ways of making vaccines. One of the reasons why the U.S. was successful in coming up with a mRNA vaccine within a matter of 10 months after the pathogen was discovered was based on the long years of basic research in the area of mRNA medicine.

- There seems to be a neglect of basic research in India and the quality of basic research is also varied. Furthermore, basic, fundamental, applied, translational and technology-driven science are all dots that need to be connected to make a complete cycle. Presently, these appear to all be disparate and with little connection between all that is being done.

- Judging by some of the metrics with respect to the contribution of science to technology, India does well in terms of number of publications but does badly in terms of patenting. The small number of patents that India has is largely contributed by multinational companies which are operating from the country.

- For scientists working in research institutes and universities, the measurement of work done is still in terms of the number of publications they produce—for instance in the national institute ranking framework the government has been using, the number of publications is very important.

  Thus given the kind of framework that is adopted, it is very difficult for scientists to do science that contributes to technology.

- The bridge between research and innovation and commercialisation of that research and innovation is missing. There has been a lot of excitement about startups, but startups are not really doing the translation in the sense of taking the research done at academic institutions or autonomous labs all the way to commercialisation. Value is created when the research is taken all the way to commercialisation and the value of translational work needs to be considered.

- From an industry perspective, most technology is linked with manufacturing. A whole generation of manufacturing mindset and capability has been lost over the last decade. There has been a ton of emphasis on the services sector with little emphasis on manufacturing. Today, the whole gamut of manufacturing has changed dramatically. Now that India is trying to revive that muscle of manufacturing that has been lost, India needs to be ready to receive the new wave of manufacturing technology and be able to absorb it and apply that technology that is the most contemporary and recent in the world.

- The domestic market in India needs to be tapped in a manner that products are designed for the domestic market and driven into the global markets. Serious thought needs to be given to the market as it opens up opportunities for which industries are willing to take risk. India also needs to increase its focus on exports and quality—the amount of focus on exports that a country like Turkey has, where an export association drives their R&D and innovation, is currently missing in India.

Funding research in Higher Education Institutions and new models of R&D funding

- In the U.S., universities compete for resources, whether it is NIH funds or NSF funds or even SBIR funds and that competition results in a situation where collaborations happen with industry as they try to raise resources for research from government sources. In India, we currently lack a situation where university institutions compete with each other for larger resources. One component we need to think about is whether state funds should be going to state institutions in a situation where allocation is done and there is no competition for these resources, or a situation where multiple institutions compete for these resources and in the process their quality is improved.

- We need to consider moving our research funding progressively into the higher education system. One way to do this would be to take the total increase we provide each year in the annual budget for funding for R&D autonomous labs and freeze it in nominal terms after the current level. But increase the funding by Rs 7,000-8,000 Crores a year and provide that full funding to the higher education system for research. In a matter of 5 years one would see a huge increase in total research work going on in the higher education system. This would not be a popular move with the labs but it would be a way of bringing about quite a transformed research system. And public and private higher education institutions should compete equally on a peer reviewed basis for this funding.

- The proposal for the National Research Foundation aims to address the above, and the funding amount is possibly a little more. However there is also a need to expand the footprint of quality leadership and quality foundational scientists to be able to absorb this funding and also make the state universities and other institutions in new locations adept at handling these funds.

- It would be good to have a new model of R&D funding in place which covers TRL from 1 to TRL 10 covering the fundamental science, the basic science, the discovery science or the new knowledge science to its application, its translation and its commercialization. If this whole model of R&D funding in the country can be divided based on the TRL where we may put in a mechanism where even the industry comes in as an equal player in certain steps of the TRL. Industry may not be at all interested in the TRLs 1 to 3 which has to be supported by the state—creation of basic and fundamental new knowledge should remain the mandate of the state. For the higher TRL levels, there could be a mechanism where a model of funding needs to be put in where the public and private sector can come together and work to create new IPs.

Expanding the footprint of science: networks and collaborations

- Basic research cannot be performed at just one IISc or an IIT or an IISER, it has to happen in more places. Our best research centres are just a short walk from India. The national labs, the central universities, the state universities, and other research establishments are all over the country but they clearly are not connected to each other at all. Right now, the footprint of science is very small, and needs to expand outside the national laboratories into our central and state universities.

- Access to the right kind of equipment, and maybe having a regional network for this, is critical. There is no lack of funds for equipment—many universities do have equipment but it does not get used. Perhaps there is a way to get Industry to participate through a pay and use system.

- Some collaborative research may be taking place between government labs and higher education institutions, but there is very little connection or research collaborations taking place between government labs and industry.

- When it comes to partnership between government and industry, with respect to innovation and not just in terms of funding, the willingness of the government to commit to long term programs even if they are outcome based (for example in areas linked to Defence which is perhaps at the highest end of technology) seems to be missing. There needs to be that kind of partnership between government and industry as seen in the U.S. where the government clearly makes commitments and even cofunds projects.

- India is a leading destination for global R&D investments. There are people who are alumni of these industries which have global investments that are going out into Indian industry and this needs to be tapped more.
- India should partner with other countries that have good network ecosystems for innovation—for example Singapore.

Strengthening India's STEM workforce: Building a better trained and creative workforce

- We need to inculcate a research environment in our state universities where 93 percent of our students go. There is an important role here for the state universities and industries to come together. The biggest challenge faced by industry is getting skilled manpower. One of the fundamental challenges for the country is that the human capacity in S&T in India is very limited—even if we scale up our funding, we will not be able to absorb it.
- Strong arguments have been made that by doing research in the higher education system, there is this automatic connection with industry and with the innovation system, and more importantly the outcome is talent. The talent ends up being the most productive output of the public research system. One is training great researchers by doing research within the higher education system.
- Catching up is made easier if we train people in large numbers because of many of the technologies today have in their foundations design and theory, allowing young people to contribute enormously.
- The kind of training that is needed is in creative basic science and not just basic science. For example nanoscience is a well explored field but what is not well explored are things like topological insulators, or new novel materials which have completely different mechanisms of how they function. Creative basic science even in material science is not well represented in India. There are many groups doing material science but it is difficult to think of groups thinking seriously about topological materials in India. If research is done for publications, it will still get published even if it is not interesting or creative, but that will not help us make major progress. In defining basic and applied science, we need to set apart creative basic or creative applied science from other kinds of basic and applied science.
- We should see how we can get better diversity in our student population and even faculty—even possibly attracting many more students from other countries in the region. Management institutions have perhaps been better at attracting global faculty than engineering institutions, and we could do better in attracting global faculty in STEM.
- The scientific community should be role models in inclusivity. The effort of the scientific community has to go a little bit further in terms of trying to address the invisible biases that exist throughout the system, be it in academia, research, industry.

- Since the large amount of funding comes from the public agencies, we should develop a strong peer review system. Quality peer review has a long lasting effect on productivity.
- When thinking about strengthening the science and R&D workforce, we also need to consider management capability for R&D and science if we want to get somewhere in making progress in this area.

Themes for Future Deliberations

1. **Revisiting Public Research in India**
   There is a need to have an independent assessment of how effective our public R&D spending is. There is a general concern about the global competitiveness of the autonomous R&D institutions/government laboratories, even if they rank relatively higher than other institutions in the country in terms of their research output. This particular model which does not separate the sector of funding and sector of performance was possibly driven by national priorities 75 years ago. It is worth revisiting these institutions to understand the role these public institutions can play in India's economic development going forward.
2. **Expanding footprint of science through ensuring ease of use of resources**
   With respect to public funded research, one needs to consider the ease of use of resources. It is very difficult for people to use the resources that seem to be earmarked which leads to poor productivity. India needs to expand its footprint of science outside of the national laboratories and into our central and state university system.
3. **Expanding into newer but important areas and thinking about sustainability**
   Two approaches to improving the system focus on certain sectors and do really well in them or think about rising tides and whether we would really want to invest in raising the bar for everybody. We need to think of how to expand into newer but important areas and sectors where we can stand out, such as climate change. India's science and technology policies need to look at this closely. Sustainability as an opportunity needs to be brought into focus—several things may have to be reinvented and while India would not be the sole player with respect to the R&D required for this, it should try and take a leadership position. India should use its cultural advantage when thinking about sustainability.
4. **Newer metrics to measure contributions to convince policymakers on need to spend on R&D**
   When one compares R&D spending in India as a percent of GDP to that of Korea and China, there is a significant difference. However newer metrics may be needed to convince policymakers about the need to increase spending on R&D—especially when growth rates in India too have in the past seen similar high growth rates seen in Korea and China. Furthermore, if one looks at investment in R&D or full time equivalent in science in India and extrapolates those to what they would be if we want to have some of the advanced

economy numbers, it is not something which is likely to be feasible. India is unlikely to be able to reach those kinds of numbers and therefore the pattern of development would need to be looked at differently.

5. **Exploring models which will allow India to stand on global foundations of basic science**
   The development one sees in China is standing on the shoulders of basic science in the West and now it is catching up enormously on basic science research. China opened up its economy to attract global industry whose IP contributed to the growth of the Chinese industry. China simultaneously invested significantly in having its students go abroad and also capitalised on the intellectual presence it already had in the West. This pattern of development may not entirely be open to India and we need to think of a model which will allow India to stand on global foundations of basic science.

6. **Leveraging India's global network**
   If one compares the kind of investment in R&D in India vis-a-vis Israel and Taiwan, one needs to consider what return does India get for the similar kind of investment, and what is preventing us from being very highly productive. The issue of interconnectedness needs to be looked at closely—one knows the connectedness between Israel and the U.S. and Taiwan and the U.S., and so what is the nature of interconnectedness for India that is different from those of others. There are several programmes where R&D spending is connected with international programmes—we need to look at the key areas where we need technology for our competitive advantage and whether we are getting these technologies through current collaborations.

Mexico

Aspen Institute Mexico held a roundtable discussion to explore pure science in Mexico.

Basic Science In Mexico

Aspen Institute Mexico organized a roundtable with prominent Mexican scientists to discuss the state of pure science in the country in order to contribute to the Aspen Institute project for pure science. The dialogue was moderated by Ambassador Enrique Berruga, Director of Aspen Institute Mexico, and it began with introductory remarks by Dr. Aaron Mertz, Director of the Aspen Institute Science & Society Program, about the purpose and scope of the project.

It is worth noting that most of the discussion focused on the participants' serious and strong concerns about the direction that science is taking under the current administration. They stressed that the National Council for Science and Technology (CONACYT for its Spanish acronym) is making decisions based on political ideology which are harming the scientific ecosystem (institutions, researchers, students, etc.).

The Council, which is the main agency that governs, promotes, and funds scientific research in México—and the only one that finances *pure* science—, has had public and direct confrontations with a wide and diverse group of members of the scientific community. Budget cuts, a centralized vision of decision-making power in CONACYT and the bias and prejudices against international collaborations and public-private partnerships have turn into the dismantlement of *fideicomisos* (trusts) put in place to receive external grants, programs to repatriate Mexican scientists and fight "brain drain," numerous scholarships to study PhDs abroad, among other projects.

These measures are harming institutions, scientists and students in the short term, and could have dreadful effects for the country's future and for generations to come. It is particularly worrisome since no one expected such attacks to the scientific community from one of its members. As they stated: "this is not our first crisis, we have always suffered from budget cuts, but it is the first one that is not only about money, it is also about politics."

In this complex context, the participants discussed five specific issues on pure/basic since in Mexico.

1. How can we engage non-obvious stakeholder groups so pure/basic science becomes a priority for them in Mexico?

Participants considered that there is a poor scientific culture among the general population. Therefore, it is necessary to increase and improve communication and outreach on what science is and why it is crucial to support it. In this regard, Academia needs to better communicate its contributions to society and to educate public opinion through different means (newspapers, tv, radio, etc.). An institutional approach is also needed to challenge prejudices and stereotypes against scientists who are, for example, negatively depicted in movies as bad, crazy people that endanger the world.

Moreover, scientists need to reach law and policy-makers. The development of science, technology and innovation needs strong engagement between researchers, political parties, and national/state level authorities. Public discourse needs to be aligned with academia to strengthen public support and the budget toward research.

2. What cross-sector (university, institute, government, private, etc.) partnerships do we need to support or create in order to bolster pure/ basic science?

A crucial partnership is the one between academia and the private sector. CONACYT had a successful program called "Masters and PhDs Graduates in the Industry" that ran on matching funds between public-private sector to incorporate young PhDs graduates to certain industries. It increased the number of scientists in the industry, helped foster innovation and brought together both worlds. Unfortunately, the program has been discontinued. Another suggestion is to approach specialized industrial chambers like the ones for the pharmaceutical, electronics, and food sectors to agree on joint collaborations.

The participants shared other examples of successful programs that used to work in former administrations but have been canceled. Another source of concern in this regard is that CONACYT intends to exclude private university researchers from the financial support they receive from the National System of Researchers. There is an ongoing legal battle in this regard.

3. What can be done in Mexico to increase global collaboration for pure/ basic science?

Global collaboration is under critical circumstances for Mexico. Bilateral agreements that had provided the framework-and funding- for joint ventures have lapsed. International scientific and development agencies that had supported Mexican projects for decades are worried—to say the least—that they are being ignored by CONACYT and they are looking for other partners in the country to work with. Many universities and research institutions are being left out and the country is losing opportunities and funding.

Academia, both at the institutional and the personal level, has good contacts and relationships with foreign institutions but CONACYT is no longer providing “matching funds.” Besides the lack of budget, there is an ideological component. The current administration distrusts certain developed countries and is reluctant to participate with them. It has the goal to develop an “autochthonous” national system which is turning into isolation.

On the other hand, participants recognized that the Ministry of Foreign Affairs has opened a channel to collaborate with international institutions. However, its budget is small and for most universities it will be impossible to match the required funds. As a proposal, it was suggested to copy the German Model of scientific and technological cooperation with foreign governments to improve Mexico’s reputation abroad.

4. How can pure/basic science be made more inclusive in Mexico?

Three groups were mentioned as particularly “excluded” from science in Mexico: the private sector, women, and youth. Everything made by the private sector is frowned upon by the current administration: companies, universities, etc. This vision limits Mexico´s capabilities for innovation and will hurt its human capital. In terms of education, scholarships given to pursue graduate programs certified by CONACYT have drastically decreased. Without these fundings, many students have dropped out of school, probably joined the labor market, and might never go back to study. This will hurt the country for decades.

Regarding gender, educating girls is the most important factor that could make a difference in the country’s development in the long run. Things have improved for girls and women in STEM but at a very slow pace and mainly in the urban centers. The “glass ceiling” is still there for many female researchers who need more access to leadership positions. Most of the scientists “fighting back” CONACYT are women and could hopefully run high decision making/scientific positions when this crisis is over but they could go back to their desks/labs as it happened with women in the labor force during/after WWII. For young people, it is extremely difficult to have a research position or a job opportunity after graduating or doing a postdoc. There needs to be a better strategy to offer them good opportunities.

5. How can we excite younger generations to pursue careers in pure science?

It is very easy to engage children in science since it is fun! The challenge is to make a career of it. Postdoctoral young researchers need to have more job opportunities and access to research positions.

At the end of the discussion, Ambassador Berruga asked Dr. Mertz to share best practices from other countries that are experiencing similar challenges. He also made a call to the Aspen Institute Network to foster collaboration among the different scientific communities.

The following individuals participated in the roundtable discussion. None of the above statements should be attributed to any one of them, but rather those comments represent a summary of the discussion authored by the Aspen Institute.

William Lee Alardín, Ph.D.,	Scientific Research Coordinator, National Autonomous University of Mexico (UNAM)
Susana López Charretón, Ph.D.	Professor, Biotechnology Institute, National Autonomous University of Mexico (UNAM) Campus Morelos
Brenda Valderrama Blanco, Ph.D.	Outreach Officer, National Autonomous University of Mexico (UNAM) Campus Morelos

Ukraine

THE ASPEN INSTITUTE
KYIV

Aspen Institute Kyiv organized a panel discussion about pure science in Ukraine with over 350 researchers, journalists, and policymakers in attendance. The resulting conclusions are summarized below.

Reflection on Ukraine

Introduction

Ukraine has had considerable contributions to the world of scientific advancements as part of the former Soviet Union. Ukraine has inherited its previous research and development system and infrastructure and still has existing pockets of excellence. However, while the economic and geopolitical framework has significantly changed over the last 30 years of Independence, the adaptation of the field of STI (Science, Technology and Innovation) to these new frameworks was not responsive enough. The National Academy of Sciences of Ukraine has a traditionally dominant role for producing new knowledge, but, unfortunately, has no desire to modernize its way of functioning.

Reporting and scientific publications have deteriorated significantly, and Ukraine does not submit data to the international databases according to the existing criteria. There is a confusion in deciding what is basic and applied science, what is humanities and what is biomedical science among researchers. In higher education institutions and universities, there were only minor studies with mediocre or no financial support.

All these circumstances necessitated a radical reform of education and science. After the Revolution of Dignity in 2014, the Ukrainian parliament amended the Constitution and identified European and Euro-Atlantic integration as a vector for the country's future development. Many reforms have been launched since 2014. In 2014, a new Law on Higher Education was adopted, and in 2015, a new Law on Scientific and Technical Activities. Therefore, reform of education and science began.[1]

The main obstacle to reforming education and science is the lack of understanding of the importance of this area for economic development. For 25 years, education and research have been supported by residual funding, while since the 1980s, developed countries have

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[1] https://www.kmu.gov.ua/en/reformi/rozvitok-lyudskogo-kapitalu/reforma-osviti

recognized that research and education funding is not a social expense but an investment in human capital and the creation of economically valuable assets. Therefore, Ukraine must immediately begin integration into the European Research Area and the European Education Network, implementing EU principles and standards to make its research system more effective. Thus, in the coming years, Ukraine will have to provide an additional budget from national, international, European and private sources for strategic investments, covering all stages of the innovation process from basic research to market entry.

Reform is essential for the survival of research and development in Ukraine.

Global Aspen Project For Pure Science In Ukraine

Aspen Institute Kyiv joined the Global Project for Pure Science in 2021 and managed to organize a 2-hour Zoom panel discussion entitled “Pure Science and Society.” The panel was conducted in Ukrainian language and brought together over 350 researchers, journalists and policy-makers as the event was announced on many official websites. Among panellists were the highest officials from all relevant governmental institutions and the elected member of the Ukrainian Parliament:

Academician, Dr. Anatoliy Zagorodny	President of the National Academy of Sciences of Ukraine;
Dr. Olga Polotska	Executive Director of the National Research Foundation of Ukraine;
Dr. Yulia Bezvershenko	Director General, Directorate of Science and Innovation, Ministry of Education and Science of Ukraine;
Dr. Serhiy Babak	People’s Deputy of Ukraine, Head of the Committee on Matters of Education, Science and Innovation (Leading party “Servants of the People”);
Dr. Volodymyr Kamyshyn	Director of the Ukrainian Institute of Scientific and Technical Expertise and Information;
Academician, Dr. Oleg Kryshtal	President of the NGO “Ukrainian Science Club”;
Dr. Volodymyr Kuznetsov	Institute of Philosophy of the National Academy of Sciences of Ukraine;
Dr. Nataliya Shulga	CEO of the NGO “Ukrainian Science Club,” Moderator of the event.

The panel consisted of two parts.

1. **Basic research as a value in modern society.**
    - How to define basic research and its role in modern society?
    - Should all universities conduct basic research? Is there any hope for a change in HR policy?

- What changes in society do basic research provide?
- How does significant progress in basic research affect the development of society as a whole?

2. **Financing of basic science and reporting on results.**
    - What sources of funding for basic research exist in Ukraine and their effectiveness?
    - Should Ukraine participate in global research reporting (Frascati family of manuals), or should we develop and propose additional tools for monitoring research?
    - What is needed to create charitable foundations to support basic research?
    - How to create an effective alliance of stakeholders? Who can lead this process?

All speakers stressed the need to implement science reform. Here are the main conclusions that all participants in the discussion agreed with.

1. Frascati Manual was not known before the preparation for the panel discussion. It is recommended to use the manual to adapt Ukrainian standards to European ones.
2. The definitions of “basic research,” “applied research” and “experimental development” provided in the Frascati Manual are acceptable.
3. There is considerable confusion regarding the funds distribution to support all types of research activities in Ukraine. National specifics and lack of modern standards make the monitoring and reporting process very complex and controversial. Therefore, according to official data, more than 60% of all funds go to support pure science. Although publications mostly reflect applied research.
4. There is an urgent need to modernize the internal R&D monitoring and reporting system. Once the criteria are established and implemented in domestic policy, the system will become transparent and accessible for global recognition.
5. The vector of European and Euro-Atlantic integration recently introduced into the Constitution of Ukraine will facilitate faster adaptation of European standards for the development of science and technology.
6. The creation of a competitive grant system in the National Research Fund of Ukraine (the first calls started in 2020) helps to use transparent criteria and tools to support basic research in Ukraine. Other institutions should follow best practices.
7. Pure science in Ukraine is funded and will be funded in the future through state budget and resources. If decentralization of governance in Ukraine is successful, local municipalities will be allowed to spend money for pure science at their territories. They are now only allowed to invest in applied research in some specific areas, such as education, transport, energy, engineering, cybersecurity, and so on.

8. International collaboration plays a crucial role in maintaining pure science at the appropriate level in Ukraine, especially in the fields of nuclear physics, molecular biology and mathematics.
9. Education and science reform should go on hand-in-hand with the restructuring of financial support.
10. At present, there are no private funds in Ukraine to support pure science. This issue has never been considered. There is no incentive system for the creation of such funds.

The event in Aspen Institute Kyiv was a success, and the Ministry of Education and Science timely included a special paragraph in its work plan for 2021 on the translation of the Frascati Manual 2015, dissemination of translated materials and changes in research monitoring policy at the state level during 2022.

This decision resonates with previous attempts to accelerate the reform of science. In 2016, the European Commission organized a group of scientists and experts to analyse the Ukrainian research and innovation system. The group visited Ukraine, conducted numerous interviews, worked on documents, and published a report containing key policy messages and a main conclusion: “If the reform process, triggered and based on the new Law on Scientific and Technical Activity, does not advance with highest attention and support from both the policy-makers and heads and faculty members of research institutes and universities, it is likely that Ukraine loses its ultimate connectivity to leading international progress in STI (Science, Technological Development and Innovation). Therefore, Ukraine has to start immediately to make its STI system more efficient and to secure within the next three years additional budget from national, international, European and private sources for strategic investments covering every stage of the innovation process from basic research to market uptake.”[2]

In 2015, Ukraine became an associate member of Horizon 2020 and since then has had the opportunity not only to participate in pan-European projects, but also to manage them.[3] Thus, Ukrainian scientists have gained invaluable experience in building international research consortia. Additional funding for basic research and mobility has had a positive impact on the younger generation of researchers and a change in the attitude of education and science officials.

Nevertheless, pure science remains underfunded and underrepresented in higher education, so more work and effort are needed to accelerate reform and a better understanding by the general public and policymakers of the link between quality research and economic development.

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[2] “Peer Review of the Ukrainian Research and Innovation System,” https://ec.europa.eu/research-and-innovation/en/statistics/policy-support-facility/peer-review-ukrainian-research-and-innovation-system

[3] https://mon.gov.ua/ua/nauka/yevrointegraciya/ramkovi-programi-z-doslidzhen-ta-innovacij-gorizont-2020-ta-gorizont-yevropa-ta-iniciativi-yevropejskoyi-komisiyi-yevropejskij-zelenij-kurs/gorizont-2020

Colombia

The Aspen Institute Initiative for Columbia organized a moderated discussion with six panelists, who are experts in the fields of science, communication, and education in Colombia. These panelists' consensus on the topic of pure science is summarized below.

Why foster “pure science”?

Participants:

Clemente Forero Pineda	Uniandes professor and former Director of Colciencias
Elizabeth Hodson de Jaramillo	Professor emeritus at Pontificia Javeriana University
Juan Benavides Estévez-Bretón	Researcher at Fedesarrollo
Lisbeth Fog Corradine	Science journalist
Luis Caraballo	Researcher at the University of Cartagena
Moisés Wasserman Lerner	Former rector of The National University of Colombia

Moderator

Silvia Restrepo	Vice-president of Academic affairs and Vice-president of Research and Creation of the Universidad de los Andes.

Hosts

Pablo Navas Sanz de Santamaría	Executive Director of Aspen Initiative Colombia
Aaron F. Mertz	Director of the Aspen Institute Science & Society Program

In response to the Aspen Institute’s invitation, a moderated discussion was held among the panelists. The forum was opened by Pablo Navas followed by Aaron Mertz, who briefly explained the intention of the meeting. In summary, we were invited to discuss pure science research, also called basic science, to try to answer the following questions. Why is pure science important? How can we promote it? How does it help to unify the world? How can it be guided to be more inclusive both within Colombia and across borders? How can it be improved in

Colombia? What do you think can be done to increase global collaboration in pure science and how can we encourage the younger generation to be passionate about a career in pure science? This discussion, along with similar discussions, will be held in 13 other countries and will contribute to the final report of the Aspen Institute.

In the following summary, we will present the consensus of four moments of the debate. Each of these moments was prompted by questions posed by the moderator.

In a country like Colombia, under the current circumstances, should a state budget be allocated to fund basic research? We agreed with Mariana Mazzucato's proposal: should missions be the new framework that regulates conversations between what we call basic science and applied science to establish new collaborations? Is that the solution? Are there other ways?

The common answer was yes it should be a state budget to fund science to motivate knowledge generation. However, a consensus was not reach concerning the name of basic science and in general, the panelists prefer to not have a distinction between basic and applied science, it is knowledge and it should be considered as it.

About missions, it was agreed that missions are not the only strategy. It is a strategy that has given results; however, it should not be the only one that should be adopted, and this was a key point in the discussion. Missions are a way to solve problems, but if they are the only way, it closes off possibilities for invention and creation because they set us on a single path.

Basic research is of great importance and provides the fundamental knowledge that in many cases is the input for applied science, it does not mean that one is more important than the other, It means that both are necessary and of vital importance, as the pandemic has shown. For the missions to add up, curiosity-based research must not be abandoned.

The discussion of prioritization criteria is complex, but if, for example, a major prioritization is given to research that supports national objectives in the framework of the Mazzucato-style missions, this should not mean that resources, are not provided for free proposals on the initiative of scientists, perhaps at a smaller but inevitable magnitude. A prioritization that excludes personal initiative, curiosity-driven, basic science, or fundamental knowledge should never be adopted.

Can (pure) basic research contribute to the rapprochement of the global North and South, or does it rather widen the gap between rich and developing countries?

As long as we have knowledge production, the gap will be smaller and the impact on science will be greater. If we are not considered scientific peers, there will be no knowledge transfer, and to be peers we need to have the capacity to absorb and generate knowledge. We are aware that transfers do not come for free. The barriers of the knowledge market are very high and to participate in the international community, we need to demonstrate that we are competent.

It is therefore important to develop sufficient research and industrial production capacity in strategic fields to ensure the scientific autonomy of the countries of the South. Developing an absorptive capacity also means investing heavily in local science for the countries of the South. Without this capacity, it is not even possible to take advantage of the technologies that can be adopted. Achieving this requires national support, not just government policies that are transitory but, state policies that allow us to have sustainable funding over time.

Networks with diasporas and altruistic international scientists can initially help building this capacity. But such paternalistic relationships are unsustainable in the long run. We need to be recognized as competitive partners to benefit from participation in such networks.

The lack of basic research is what increases the distances between rich and poor countries. Fresh ideas are the only way to generate edge technological development. A country cannot depend on others to provide basic knowledge.

Given the current conditions in Colombia, what needs to be done to stimulate basic research? How to get young people interested in research?

Several factors were considered. First, we must consider education. We must fill the deficit we have in primary and secondary education. An important starting point would be to strengthen the capacity and vision of primary and secondary school teachers to start the basic research stimulation from childhood. Many of these teachers are not aware of the importance of developing science. Knowledge must be considered as a fundamental part of everyday life and curious subjects should be encouraged from childhood. In the same way, the interest in knowing the world, to become observers, to ask questions, to look for different options and not to give up, should be stimulated.

The second point is communication. The way how the stories of science are being told in our country, should change. The scientific community should open up to society and understand that knowledge is a multi-way process, not just from the scientific community to society, but also from society to the scientific community. Listen to them and allow the population to be part of the research processes, inviting society to come closer instead of opening the gap any wider.

The third factor is funding. For young people to become interested in research, the existence of economic and cultural incentives for those engaged in this activity is necessary. Basic research is currently in high demand and underfunded. Existing basic science groups need to be strengthened, which, like the generation of new groups, is encouraged by funding. But in addition to this, we are confronted with the low social recognition of scientists and science, our current idols are mercantilist. Developing countries, where scientists and inventors are not valued, suffer a decline in attempting to emerge. As an example, we find the scientific decline of the United Kingdom in comparison to the United States and Germany at the beginning of the 20th century. Peter Drucker explains this and attributes it to the low valuation and social esteem of the inventor and entrepreneur in the U.K. in contrast to other social elites.

Among the strategies suggested to stimulate basic research are the research seedbeds and the young researchers' or early-career programs which are an excellent complement to the training of researchers in the universities. Programs that aim to stimulate the creation of new knowledge, should also be promoted; not only the Maloka[1] and Explora[2] strategies, but also activities such as open laboratories and research centers and citizen science, should be supported allowing the population to take part in the research processes. In addition, Doctoral and master's programs should also be strengthened with permanent scholarships.

What needs to be built as a science and technology system in order to make everything you have proposed possible?

1. The reconfiguration of a true national science and technology system that includes the state and the private and social sectors. This new system needs to have a common vision in search of a collective wellbeing to articulate the independent niches that exist nowadays. This requires clear and solid public policies. The system administrative area should have a scientific participation, represented by advisors selected only for their scientific merits and decision makers who are convinced of the importance of promoting and funding science for the country's development.
2. An adequate and timely state financial support is required for the system's success. In addition, the funds should be destined not only to research that could impact economics or health. In short, the system should reward not only scientific publication, or research with immediate applied results, but also the generation of knowledge out of curiosity even if it represents a financial risk.
3. The social appropriation of scientific knowledge promoted by journalists and science communicators should be encouraged, allowing the value of basic science to be transmitted and a science sensibilization of the community.
4. A school education system that promotes curiosity and exploration as previously mentioned.

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[1] Maloka is an interactive science and technology museum located in Bogota, Colombia.

[2] Parque Explora is an interactive science museum located in Medellín, Colombia.

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